ART AND SCIENCE OF DIAGNOSIS

Almost a century ago, Dr. Hermann Prinz wrote: “The object of the practice of clinical dentistry ... is to institute preventive measures, to relieve suffering, and to cure disease. These purposes are not achieved by the haphazard utilization of a few therapeutic formulas or of certain mechanical procedures, but they are based on a thorough knowledge of clinical pathology.” But the gathering of scientific data is not enough to formulate an accurate clinical diagnosis. The data must be interpreted and processed in order to determine what information is significant, and what information might be questionable. The facts need to be collected with an active dialogue between the clinician and the patient, with the clinician asking the right questions and carefully interpreting the answers. In essence, the process of determining the existence of dental pathosis is the culmination of the art and science of making an accurate diagnosis.

The purpose of a diagnosis is to determine what problem the patient is having, and why the patient is having that problem. Ultimately, this will directly relate to what treatment, if any, will be necessary. No appropriate treatment recommendation can be made until all of the whys are answered. Therefore a planned, methodical, and systematic approach to this investigatory process is crucial.

The process of making a diagnosis can be divided into five stages:

- The patient tells the clinician why the patient is seeking advice.
- The clinician questions the patient about the symptoms and history that led to the visit.
- The clinician performs objective clinical tests.
- The clinician correlates the objective findings with the subjective details and creates a tentative differential diagnosis.
- The clinician formulates a definitive diagnosis.

This information is accumulated by means of an organized and systematic approach that requires considerable clinical judgment. The clinician must be able to approach the problem by crafting what questions to ask the patient and how to ask these pertinent questions. Careful listening is paramount to begin painting the picture that details the patient’s complaint. The diagnostic tests that are used become the science behind the creation of the diagnosis.

Neither the art nor the science is effective alone. Establishing a differential diagnosis in endodontics requires a unique blend of knowledge, skills, and ability to interpret and interact with a patient in real time. Questioning, listening, testing, interpreting, and finally answering the ultimate question of why will lead to an accurate diagnosis and in turn result in a more successful treatment plan.

Chief Complaint

Upon arrival for a dental consultation, the patient should complete a thorough registration that includes information pertaining to medical and dental history (Figs. 1–1 and 1–2). This should be signed and dated by the patient, as well as initialed by the clinician as verification that all of the submitted information has been reviewed (see Chapter 11 for more information).
TELL US ABOUT YOUR SYMPTOMS

LAST NAME ______________________ FIRST NAME ______________________

1. Are you experiencing any pain at this time? If not, please go to question 6. Yes ____ No ____

2. If yes, can you locate the tooth that is causing the pain? Yes ____ No ____

3. When did you first notice the symptoms? ______________________

4. Did your symptoms occur suddenly, or gradually? ______________________

Please check the frequency and quality of the discomfort, and the number that most closely reflects the intensity of your pain:

LEVEL OF INTENSITY FREQUENCY QUALITY
(On a scale of 1 to 10)
1=Mild 10=Severe

1 2 3 4 5 6 7 8 9 10 __ Constant ___ Sharp___

___ Intermittent ___ Dull___

___ Momentary ___ Throbbing___

___ Occasional ___

Is there anything you can do to relieve the pain? Yes ____ No ____

If yes, what? ______________________

Is there anything you can do to cause the pain to increase? Yes ____ No ____

If yes, what? ______________________

When eating or drinking, is your tooth sensitive to: Heat__ Cold__ Sweets__

Does your tooth hurt when you bite down, or chew? Yes ____ No ____

Does it hurt if you press the gum tissue around this tooth? Yes ____ No ____

Does a change in posture (lying down or bending over) cause your tooth to hurt? Yes ____ No ____

6. Do you grind, or clench your teeth? Yes ____ No ____

7. If yes, do you wear a night guard? Yes ____ No ____

8. Has a restoration (filling or crown) been placed on this tooth recently? Yes ____ No ____

9. Prior to this appointment, has root canal therapy been initiated on this tooth? Yes ____ No ____

10. Is there anything else we should know about your teeth, gums or tissues that would assist us in our diagnosis? ______________________

Signed: Patient or Parent ______________________ Date ______________________

Figure 1-1 Dental history form that also allows the patient to record pain experience in an organized and descriptive manner.
The reasons patients give for consulting with a clinician are often more important than the diagnostic tests performed. These remarks serve as important clues for the clinician that will help in formulating a correct diagnosis. Without these direct and unbiased comments, objective findings may lead to an incorrect diagnosis. The clinician may find dental pathosis, but it may not be the pathologic condition that mediates the patient’s chief complaint. Investigating these complaints may indicate that the patient’s concerns are secondary to a medical condition or possibly a result of recent dental treatment. Occasionally, the chief complaint is simply that another clinician correctly or incorrectly advised the patient that he or she had a dental problem, with the patient not necessarily having any symptoms. Therefore, the clinician must pay close attention to the actual expressed complaint, determine the chronology of events that led up to this complaint, and question the patient as to any other pertinent issues, including medical and dental history. For future reference and in order to ascertain a correct diagnosis, the patient’s chief complaint should be properly documented, using the patient’s own words.

**Medical History**

The clinician is responsible for taking a proper medical history from every patient who presents for treatment. Numerous examples of medical history forms are available from a variety of sources, or individual practitioners may choose to customize their own forms. After the form is completed by the patient, or by the parent or guardian in the case of a minor, the clinician should review the responses with the patient, parent, or guardian and indicate that this review has been done by initialing the medical history. Any patient’s chief complaint should be properly documented, using the patient’s own words.
vital signs be gathered at each treatment visit for any patient with a history of major medical problems. The
baseline blood pressure and pulse should be recorded for a patient at each treatment visit. Elevation in blood
pressure or a rapid pulse rate may indicate an anxious patient who may require a reduced stress protocol, or it
may indicate that the patient has hypertension or other cardiovascular health problems. It is imperative that
temporal temperature of patients presenting with subjective fever or any signs or symptoms of a dental infection should
be taken.

The clinician should evaluate a patient’s response to the health questionnaire from two perspectives: (1) those
medical conditions and current medications that will necessitate altering the manner in which dental
care will be provided and (2) those medical conditions that may have oral manifestations or mimic dental
pathosis. Patients with the following medical conditions may require either a modification in the manner in which the
dental care will be delivered or a modification in the dental treatment plan:

**Cardiovascular:** High- and moderate-risk categories of endocarditis, pathologic heart murmurs, hypertension, unstable angina pectoris, recent myocardial infarction, cardiac arrhythmias, poorly managed congestive heart failure.

**Pulmonary:** Chronic obstructive pulmonary disease, asthma, tuberculosis.

**Gastrointestinal and renal:** End-stage renal disease; hemodialysis; viral hepatitis (types B, C, D, E); alcoholic liver disease; peptic ulcer disease; inflammatory bowel disease; pseudomembranous colitis.

**Hematologic:** Sexually transmitted diseases, HIV and AIDS, diabetes mellitus, adrenal insufficiency, hyperthyroidism and hypothyroidism, pregnancy, bleeding disorders, cancer and leukemia, osteoarthritis and rheumatoid arthritis, systemic lupus erythematosus.

**Neurologic:** Cerebrovascular accident, seizure disorders, anxiety, depression and bipolar disorders, presence or history of drug or alcohol abuse, Alzheimer’s disease, schizophrenia, eating disorders, neuralgias, multiple sclerosis, Parkinson’s disease.

Additionally, the clinician should be aware if the patient has drug allergies or allergies to dental products, an
artificial joint prosthesis, or organ transplants or is taking medications that may negatively interact with
common local anesthetics, analgesics, and antibiotics.

The previous listing may seem overwhelming, but it emphasizes the importance of attaining a thorough and
accurate medical history before any dental treatment is provided. A multitude of textbooks and journal articles
are available to keep the dental community current on the appropriate ways to provide dental care for patients
with medical problems (e.g., *The Merck Manual* at [http://www.merck.com/mrkshared/mmanual/home.jsp](http://www.merck.com/mrkshared/mmanual/home.jsp)). These sources provide the clinician with details about the various medical conditions and the dental treatment modifications that must be made in order to provide the appropriate care.

Several medical conditions have oral manifestations, which must be carefully considered when attempting to
arrive at an accurate dental diagnosis. Many of the oral soft tissue changes that occur are more related to the
medications used to treat the medical condition than the medical condition itself. More common examples of
medication side effects are stomatitis, xerostomia, petechiae, ecchymoses, lichenoid mucosal lesions, and
bleeding of the oral soft tissues.

In arriving at an accurate dental diagnosis, a clinician must also be aware that some medical conditions can
have clinical presentations that mimic oral pathologic lesions. Tuberculosis involvement of the cervical and
submandibular lymph nodes can lead to a misdiagnosis of lymph node enlargement as a result of an
odontogenic infection. Lymphomas can also involve these same lymph nodes. Immunocompromised
patients and patients with uncontrolled diabetes mellitus respond poorly to dental treatment and may exhibit
recurring abscesses in the oral cavity that must be differentiated from abscesses of dental origin. Patients with iron deficiency anemia, pernicious anemia, and leukemia frequently exhibit paresthesia of the oral soft tissues. This finding may complicate making a diagnosis when other dental pathosis is also present in the same area of the oral cavity. Sickle cell anemia has the complicating factor of bone pain, which mimics odontogenic pain and loss of trabecular bone pattern on radiographs, which can be confused with.
radiographic lesions of endodontic origin. Multiple myeloma can result in unexplained mobility of teeth. Radiation therapy to the head and neck region can result in increased sensitivity of the teeth and osteoradionecrosis.\textsuperscript{[51]} Trigeminal neuralgia, referred pain from cardiac angina, and multiple sclerosis can also mimic dental pain (see also Chapter 3). Acute maxillary sinusitis is a very common condition that may create diagnostic confusion since it may mimic tooth pain in the maxillary posterior quadrant. In this situation the teeth in the quadrant will be extremely sensitive to cold and percussion, thus mimicking the signs and symptoms of pulpitis. This is certainly not a complete list of all the medical entities that can mimic dental disease, but it should alert the clinician that a medical problem could confuse and complicate the diagnosis of dental pathosis; this will be discussed in more detail in subsequent chapters.

If at the completion of a thorough dental examination, the subjective, objective, clinical testing, and radiographic findings do not result in a diagnosis with an obvious dental etiology, then consideration must be given that an existing medical problem could be the true etiology. In such instances a consultation with the patient’s physician is always appropriate. As noted above, there are many current textbooks and journal articles that can serve as reference materials for clinicians who encounter some of these medical problems on an infrequent basis.

**Dental History**

The chronology of events that lead up to the chief complaint is recorded as the *dental history*. This information will help guide the clinician as to which diagnostic tests are to be performed. The history should include any past and present symptoms, as well as any procedures or trauma that might have evoked the chief complaint. Proper documentation is imperative. It may be helpful to use a premade form to record the pertinent information obtained during the dental history interview and diagnostic examination. Often a S.O.A.P. format is used, designating the Subjective Objective Appraisal Plan for the diagnostic workup. There are also built-in features within some practice management software packages that allow digital entries into the patients’ electronic file for the diagnostic workup (Figs. 1–3 and 1–4).
When taking a dental history and performing a diagnostic examination, often a premade form can be helpful in facilitating complete and accurate documentation. (Courtesy Dr. Ravi Koka, San Francisco, CA.)
History of Present Dental Problem

The dialogue between the patient and the clinician should encompass all of the details pertinent to the events that led up to the chief complaint. The conversation should be directed by the clinician in order to produce a clear and concise narrative that chronologically depicts all of the necessary information about the patient’s symptoms and the development of these symptoms. In order to help elucidate this information, the patient is first instructed to fill out a dental history form as a part of the patient’s office registration. This information will help the clinician decide which approach to use when asking the patient questions. The interview first determines what is going on in an effort to determine why is it going on for the purpose of eventually determining what is necessary for the resolution of the chief complaint.

Dental History Interview

After starting the interview and determining the nature of the chief complaint, the clinician continues the conversation by documenting the sequence of events that promulgated the request for an evaluation. The dental history is divided into five basic directions of questioning: localization, commencement, intensity, provocation, and duration.

Figure 1-4  Several practice management software packages have features for charting endodontic diagnosis using mouse-driven inputs, user-defined drop-down menus, and areas for specific notations. Note that for legal purposes, it is desirable that all recorded documentation have the ability to be locked, or if any modifications are made after 24 hours, the transaction should be recorded with an automated time/date stamp. This is necessary so that the data cannot be fraudulently manipulated. (Courtesy PBSendo, Austin, TX.)
Localization: “Can you point to the offending tooth?”

Often the patient can point or “tap” the offending tooth. This is the most fortunate scenario for the diagnostician because it helps direct the interview toward the events that might have caused any particular pathosis in this tooth. Additionally, localization allows subsequent diagnostic tests to focus more on this particular tooth. When the symptoms are not well localized, the diagnosis is a greater challenge.

Commencement: “When did the symptoms first occur?”

A patient who is having symptoms may remember when these symptoms started. Sometimes, the patient will even remember the initiating event: it may be spontaneous in nature, it may have begun after a dental visit for a restoration, trauma may be the etiology, or biting on a hard object may have initially produced the symptoms. However, the clinician should resist the tendency to make a premature diagnosis based on these circumstances. The clinician should not simply assume “guilt by association” but instead should use this information to enhance the overall diagnostic process.

Intensity: “How intense is the pain?”

It often helps to quantify how much pain the patient is actually having. The clinician might ask, “On a scale from 1 to 10, with 10 the most severe, how would you rate your symptoms?” Hypothetically, a patient could present with “an uncomfortable sensitivity to cold” or “an annoying pain when chewing” but might rate this “pain” only as a 2 or a 3. These symptoms certainly contrast with the type of symptoms that prevent a patient from sleeping at night. Often the intensity can be subjectively measured by what is necessary for the diminution of pain, e.g., acetaminophen versus a narcotic pain reliever. This intensity level may affect the decision to treat or not to treat with endodontic therapy.

Provocation and Relief of Pain: “What produces or reduces the symptoms?”

Mastication and locally applied temperature changes account for the majority of initiating factors that cause dental pain. The patient may relate that drinking something cold causes the pain or possibly that chewing or biting is the only stimulus that “makes it hurt.” The patient might say that the pain is only reproduced upon “release from biting.” Occasionally, a patient may present to the dental office with a cold drink in hand and state that the symptoms can only be reduced by bathing the tooth in cold water. Some symptoms may be relieved by nonprescription pain relievers, and others may require narcotic medication for the reduction of symptoms (see Chapter 18 for more information). Note that patients who are using narcotic pain relievers may respond differently to questions and diagnostic tests, which may alter the objectivity of the diagnostic results. These provoking and relieving factors may help to determine which diagnostic tests should be performed to establish a more objective diagnosis.

Duration: “Do the symptoms subside shortly, or do they linger after they are provoked?”

The difference between a cold sensitivity that subsides in seconds and one that subsides in minutes may determine whether a clinician repairs a defective restoration or provides endodontic treatment. The duration of symptoms after a stimulating event should be recorded as to how long the sensation is felt by the patient, and documented in terms of seconds or minutes.

With the dental history interview complete, the clinician has a better understanding of the patient’s chief complaint and can concentrate on making an objective diagnostic evaluation, although the subjective (and artistic) phase of making a diagnosis is not yet complete and will continue after the more objective testing and scientific phase of the investigatory process.
EXAMINATION AND TESTING

Extraoral Examination

Basic diagnostic protocol suggests that a practitioner observe patients as they enter the operatory. Signs of physical limitations may be present, as well as signs of facial asymmetry that result from facial swelling. Visual and palpation examinations of the face and neck are warranted to determine if swelling is present. Many times a facial swelling can be determined only by palpation when a unilateral “lump or bump” is present. The presence of bilateral swellings may be indicative of a normal finding for any given patient; however, it may also be a sign of a systemic disease. Palpation allows the practitioner to determine if the swelling is localized or diffuse, firm or fluctuant. These latter findings will play a significant role in determining the appropriate treatment.

Palpation of the cervical and submandibular lymph nodes is an integral part of the examination protocol. If the nodes are found to be firm and tender along with facial swelling and an elevated temperature, there is a high probability that an infection is present. The disease process has moved from a localized area immediately adjacent to the offending tooth to a more widespread systemic involvement.

Extraoral facial swelling of odontogenic origin typically is the result of endodontic etiology because diffuse facial swelling resulting from a periodontal abscess is rare. Swellings of nonodontogenic origin must always be considered in the differential diagnosis especially if an obvious dental etiology is not found. This will be discussed in subsequent chapters.

A subtle visual change such as loss of definition of the nasolabial fold on one side of the nose (Fig. 1–5) may be the earliest sign of a canine space infection. Pulpal necrosis and periradicular disease associated with a maxillary canine should be suspected as the source of the problem. Extremely long maxillary central incisors may also be associated with a canine space infection, but most extraoral swellings associated with the maxillary centrals express themselves as a swelling of the upper lip and base of the nose. Further discussions of space infections may be found in Chapter 15.

Figure 1-5 A, Canine space swelling of left side of face extending into and involving the left eye. B, Swelling of the upper lip and the loss of definition of the nasolabial fold on the patient’s left side, which is indicative of an early canine space infection.
If the buccal space becomes involved, the swelling will be extraoral in the area of the posterior cheek (Fig. 1–6). These swellings are generally associated with infections originating from the buccal root apices of the maxillary premolar and molar teeth and the mandibular premolar (Fig. 1–7) and first molar teeth. The mandibular second and third molars may also be involved, but infections associated with these two teeth have as much likelihood to exit to the lingual where other spaces would be involved. For infections associated with these teeth, the root apices of the maxillary teeth must lie superior to the attachment of the buccinator muscle to the maxilla, and the apices of the mandibular teeth must be inferior to the buccinator muscle attachment to the mandible.

Extraoral swelling associated with mandibular incisors will generally exhibit itself in the submental (Fig. 1–8) or submandibular space. Infections associated with any mandibular teeth, which exit the alveolar bone on the lingual and are inferior to the mylohyoid muscle attachment, will be noted as swelling in the submandibular space. There is a complete review of facial space infections in Chapter 15.
Sinus tracts of odontogenic origin may also open through the skin of the face (Figs. 1-9 and 1-10). These openings in the skin will generally close once the offending tooth is treated and healing occurs. A scar is more likely to be visible on the skin surface in the area of the sinus tract stoma than on the oral mucosal tissues (Figs. 1-9 and Fig. 1-11). Many patients with extraoral sinus tracts will give a history of being treated by general physicians and dermatologists with systemic or topical antibiotics and/or surgical procedures in attempts to heal the extraoral stoma. In these particular cases, only after multiple treatment failures are the patients finally referred to a dental practitioner to determine if there is a dental etiology.\[40\]

**Figure 1-8** Swelling of the submental space associated with periradicular disease from the mandibular incisors.

**Figure 1-9**

A, Note parulis on the right anterior side of the face. The extraoral drainage was found to be associated with periradicular disease from the mandibular right canine. B, Note the initial scar associated with the extraoral drainage incision after parulis was drained and root canal therapy was performed on the canine. C, The healed incision area three months after drainage was achieved.
Note the slight inversion of the scar area.

Figure 1-10  A. Extraoral sinus tract opening on the skin in the central chin area. B. Radiograph of mandibular incisors and canine after root canal therapy.
Intraoral Examination

The extraoral examination may give the clinician insight as to which intraoral areas may need a more focused evaluation. Extraoral swelling, localized lymphadenopathy, or an extraoral sinus tract should provoke a more detailed assessment of relating and proximal intraoral structures.

Soft Tissue Examination

As with any dental examination, there should be a routine evaluation of the intraoral soft tissues. The gingiva and mucosa should be dried, either with an air syringe or a 2 × 2-in. gauze. By retracting the tongue and cheek, all of the soft tissue should be examined for any abnormalities in color or texture. Any raised lesions or ulcerations should be documented and, when necessary, evaluated with a biopsy or referral.

Intraoral Swelling

Intraoral swellings should be visualized and palpated to determine if they are diffuse or localized and if they are firm or fluctuant. These swellings may be present in the attached gingivae, alveolar mucosa, mucobuccal fold, palate, or sublingual. Other testing methods are required to determine if the etiology is endodontic, periodontic, or a combination of these two or is of nonodontogenic origin.

Swelling in the anterior part of the palate (Fig. 1-12) is most frequently associated with an infection present at the apex of the maxillary lateral incisor or the palatal root of the maxillary first premolar. More than 50% of the maxillary lateral incisor root apices deviate toward the distal or palate. A swelling in the posterior palate
(Fig. 1-13) is most likely associated with the palatal root of one of the maxillary molars.\[50][84]

Intraoral swelling present in the mucobuccal fold (Fig. 1-14) can result from an infection associated with the apex of the root of any maxillary tooth that exits the alveolar bone on the facial and is inferior to the muscle attachment present in that area of the maxilla. The same is true with the mandibular teeth if the root apices are superior to the level of the muscle attachments and the infection exits the bone on the facial. Intraoral swelling can also occur in the sublingual space if the infection from the root apex spreads to the lingual and exits the alveolar bone superior to the attachment for the mylohyoid muscle. The tongue will be elevated and the swelling will be bilateral because the sublingual space is contiguous with no midline separation. Severe infections involving the maxillary and mandibular molars can extend into the parapharyngeal space, resulting in intraoral swelling of the tonsillar and pharyngeal areas. This can be life threatening if the patient’s airway becomes obstructed.\[50][84]
Intraoral Sinus Tracts

Occasionally a chronic endodontic infection will drain through an intraoral communication to the gingival surface known as a *sinus tract*. This pathway, which is sometimes lined with epithelium, extends directly from the source of the infection to a surface opening, or *stoma*, on the attached gingival surface. As previously described, it can also extend extraorally. The term *fistula* is often inappropriately used to describe this type of drainage. The fistula by definition is actually an abnormal communication between two internal organs or a pathway between two epithelium-lined surfaces.

Histologic studies have found that most sinus tracts are not lined with epithelium throughout their entire length. Harrison and Larson found only 1 of the 10 sinus tracts they studied were lined with epithelium. The other nine specimens were lined with granulation tissue. In a study with a larger sample size, Baumgartner et al found 20 of 30 specimens did not have epithelium that extended beyond the level of the surface mucosa rete ridges. The remaining ten specimens had some epithelium that extended from the oral mucosa surface to the periradicular lesion. The presence or absence of an epithelial lining does not seem to prevent closure of the tract as long as the source of the problem is properly diagnosed and adequately treated and the endodontic lesion has healed. Failure of a sinus tract to heal will necessitate further diagnostic procedures to determine if other etiologic factors are present or if a misdiagnosis occurred.

Generally, a periapical infection that has an associated sinus tract is not painful, although often there is pain of varying magnitude prior to the sinus tract development. Besides providing a conduit for the release of infectious exudate and the subsequent relief of pain, the sinus tract can also provide a useful aid in determining the source of a given infection. Sometimes objective evidence as to the origin of an odontogenic infection is lacking. The stoma of the sinus tract may be located directly adjacent to or at a distant site from the infection. Tracing the sinus tract will provide objectivity in diagnosing the location of the problematic tooth. To trace the sinus tract, a size #25 gutta percha cone is threaded into the opening of the sinus tract. Although this may be slightly uncomfortable to the patient, the cone should be inserted until resistance is felt. After a periapical radiograph is exposed, the termination of the sinus tract is determined by following the path taken by the gutta percha cone (Fig 1-15). This will direct the clinician to which tooth is involved, and more specifically, which root of that tooth is the source of the pathosis. Once the causative factor of the sinus tract is removed, the stoma and the sinus tract will close within a few days.

**Figure 1-14** Fluctuant swelling in mucobuccal fold associated with periradicular disease from the maxillary central incisor.
The stoma of intraoral sinus tracts may open in the alveolar mucosa, in the attached gingiva, or through the furcation or gingival crevice. They may exit through either the facial or lingual tissues depending upon the proximity of the root apices to the cortical bone. If the opening is in the gingival crevice, it is normally present as a very narrow defect in one or two isolated areas along the root surface. When a narrow defect is present, the differential diagnosis must include the opening of a periradicular endodontic lesion, a vertical root fracture, or the presence of a developmental groove on the root surface. This type of sinus tract can be differentiated from a primary periodontal lesion because the latter generally presents as a pocket with a very broad coronal opening and more generalized alveolar bone loss around the root. Other pulp testing methods will assist in verifying the etiology.

**Palpation**

In the course of the soft tissue examination, the alveolar hard tissues should also be palpated. Emphasis should be placed on detecting any soft tissue swelling or boney expansion, especially noting how it compares with and relates to the adjacent and contralateral tissues. In addition to objective findings, the clinician should question the patient on any areas that feel unusually sensitive during this palpation part of the examination.

**Percussion**
Referring back to the patient’s chief complaint may indicate how essential percussion testing can be. If the patient is experiencing acute sensitivity or pain upon mastication, this response can typically be duplicated by individually percussing the teeth, which often isolates the symptoms to a particular tooth. Pain to percussion does not indicate that the tooth is vital or nonvital, but is rather an indication of inflammation in the periodontal ligament (i.e., an acute periradicular periodontitis). This inflammation may be secondary to physical trauma, occlusal prematurities, periodontal disease, or the extension of pulpal disease into the periodontal ligament space. The indication of where the pain is coming from is interpreted by the mesencephalic nucleus, receiving its information from proprioceptive nerve receptors. Although subject to debate, the general belief is that there are few, if any, proprioceptors in the dental pulp; however, they are prevalent in the periodontal ligament spaces. This is why it may be difficult for the patient to discriminate the location of dental pain in the earlier stages of pathosis, when only the C-fibers are stimulated. Once the disease state extends into the periodontal ligament space, the pain may become more localized for the patient; therefore the affected tooth will be more identifiable with percussion and mastication testing.

Before percussing any teeth, the clinician should tell the patient what will transpire during this test. Because the presence of acute symptoms may create anxiety and possibly alter the patient’s response, properly preparing the patient will give more accurate results. The contralateral tooth should first be tested as a control, as well as several adjacent teeth that are certain to respond normally. The clinician should advise the patient that the sensation from this tooth is normal and ask to be advised of any tenderness or pain from subsequent teeth. The testing should initially be done gently, with light pressure being applied digitally with a gloved finger-tapping. If the patient cannot detect any significant difference between any of the teeth, the test should be repeated using the blunt end of an instrument, like the back end of a mirror handle (Fig. 1–16). The teeth should first be percussed occlusally, and if the patient discerns no difference, the test should be repeated, percussing the buccal and lingual aspects of the teeth. For any heightened responses, the test should be repeated as necessary to determine that it is accurate and reproducible, and the information should be documented.

**Figure 1-16** Percussion testing of a tooth, using the back end of a mirror handle.

**Mobility**

Like percussion testing, an increase in tooth mobility is not an indication of pulp vitality. It is merely an indication of a compromise to the periodontal attachment apparatus. This compromise could be the result of acute or chronic physical trauma, occlusal trauma, parafunctional habits, periodontal disease, root fractures, rapid orthodontic movement, or the extension of pulpal disease, specifically an infection, into the periodontal ligament space. Often the mobility reverses to normal after the initiating factors are repaired or eliminated. Because determining mobility by simple finger pressure can be visually subjective, the back ends of two mirror handles should be used, one on the buccal aspect of the tooth, and one on the lingual aspect of the tooth (Fig. 1–17). The degree to which the tooth moves should be recorded as follows:

+1 mobility: the first distinguishable sign of movement greater than normal
+2 mobility: horizontal tooth movement no greater than 1 mm
Any mobility over +1 mobility should be considered abnormal. However, the teeth should be evaluated on the basis of how mobile they are relative to the adjacent and contralateral teeth.

Periodontal Examination

Periodontal probing is an important part of any intraoral diagnosis. The measurement of periodontal pocket depth is an indication of the depth of the gingival sulcus, which corresponds to the distance between the height of the free gingival margin and the height of the attachment apparatus below. Deep pocket depths indicate pathologic horizontal or vertical bone loss. Using a calibrated periodontal probe, the clinician should record the periodontal pocket depths on the mesial, middle, and distal aspects of both the buccal and lingual of the tooth, noting the depths in millimeters. The periodontal probe is “stepped” around the long axis of the tooth, progressing in 1-mm increments. Periodontal bone loss that is wide, as determined by a wide span of deep periodontal probings, is generally considered to be of periodontal etiology and is typically more generalized in other areas of the mouth. However, isolated areas of vertical bone loss may be of an endodontic etiology, specifically from a nonvital tooth whose infection has extended from the periapex to the gingival sulcus. Again, proper pulp testing is imperative, not just for the determination of a diagnosis but also for the development of an accurate prognosis assessment. For example, a periodontal pocket of endodontic origin may resolve after endodontic treatment, but if the tooth was originally vital with an associated deep periodontal pocket, endodontic treatment will not improve the periodontal condition. Additionally, as discussed elsewhere in this chapter, a vertical root fracture may often cause a localized narrow periodontal pocket that extends deep down the root surface. Characteristically, the adjacent periodontium is usually within normal limits.

Furcation bone loss can be secondary to periodontal or pulpal disease. The amount of furcation bone loss, as observed both clinically and radiographically, should be documented. Furcation defects should also be recorded as follows:

Class I furcation defect: The furcation can be probed, but not to a significant depth.
Class II furcation defect: The furcation can be entered into but cannot be probed completely through to the opposite side.
Class III furcation defect: The furcation can be probed completely through to the opposite side.

Pulp Tests

Thermal

Various methods and materials have been used to test the pulp’s response to thermal stimuli. The baseline or normal response to either hot or cold is a patient’s report that a sensation is felt but disappears immediately upon removal of the thermal stimulus. Abnormal responses include a lack of response to the stimulus, the lingering or intensification of a painful sensation after the stimulus is removed, or an immediate, excruciating painful sensation as soon as the stimulus is placed upon the tooth.

Heat testing is most useful when a patient’s chief complaint is intense dental pain upon contact with any hot
liquid or food. In instances where a patient is unable to identify which tooth is sensitive, a heat test is appropriate. Starting with the most posterior tooth in that area of the mouth, each tooth is individually isolated with a rubber dam. An irrigating syringe is filled with a liquid (most commonly plain water) that has a temperature similar to that which would cause the painful sensation. The liquid is then expressed from the syringe onto the isolated tooth to determine whether the response is normal or abnormal. The clinician moves forward in the quadrant, isolating each individual tooth until the offending tooth is located. That tooth will exhibit an immediate, intense painful response to the heat. With heat testing a delayed response may occur, so waiting 10 seconds between each heat test will allow sufficient time for any onset of symptoms.

Another method for heat testing is to apply heated gutta-percha or compound stick to the surface of the tooth. If this method is used, a light layer of lubricant should be placed onto the tooth surface prior to applying the heated material to prevent the hot gutta percha or compound from adhering to the dry tooth surface. Heat can also be generated by the friction created when a dry rubber-polishing wheel is run at a high speed against the dry surface of a tooth. This latter method is seldom used today.

If the heat test confirms the results of other pulp testing procedures, emergency care can then be provided. Often a tooth that is sensitive to heat may also be responsible for some spontaneous pain. In these cases the patient may present with cold liquids in hand just to minimize the pain (Fig. 1–18). In these cases, the application of cold to a specific tooth may eliminate the pain and greatly assist in the diagnosis.

![Image](image_url)

**Figure 1-18** Patient has irreversible pulpitis associated with the mandibular right second molar and has found that the only way to alleviate the pain is to place a jar filled with ice water against the right side of his face.

Cold is the primary pulp testing method for many practitioners today. To be most reliable, cold testing should be used in conjunction with the electric pulp tester so that the results from one test will verify the findings of the other test. If a mature, untraumatized tooth does not respond to both electric pulp test and cold test, then the tooth should be considered nonvital. However, a multirooted tooth, with at least one root containing vital pulp tissue, may respond to a cold test even if one or more of the roots contain nonvital pulp tissue. Cold testing can be accomplished similarly to heat testing, by individually isolating teeth with a rubber dam. This technique for cold testing is especially useful for patients presenting with porcelain jacket crowns or porcelain-fused-to-metal crowns where there is no natural tooth surface (or much metal) accessible. Another benefit of this technique for cold testing is that it requires no armamentarium except for a rubber dam. If a clinician chooses to perform this test with sticks of ice, then the use of the rubber dam is recommended because melting ice will run onto adjacent teeth and gingiva, yielding potentially false-positive responses.

Frozen carbon dioxide (CO₂), also known as “dry ice” or “carbon dioxide snow,” has been found to be very reliable in eliciting a positive response if vital pulp tissue is present in the tooth. One study found that vital teeth will respond to both CO₂ and skin refrigerant, with skin refrigerant producing a slightly quicker response. Carbon dioxide has also been found to be effective in evaluating the pulpal response in teeth with full coverage crowns for which electric pulp testing is not possible. For testing purposes a solid stick of CO₂ is prepared by delivering CO₂ gas into a specially designed plastic cylinder (Fig. 1–19). The resulting CO₂ stick is applied to the facial surface of either the natural tooth structure or crown. Several teeth can be tested with a single CO₂ stick. The teeth should be isolated and the oral soft tissues should be protected with a 2 × 2 gauze or cotton roll so the CO₂ will not come into contact with these structures. Due to the extremely cold temperature of the CO₂ (-69°C to -119°F; -56°C to -98°C) burns of the soft tissues can occur.
Investigators\textsuperscript{[5]} demonstrated on extracted teeth that \( \text{CO}_2 \) application resulted in a significantly greater intrapulpal temperature decrease than either skin refrigerant or ice. Studies\textsuperscript{[40][68]} have also shown that the application of \( \text{CO}_2 \) to teeth does not result in any irreversible damage to the pulp tissues or cause any significant enamel crazing.

The most popular method of performing cold testing is with a refrigerant spray. It is readily available, easy to use, and provides test results that are reproducible, reliable, and equivalent to that of \( \text{CO}_2 \).\textsuperscript{[29][43]} The current product contains 1,1,1,2 - tetrafluoroethane, which has zero ozone depletion potential and is environmentally safe. It has a temperature of -26.2\(^\circ\text{C}\).\textsuperscript{[43]} The spray is most effective for testing purposes when it is applied to the tooth on a large #2 cotton pellet (\textbf{Fig. 1-20}). In a recent study\textsuperscript{[42]} a significantly lower intrapulpal temperature was achieved when a #2 pellet was dipped or sprayed with the refrigerant compared with a small #4 cotton pellet or cotton applicator. The sprayed cotton pellet should be applied to the midfacial area of the tooth or crown. As with any other pulp testing method, adjacent or contralateral “normal” teeth should be tested to establish a baseline response. It appears that \( \text{CO}_2 \) and refrigerant spray are superior to other cold testing methods and equivalent or superior to the electric pulp tester for assessing pulp vitality.\textsuperscript{[5][29]}

\textbf{Figure 1-19}  
\textbf{A.} Carbon dioxide tank with apparatus attached to form solid \( \text{CO}_2 \) stick/pencil.  
\textbf{B.} \( \text{CO}_2 \) gas being formed into a solid stick/pencil.  
\textbf{C.} \( \text{CO}_2 \) stick/pencil being extruded from the end of the plastic carrier.
A recent study compared the ability of thermal and electric pulp testing methods to register the presence of vital pulp tissue. The sensitivity, which is the ability of a test to identify teeth that are diseased, was 0.83 for the cold test, 0.86 for heat test and 0.72 for the electric test. This means the cold test correctly identified 83% of the teeth that had a necrotic pulp, while heat tests were correct 86% of the time and electric pulp tests were correct only 72% of the time. This same study evaluated the specificity of these three tests. Specificity relates to the ability of a test to identify teeth without disease. Ninety-three percent of teeth with healthy pulps were correctly identified by both the cold and electric pulp tests, while only 41% of the teeth with healthy pulps were identified correctly by the heat test. From the results of the testing it was found that the cold test had an accuracy of 86%, the electric pulp test 81%, and the heat test 71%.

**Electric**

Assessment of pulp vitality is most frequently accomplished by electric pulp testing and/or cold testing. The vitality of the pulp is determined by the intactness and health of the vascular supply, not the status of the pulpal nerve fibers. Even though advances are being made with regard to determining the vitality of the pulp on the basis of the blood supply, this technology is not accurate enough to be used on a routine basis in a clinical setting.

The electric pulp tester has limitations in providing information about the vitality of the pulp. The response of the pulp to electric testing does not reflect the histologic health or disease status of the pulp. A response by the pulp to the electric current only denotes that some viable nerve fibers are present in the pulp and are capable of responding. Numerical readings on the pulp tester have significance only if the number differs significantly from the readings obtained from a control tooth tested on the same patient with the electrode positioned at a similar area on both teeth. Studies have shown that electric pulp test results are most accurate when no response is obtained to any amount of electric current. This lack of response has been found most frequently when a necrotic pulp is present. The electric pulp tester will not work unless the probe can be placed in contact with or be bridged to the natural tooth structure. With the advent of universal precautions for infection control, the patient may be required to place a finger or fingers on the tester probe to complete the electric circuit for some models; however, lip clips are an alternative to having patients hold the probe.
tester. The use of rubber gloves prevents the clinician from completing the circuit. Proper use of the electric pulp tester requires that the teeth to be evaluated be isolated and dried. A control tooth of similar tooth type and location in the arch should be tested first in order to establish a baseline response and to inform the patient what a “normal” sensation is. The suspected tooth should be tested at least twice to confirm the results. The tip of the testing probe that will be placed in contact with the tooth structure must be coated with a water- or petroleum-based media. The most commonly used media is toothpaste. The coated probe tip is placed in the incisal third of the facial or buccal area of the tooth to be tested. Once the probe is in contact with the tooth, the patient is asked to touch or grasp the tester probe (Fig. 1-21, A). This completes the circuit and initiates the delivery of electric current to the tooth. The patient is instructed to remove his or her finger(s) from the probe when a “tingling” or “warming” sensation is felt in the tooth. The readings from the pulp tester are recorded (Fig. 1-21, B) and will be evaluated once all the appropriate teeth have been tested and the results obtained from other pulp testing methods.

If a complete coverage crown or extensive restoration is present, a bridging technique can be attempted to deliver the electric current to any exposed natural tooth structure. The tip of an endodontic explorer is coated with toothpaste or other appropriate media and placed in contact with the natural tooth structure. The tip of the electric pulp tester probe is coated with a small amount of toothpaste and placed in contact with the side of the explorer. The patient completes the circuit and the testing proceeds as described previously. If no natural tooth structure is available then an alternative pulp testing method, such as cold, should be used.

As noted previously, studies have shown that there does not appear to be any significant difference between the pulp testing results obtained with the electric pulp tester and those obtained with the thermal methods, although cold tests have been shown to be more reliable than electric pulp tests in younger patients with less developed apices. However, unlike electric pulp testing, cold testing can reveal the health and integrity of pulp tissue (i.e., no response, a momentary response, or a prolonged, painful response after the thermal stimulus is removed). This is why it is a good rationale to verify the results obtained with one testing method to those obtained with the other method. Until such time that the testing methods used to assess the vascular supply of the pulp become less time consuming and technique sensitive, thermal and electric pulp testing will continue to be the primary methods for determining pulp vitality.

**Laser Doppler Flowmetry**

Laser Doppler Flowmetry (LDF) is a method used to assess blood flow in microvascular systems. Attempts are being made to adapt this technology to assess pulpal blood flow. A diode is used to project an infrared light beam through the crown and pulp chamber of a tooth. The infrared light beam is scattered as it passes through the pulp tissue. The Doppler principle states that the light beam will be frequency-shifted by moving red blood cells but will remain unshifted as it passes through static tissue. The average Doppler frequency shift will measure the velocity at which the red blood cells are moving.

Several studies have found the LDF to be an accurate, reliable, and reproducible method of assessing pulpal blood flow. Even with these positive findings, the technology is not advanced enough for this

![Figure 1-21 A. View of an electric pulp tester with probe. The probe tip will be coated with a media such as toothpaste and placed into contact with the tooth surface. The patient will activate the unit by placing a finger into contact with the metal shaft of probe. B. View of the electric pulp tester control panel: The knob on the right front of the unit controls the rate at which the electric current is delivered to the tooth. The plastic panel on the left front displays the digital numerical reading obtained from the pulp test. The digital scale runs from 0 to 80.](http://home.mdconsult.com.eproxy1.lib.hku.hk/das/book/body/0/1357/9...
method to be used on a routine basis in a dental practice. In one clinical trial fabricating the individualized stabilization jig, making the LDF recordings took approximately 1 hour, a finding not unique to this study. If technology can be developed whereby the testing with the LDF can be accomplished in minutes, it will likely replace the thermal and electric pulp testing methods.

As will be discussed in Chapter 16, certain luxation injuries will cause inaccuracies in the results of electric and thermal pulp testing. LDF has recently been shown to be a great indicator for pulpal vitality in these cases.

**Pulse Oximetry**

Another noninvasive method that has been investigated as a method to determine pulpal blood flow uses a pulse oximeter, which is designed to measure the oxygen concentration of the blood and the pulse rate. The oximeter works on the principle that two wavelengths of light transmitted by a photoelectric diode detect oxygenated and deoxygenated hemoglobin as they pass through a body part to a receptor. The difference between the light emitted and the light received is calculated by a microprocessor to provide the pulse rate and oxygen concentration in the blood.

Attempts to use the pulse oximeter to diagnosis pulp vitality have met with mixed results. Some studies have reported that the pulse oximeter is a reliable method for assessing pulp vitality. Others have stated that its present form the pulse oximeter is not of predictive diagnostic value for diagnosing pulp vitality. Most of the problems appear to be related to the present available technology. The devices used for pulp testing are too cumbersome and complicated to be used on a routine basis in a dental practice.

**Special Tests**

**Bite Test**

Percussion and bite tests are indicated when a patient presents with pain while biting. Occasionally the patient may not know which tooth is sensitive to biting pressure, and percussion and bite tests may help to localize the tooth involved. The tooth may be sensitive to biting when the pulpal pathosis has extended into the periodontal ligament space, creating a periradicular periodontitis, or the sensitivity may be present secondary to a crack in the tooth. The practitioner can often differentiate between periradicular periodontitis and a cracked tooth or fractured cusp. If periradicular periodontitis is present, the tooth will respond with pain to percussion and biting tests regardless of where the pressure is applied to the coronal part of the tooth. A cracked tooth or fractured cusp will elicit pain only when the percussion or bite test is applied in a certain direction to one cusp or section of the tooth.

For the bite test to be meaningful a device should be used that will allow the practitioner to apply pressure to individual cusps or areas of the tooth. A variety of devices have been used for bite tests, including cotton applicators, toothpicks, orangewood sticks, and rubber polishing wheels. Today several devices are specifically designed to perform this test. The Tooth Slooth (Professional Results, Inc., Laguna Niguel, CA) and Frac Finder (Hu Friedy Co., Chicago, IL) are just two of the commercially available devices used for the bite test. As with all pulp tests, adjacent teeth should be used as controls so that the patient is aware of the “normal” response to these tests. The small cupped-out area on these instruments is placed in contact with the cusp to be tested. The patient is then asked to apply biting pressure with the opposing teeth to the flat surface on the opposite side of the device. The biting pressure should be applied slowly until full closure is achieved. The firm pressure should be applied for a few seconds; the patient is then asked to release the pressure very quickly. Each individual cusp on a tooth can be tested in a like manner. The practitioner should note if the pain is elicited during the pressure phase or upon quick release of the pressure. A common finding with a fractured cusp or cracked tooth is the frequent presence of pain upon release of biting pressure.
Test Cavity

The test cavity method for assessing pulp vitality is very seldom used today. This method is used only when all other test methods are deemed impossible or the results of the other tests are inconclusive. An example of a situation where this method might be used is when the tooth suspected of having pulpal disease has a full coverage crown. If no sound tooth structure is available to use a bridging technique with the electric pulp tester and cold test results are inconclusive, a small class I cavity preparation is made through the occlusal surface of the crown. This is accomplished with a high-speed #1 or #2 round bur with proper air and water coolant. The patient is not anesthetized while this procedure is performed, and the patient is asked to respond if any painful sensation is felt during the drilling procedure. If the patient feels pain once the bur contacts sound dentin, the procedure is terminated and the class I cavity preparation is restored. This sensation signifies only that there is some viable nerve tissue remaining in the pulp, not that the pulp is totally healthy. If the patient fails to feel any sensation when the bur reaches the dentin, it is a good indication that the pulp is necrotic and root canal therapy is indicated.

Staining and Transillumination

In order to determine the presence of a crack in the surface of the tooth, the application of a stain to the area is often of great assistance. Shining a very bright light on the surface of the tooth is also very helpful. This will be elaborated on later in this chapter in the discussion of the detection of cracks and fractures.

Selective Anesthesia

When symptoms are nonlocalized or referred, the diagnosis may be very challenging. Sometimes the patient may not even be able to specify whether the symptoms are emanating from the maxillary or mandibular arch. In these instances, when pulp testing is inconclusive, selective anesthesia may be very helpful.

If the patient cannot determine which arch the pain is coming from, then the clinician should first selectively anesthetize the maxillary arch. This should be accomplished by using a periodontal ligament (intraligamentary) injection. The injection is administered to the most posterior tooth in the quadrant of the arch that may be suspected, starting from the distal sulcus. The anesthesia is subsequently placed more forward, one tooth at a time, until the pain is eliminated. If, after an appropriate period of time, the pain is not eliminated, the clinician should similarly repeat this technique on the mandibular teeth below. It should be understood that periodontal ligament injections may inadvertently anesthetize an adjacent tooth, and thus are more useful for identifying the arch rather than the specific tooth.

Radiographic Examination and Interpretation

Intraoral Radiographs

Few diagnostic tests provide as much useful information as dental radiography. For this reason, the clinician is sometimes tempted to prematurely make a definitive diagnosis based solely on radiographic interpretation. However, the image should be used only as one sign, providing important clues in the diagnostic investigation. When not coupled with a proper history and clinical examination and testing, the radiograph alone can lead to a misinterpretation of normality and pathosis (Fig. 1-23). Since treatment planning will
ultimately be based upon this diagnosis, the potential for inappropriate treatment may be great if the radiograph alone is used for making this diagnosis. The clinician should not subject the patient to unnecessary multiple radiation exposures; often two preoperative images from different angulations are sufficient. But in extenuating circumstances, especially when the diagnosis is difficult, multiple exposures may be necessary in order to determine the presence of multiple roots, multiple canals, resorptive defects, caries, restoration defects, root fractures, and the extent of root maturation and apical development.

The radiographic appearance of endodontic pathosis can sometimes be very subjective. In a study by Goldman et al,[31] there was agreement of pathosis in only 50% of the radiographically evaluated cases, as interpreted by two endodontists, three second-year residents, and an associate professor in radiology. Additionally, when the cases were evaluated several months later, the evaluators agreed with their own original diagnosis only 75% to 83% of the time. Again, this emphasizes the necessity for other objective diagnostic tests, as well as the importance of obtaining and comparing older radiographs.

Figure 1-23  Radiograph of what appears to be a periapical lesion associated with a nonvital tooth; however, the tooth is vital. The appearance of apical bone loss is actually secondary to a cementoma.

The radiographic appearance of endodontic pathosis can sometimes be very subjective. In a study by Goldman et al,[31] there was agreement of pathosis in only 50% of the radiographically evaluated cases, as interpreted by two endodontists, three second-year residents, and an associate professor in radiology. Additionally, when the cases were evaluated several months later, the evaluators agreed with their own original diagnosis only 75% to 83% of the time. Again, this emphasizes the necessity for other objective diagnostic tests, as well as the importance of obtaining and comparing older radiographs.

In the practice of medicine, computerized axial tomography (CAT) scans can give the clinician a virtual three-dimensional image that can be rotated in a multitude of directions in order to better visualize and interpret anatomic structures and pathosis. This type of imagery will eventually be miniaturized and available for the dental office (see Chapter 9 for examples). For now clinicians must rely on x-ray visualization in only two dimensions. Clinicians basically project X-radiation through an object and capture the image on a recording medium—either x-ray film or a digital sensor. Much like casting a shadow from a light source, the image appearance may vary greatly depending on how the radiographic source is directed. Therefore, the three-dimensional interpretation of the resulting two-dimensional image requires not only knowledge of normality and pathosis but also advanced knowledge of how the radiograph was exposed. By virtue of “casting a shadow,” the anatomic features that are closest to the film (or sensor) will move the least when there is a change in the horizontal or vertical angulation of the radiation source (Fig. 1-24). This may be very helpful in determining the existence of additional roots, the location of pathosis, and the unmasking of anatomical structures. Changes in the horizontal or vertical angulation may help elucidate valuable anatomic and pathologic information; it also has the potential to hide important information. An incorrect vertical angulation may cause the buccal roots of a maxillary molar to be masked by the zygomatic arch. An incorrect horizontal angulation may cause roots to overlap with the roots of adjacent teeth, or it may incorrectly create the appearance of a one-rooted tooth, when two roots are actually present.
Generally, when endodontic pathosis appears radiographically, it appears as bone loss in the area of the periapex. The infection in the pulpal space transgresses through the pulpal canal and into the associated bone. The pathosis may present merely as a widening or break in the lamina dura—the most consistent radiographic finding when a tooth is nonvital,[44] or it may present as a radiolucent area at the apex or in the area of a lateral or furcation canal. Occasionally there may be no radiographic change at all, even in the presence of an acute periradicular abscess.

The variability in the radiographic expression of osseous pathosis has much to do with the relative location of the root of the tooth and how it is oriented with respect to the cortical and cancellous bone. Radiographic changes from bone loss will not be observed if the bone loss is only in cancellous bone. However, radiographic evidence of pathosis will be observed once this bone loss extends to the junction of the cortical and cancellous bone, as was illustrated by Bender and Seltzer[10] whereby artificial lesions were created in cadaver bone and evaluated radiographically. As a follow-up to this study, the authors reported why certain teeth are more prone to exhibit radiographic changes than others, depending on their anatomic location.[11] Their findings revealed that the radiographic appearance of endodontic pathosis is correlated with the relationship of the periapex of the tooth and its juxtaposition to the cortical-cancellous bone junction. Most anterior and premolar teeth are located very close to the cortical-cancellous bone junction. For this reason, periapical pathosis from these teeth is exhibited sooner. By comparison, the distal roots of mandibular first molars and both roots of mandibular second molars are generally positioned more centrally within the cancellous bone, as are maxillary molars, especially the palatal roots. Periapical lesions from these roots have to expand more before they reach the cortical-cancellous bone junction and are recognized as radiographic pathosis. For these reasons, it is important not to exclude the possibility of pulpal pathosis in situations in which there are no radiographic changes.

Many factors can influence the quality of the radiographic interpretation, including the ability of the person exposing the radiograph, the quality of the radiographic film, the quality of the exposure source, the quality of the film processing, and the quality of how the film is viewed. Controlling all of these variables can be a
difficult challenge but is paramount for obtaining an acceptable radiographic interpretation.

**Digital Radiography**

One technique for controlling many of the variables in the diagnostic quality of conventional radiography has been the advent of digital radiography. This technology has been around for about 20 years but has recently been refined with better hardware and more user-friendly software. Digital radiography has the ability to capture, view, enhance and store radiographic images in an easily reproducible format that does not degrade over time.

Digital radiography uses no x-ray film and requires no chemical processing. Instead, a sensor is used to capture the image created by the radiation source. This sensor is either directly or remotely attached to a local computer, which interprets this signal and, using specialized software, translates the signal into a digital image that can be displayed and enhanced. The image is stored in the patient’s file, typically in a dedicated network server, and can be recalled as needed. Further information about digital radiography may be found in Chapters 5 and 26.

The viewing of a digital radiographic image on a high resolution monitor allows for rapid and easy interpretation for both the clinician and the patient. The image appears almost instantly, with no potential for image distortion from improper chemical processing, since there is none. The clinician can zoom in to different areas on the x-ray image, digitally enhance the image in order to better visualize certain anatomic structures, and in some cases, the image can even be colorized, a useful tool for patient education (Fig. 1–25).

![Figure 1-25](image)

**Figure 1-25** Digital radiography has as an advantage over conventional film in that the image can be enhanced and colorized, a useful tool for patient education.

Until recently, x-ray film has had a slightly better resolution than most digital radiography images, at about 16 line pairs per millimeter (lp/mm) [57]. However, some sensor manufacturers are now claiming to have resolutions beyond that of film and up to 22 lp/mm. However, under the best of circumstances, the human eye can only see about 10 lp/mm, which is the lowest resolution for most dental digital radiography systems. The digital sensors are much more sensitive to radiation than conventional x-ray film and thus require 50% to 90% less radiation in order to acquire an image, an important feature for generating greater patient acceptability of dental radiographs.

The diagnostic quality of this expensive technology has been shown to be comparable to, but not necessarily superior to, perfectly exposed and perfectly processed conventional film-based radiography [22][47][61]. However, digital radiography has the advantage over conventional film in that there is no diminution in diagnostic quality caused by developing and processing errors, and it has the ability to enhance, magnify, store, and electronically send the images, as well as the ability to duplicate the original radiograph as a perfect copy. In 1998, the American Association of Endodontists stated that “digital radiography will rapidly replace conventional dental X-rays.” [9] The reader is referred to Chapter 26 for more information on digital radiography.

**Root Fractures and Cracks**

Because of the wide variety of different types of cracks in teeth, there may be a myriad of symptoms and presentations, making the diagnosis of a crack often difficult. The extensiveness of a crack may directly alter the prognosis assessment for a given tooth. Therefore, any possible crack should be examined prior to dental
treatment. These cracks may be as innocent as a superficial enamel craze line, or they may be as prominent as a fractured cusp. The crack may progress into the root system to involve the pulp, or it may even split the entire tooth into two separate pieces. The crack may be oblique, extending cervically, such that once the coronal segment is removed the tooth may or may not be restorable. Any of these situations may present with mild, moderate, or severe symptoms or possibly no symptoms at all. Because of the high prevalence of fractures and cracks in teeth and how they can directly alter the prognosis for a tooth, an extensive review is presented.

Crack Types

There have been many attempts in the literature to classify cracks in teeth, trying to differentiate the extent to which the crack has progressed into the tooth structure. By defining the type of crack present, an assessment of the prognosis may be determined and treatment alternatives may be planned as fully described in Chapter 16. Unfortunately, it is often impossible to determine how extensive a crack is until the tooth is extracted. Therefore, the determination of a crack is often more of a prediction, rather than a definitive diagnosis.

Cracks in teeth can be divided into three basic categories:

- Craze lines
- Fractures (also referred to as cracks)
- Split roots

**Craze lines** are merely cracks in the enamel that do not extend into the dentin and either occur naturally or develop secondary to trauma. They are more prevalent in adult teeth and usually occur more in the posterior teeth. If light is transilluminated through the crown of such a tooth, these craze lines may show up as fine lines in the enamel with light being able to transmit through them, indicating that the crack is only superficial. Craze lines typically will not manifest with symptoms. No treatment is necessary for craze lines unless they create a cosmetic issue.

**Fractures** extend deeper into the dentin than superficial craze lines and primarily extend mesially to distally, involving the marginal ridges. Dyes and transillumination are very helpful in visualizing potential root fractures. Symptoms from a fractured tooth range from none to severe pain. A fracture in the tooth does not necessarily dictate that the tooth has split into two pieces, but left alone, especially with provocations like occlusal prematurities, the fracture may progress to a split root. A fractured tooth may be treated by a simple restoration, endodontics, or even extraction, depending upon the extent and orientation of the fracture, the degree of symptoms, and whether or not the symptoms can be eliminated. This makes the clinical management of fractured teeth difficult and sometimes unpredictable.

A definitive combination of factors, signs, and symptoms that, when collectively observed, allows the clinician to conclude the existence of a specific disease state is termed a syndrome. However, given the multitude of signs and symptoms that fractured roots can present with, it is often difficult to achieve an objective definitive diagnosis. For this reason, the terminology of cracked tooth syndrome should be avoided. The subjective and objective factors seen in cases of fractured teeth will generally be diverse; therefore a tentative diagnosis of a fractured tooth will most likely be more of a prediction. Once this prediction is made, the patients must be properly informed as to any potential decrease in the prognosis of the pending dental treatment. Since treatment options for repairing fractured teeth have only a limited degree of success, early detection, prevention, and proper informed consent are crucial.

**Split roots** occur when a fracture extends from one surface of the tooth to another surface of the tooth, with the tooth separating into two segments. If the split is more oblique, it is possible that once the smaller separated segment is removed, the tooth might still be restorable, e.g., a fractured cusp. However, if the split extends below the osseous level or involves the pulp, the tooth may not be restorable and endodontic treatment may not result in a favorable prognosis.

Proper prognosis assessment prior to any dental treatment is imperative, but is often difficult in cases of cracked teeth. Because of the questionable long-term success from treating cases of suspected or known fractures, the clinician should be cautious in the decision to continue with treatment and should avoid treating cases of definitive split roots.

**Vertical Root Fractures**
Certainly, of the previous three categories, fractured teeth are the most variable in presentation, in that the extent of the fracture is often difficult to determine. One of the more common reasons for recurrent endodontic pathosis is the **vertical root fracture**, a severe crack in the tooth that extends longitudinally down the long axis of the root. Often it extends through the pulp and to the periodontium. It tends to be more centrally located within the tooth, as opposed to being more oblique, and typically traverses through the marginal ridges. These fractures may be present prior to endodontic treatment, secondary to endodontic treatment, or they may develop after endodontic treatment has been completed. Because diagnosing these vertical root fractures may be difficult, they often go unrecognized. Typically, these cracks lead to a split root, leaving the tooth with a poor prognosis. Therefore, diagnosing the existence and extent of a vertical root fracture is imperative prior to any restorative or endodontic treatment since these cracks can dramatically affect the overall success of treatment. Because the presence of vertical root fractures play such an important role in the prognosis assessment of teeth, a detailed analysis of vertical root fractures is presented here.

**Etiology of a Vertical Root Fracture**

Vertical root fractures may arise from a physical traumatic injury, occlusal prematurities, repetitive parafunctional habits of heavy stressful chewing, or resorption-induced pathologic root fractures. However, the most common cause of vertical root fractures may be iatrogenic dental treatment. Dental procedures such as the placement of posts and pins or the tapping into place of a tightly fitting post or intracoronal restoration may induce a vertical root fracture. The most common dental procedure contributing to vertical root fractures is endodontic treatment. Preoperatively, teeth that are about to undergo endodontic treatment may be predisposed to vertical root fractures since quite often the tooth is already compromised from extensive coronal restorations, caries, resorption, or trauma. Teeth were once thought to be more susceptible to fracturing after endodontic treatment because of a decrease in hydration. However, later studies found no difference in the dentin properties after endodontic procedures. Although the physical characteristics of the dentin may not be compromised by endodontic treatment, the over-enlarging of an endodontic access and excessive canal shaping will result in an increased amount of dentin removal. Consequently, the root may become weaker and may be more predisposed to vertical root fractures. Intracanal forces from excessive compaction pressure during obturation may also contribute to an increased incidence of vertical root fractures.
The assessment of a potential vertical root fracture may be based more on subjective than on objective findings, making the diagnosis more like an art than a science, but early detection is crucial. Many subtle findings can lead the clinician to suspect a vertical root fracture. Medical and dental histories are very important. Clinical, periodontal, and radiographic examinations may be at best only suggestive of a vertical root fracture. The tooth is typically painful, with symptoms ranging from mild to severe in intensity. When the tooth is painful, patients will typically complain of symptoms when they occlude or release on the tooth in a specific direction. Also noteworthy is the anatomic location of the tooth in question. Mandibular second molars have a higher incidence of vertical root fractures, followed by maxillary first molars and maxillary premolars. Prominent cusps, balancing interferences, and occlusal prematurities may all be factors in this predisposition to fracturing.

**Medical History**

*Figure 1-26* Poorly fitting intracoronal restorations can place stresses within the tooth that can cause a vertical root fracture. **A**, This radiograph of a mandibular second premolar (with a gold inlay) reveals extensive periapical and periradicular bone loss, especially on the distal. **B**, The tooth pulp tested nonvital, and there was an associated 12-mm-deep, narrow, isolated periodontal pocket on the buccal aspect of the tooth. After the tooth was extracted, the distal aspect was examined. **C**, Upon magnification (16x) the distal aspect of the root revealed an oblique vertical root fracture. Similarly, the placement of an ill-fitting post may exert intraradicular stresses on a root that can cause a fracture to occur vertically. **D**, This radiograph depicts a symmetrical space between the obturation and the canal wall, suggesting a vertical root fracture. **E**, After the tooth is extracted, the root fracture can be easily observed.
The patient’s medical history may seem like an unlikely place to discover any suggestion of a vertical root fracture. But a history of facial trauma may add information to help in the creation of a differential diagnosis. For example, patients with seizure disorders may be prone to dental trauma, either from severe seizure-induced clenching, or from physical injuries sustained secondary to a grand mal seizure (Fig. 1-27). Additionally, a patient who has had a stroke, heart attack, or any other ailment that might have resulted in lack of consciousness could have traumatized a tooth. This could result in a vertical root fracture if the trauma is directed accordingly.

**Dental History**

Various comments made by a patient when a dental history is taken may direct the clinician to suspect a vertical root fracture. A patient might report ice chewing or other parafunctional habits. A patient might also describe a symptom by stating “the tooth only hurts when I bite a certain way.” Comments like “it only started hurting after I accidentally bit down on a cherry pit” might also be suggestive of a vertical root fracture. Other comments concerning recent dental treatment may also be significant. Localized pain on tooth after the placement of a cast post or cast intracoronal restoration could also implicate a vertical root fracture. The repeated falling out of a coronal restoration could be due to a fracture between the axial walls of the preparations; as the fractured segments flex or move apart, the restoration between these segments may lose its resistance form, become loose, and dislodge. Similarly, a retrograde restoration that has become dislodged could be secondary to a vertical root fracture apically.[24][65] As the apical fracture opens up, the retrograde restoration may come out (Fig. 1-28). An endodontic procedure that was performed well but does not result in healing may also be suggestive of a vertical root fracture, especially if the tooth does not heal after retreatment or apical surgery.

**Figure 1-27** Physical trauma from sports-related injuries or seizure-induced trauma, if directed accordingly, may cause a vertical root fracture in a tooth. This fracture occurred in a 7-year-old child secondary to trauma from a grand mal seizure.
Clinical Evaluation of a Vertical Root Fracture

Crack Probing.

Occasionally a vertical root fracture can be observed upon clinical examination. The use of a dental operating microscope may be invaluable in detecting cracks and fractures in the clinical crown and root surfaces. Probing the crack may elicit pain or even reveal moving segments on either side of the crack line, indicating a split tooth. To determine the extent of the fracture, it is important to apply some pressure to the cusps that are adjacent to any visible crack (Fig. 1–29). Occasionally, pressure to the cusp or actual probing of the crack will reveal a split tooth that would not have otherwise been found.
Selective Sensitivity.

Vertical root fractures may manifest as a selective sensitivity when the tooth is percussed in a particular direction. The back end of a dental mirror handle is a very useful instrument. There are also specially designed bite sticks that when applied to a certain part of the tooth may elicit pain that would not be present when biting on another location of the tooth’s occlusal surface (see Fig. 1–20).

Restorative Treatment.

Highly suspect of a vertical root fracture is a tooth with minimal or no restoration or caries that is nonvital. Except for luxation injuries, systemic disease (for example, intraoral herpes zoster) or surgical procedures that may accidentally devitalize a tooth (i.e., sinus surgery, orthognathic surgery, accidental extraction of a tooth with subsequent replantation); for example, a vertical root fracture is one of the few reasons for such a tooth to become nonvital (Fig. 1–30). A tooth with recurrent endodontic pathosis and a post that is an abutment to a cantilever bridge should also be suspected of having a vertical root fracture (Fig. 1–31). The torque created during mastication on the cantilevered pontic and the subsequent flexing of the bridge can cause stresses in the root that lead to vertical root fracture. Persistent symptoms on a tooth with a conservative cast intracoronal restoration should also make the clinician suspicious of a vertical root fracture. Generally speaking, there has to be a reason for a tooth becoming nonvital and/or causing pain. The clinician should evaluate the restorative treatment, or lack thereof, and try to make an assessment as to whether or not there is sufficient cause for necrosis or symptoms; differential diagnosis should always include vertical root fracture under these circumstances.
Also indicative of a vertical root fracture is the presence of multiple sinus tracts adjacent to the tooth in question. Since the fracture may be present on at least two surfaces of the tooth, the infected area may drain...
to multiple sites, creating multiple sinus tracts. [24]

**Dental Operating Microscope.**

Used in medicine for years, the dental operating microscope (DOM) has become an invaluable tool when doing endodontic treatment. With magnification capabilities of over $25 \times$, and with superb illumination, the clinician is now capable of observing intracoronarional and extracoronarional details with great precision. Sometimes a fracture may be observed extracoronally prior to endodontic treatment; its depth can be visualized intracoronally with the DOM after an endodontic access has been created (Fig. 1–32).

**Surgical Exposure.**

Often the only definitive way of determining if there is a vertical root fracture or split tooth is by direct surgical exposure. For optimal visualization of a potential fracture, a full thickness mucoperiosteal flap incision should be created at the level of the sulcus and reflected apically. Typically, only a small flap is necessary, since once the flap is reflected, if there is a vertical root fracture, it can usually be seen after the overlying granulation tissue is removed. Many times there is an associated boney dehiscence directly over the fracture. The use of a DOM is especially helpful in maximizing the illumination and visualization of these defects (Fig. 1–33).

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**Figure 1-32.** Often the radiograph does not give a good indication of a vertical root fracture. **A,** This mandibular second premolar is nonvital, with a restoration that is not significantly close to the pulp chamber. **B,** The interior walls of the pulp chamber are examined under high magnification (12X) to reveal a vertical root fracture.
Transillumination and Dyes.

Often it may be necessary to remove the restoration in the tooth to better visualize the fracture. Methylene blue dye when painted on the tooth surface with a cotton tip applicator will penetrate into cracked areas. The excess dye may be removed with a moist application of 70% isopropyl alcohol. The dye will indicate the possible location of a crack. Transillumination may be more helpful (Fig. 1-34). Directing a high-intensity light directly on the exterior surface of the tooth at the cementum-enamel junction (CEJ) may indicate the extent of the fracture. Teeth with fractures block transilluminated light. The part of the tooth that is proximal to the light source will absorb this light and glow, whereas the area beyond this fracture will not have light transmitted to it and will be grey by comparison.[65] Although the presence of a fracture may be evident using dyes and transillumination, the depth of the fracture cannot always be determined.

Figure 1-33 When a vertical root fracture is suspected, sometimes the reflection of a surgical flap over the root may allow better visualization. A, The radiograph here shows no indication of a root fracture. B, However, after surgical exposure, the fracture can be seen. C, Unfortunately, this tooth was never extracted and is observed with a prominent split root a year later. D, Similarly, the radiograph of this mandibular anterior tooth shows no indication of a root fracture. E, However, when the root is surgically exposed, the fracture is easily seen.
Radiographic Evaluation of a Vertical Root Fracture

Occasionally, a vertical root fracture or a split tooth may be an obvious diagnosis based on radiographic findings (Fig. 1–35). However, most of the time the fracture is in a plane that is not perceptible from a periapical radiograph. In one study using extracted teeth, investigators determined that a fracture becomes visible when the x-ray beam is directed within 4 degrees of the fracture plane. Outside of this horizontal angulation, a fracture may not be discernible. They also found that when a vertical root fracture is present, it is observed in a radiograph only 35.7% of the time (Fig. 1–36).

Figure 1-34 Sometimes there is no clear indication of why a tooth is symptomatic. This radiograph shows a mandibular second molar with a moderately deep restoration (A); the pulp tests nonvital. Without any transillumination a fracture cannot be detected (B). However, by placing a high-intensity light source on the tooth surface, a root fracture can be observed on the buccal (C) and the distal-lingual (D).

A

B

C

D

Figure 1-35 A and B. Vertical root fractures that develop into split roots are sometimes easy to diagnose from a radiograph.
Another interesting way of detecting vertical root fractures or split teeth is from a CAT scan. This technique has been shown to be superior to dental radiography in the detection of vertical root fractures. However, this type of imaging is typically not yet available in a dental office.

To assist the clinician, other radiographic signs may be helpful in the detection of vertical root fractures.

**Cement Trail**

When the vertical root fracture or split root extends from the mesial to the distal of the tooth, often this crack can be “interpreted” after endodontic treatment has been performed. Sometimes a “cement trail” can be seen up or across the root. This is the cement extruded through and out of the fracture site, after which it becomes visible radiographically. It can be confused with the obturation passing through accessory canals, but the appearance is more diffuse in cases of vertical root fractures, with no observation of a symmetrical lateral canal passing from a main canal (Fig. 1-37).

**Halo-like Bone Loss**

Typically, when a nonvital tooth causes radiographic changes, the bone loss occurs apically. However, often when there is a vertical root fracture or split root, the bone loss has a tendency to give a “halo-like” appearance, traversing circumferentially around the root. The radiolucent area may also travel almost completely up one side of the root, with this pattern of bone loss often termed a “J-type” lesion (Fig. 1-38).
Isolated Bone Loss

The clinician should be aware of unusual radiographic changes revealing extensive bone loss that is isolated to just one tooth in the absence of advanced periodontal disease (Fig. 1-39). This could be suggestive of a vertical root fracture or split tooth.

When attempting to make a diagnosis of a vertical root fracture or split tooth, the clinician should also look for the following:

- A widened canal space which is inconsistent with the canal spaces of the adjacent roots (Fig. 1-40).
- A radiolucent space presenting between the long axis of the obturation material (or post) and the canal wall (Fig. 1-41).
- An associated bone loss mesial and distal to the root. When a vertical root fracture or split root extends from the mesial to the distal of the tooth, there is often an atypical widening of the entire periodontal ligament space.

Figure 1-38 Often the radiographic presentation of a vertical root fracture is the pattern of bone loss occurring in a “J-shaped” radiolucency, with the bone loss originating apically and progressing coronally up one side of the root.

Figure 1-39 Extensive periodontal bone loss around an isolated tooth, with the adjacent teeth within normal limits, is suggestive of a vertical root fracture.

Figure 1-40 When there is a disproportionate widening of a canal space compared with the canals in the same tooth or adjacent teeth, as seen in this mandibular second molar, a vertical root fracture should be suspected.
When these features are visualized on the radiograph, a vertical root fracture or split tooth should be strongly suspected.

**Periodontal Evaluation of a Vertical Root Fracture**

Typically, a vertical root fracture or split tooth has associated bone loss contiguous with the fracture line. Left undetected, this creates a dehiscence in the bone and a V-type pattern of bone loss extending apically. The periodontal pocket associated with this bone loss is generally isolated, narrow, and deep (Fig. 1-42); a similar defect may occur 180 degrees opposite to the defect (i.e., the other side of the fracture on the other side of the root). When the periodontal probe is inserted into this type of periodontal pocket, it is **tight** within the pocket, and the periodontal probe’s movement from side to side is restricted. This is a classic periodontal presentation and is practically pathognomonic for a vertical root fracture or split tooth.

**Prognosis of a Vertical Root Fracture**

A patient who consents to endodontic treatment must be informed if the tooth has a questionable prognosis. The clinician must be able to interpret the subjective and objective findings that suggest a vertical root fracture.
or split tooth, be able to make a prediction as to the eventual potential of healing, and must convey these suspicions to the patient. The prognosis assessment should be described as follows:

**Good Prognosis.**

If a coronal crack is observed with nonmovable segments and the patient does not have symptoms, notwithstanding any other adverse parameters the tooth has a good prognosis.

**Fair Prognosis.**

If the tooth is sensitive upon probing the occlusal crack, with the opposing segments nonmovable, then the prognosis is more guarded. The patient should understand that the pending endodontic treatment may not resolve the symptoms and that the prognosis is only fair. If endodontic treatment is performed, the interior walls of the access should be carefully examined, preferably with the use of a DOM along with transillumination, to determine if the crack has traversed into the canal space (see Fig. 1–32). If this is observed, the patient should again be advised of the potential for a more compromised prognosis. The tooth should be restored with a bonded intracoronal core in the access, the use of a post should be avoided, and a full-coverage restoration with cuspal reinforcement should be placed.

**Poor Prognosis.**

If there are movable segments on either side of the occlusal crack, then the prognosis is poor. Often the movement of the segments is difficult to visualize, so magnification is essential. If this tooth is nonvital, with a minimal caries and restorative history, and has a deep, narrow, isolated periodontal pocket with normal periodontium otherwise, then a vertical root fracture or a split root should be highly suspected, and extraction should be considered.

**Referred Pain**

The perception of pain in one part of the body that is distant from the actual source of the pain is known as referred pain. Whereas pain of nonodontogenic origin can refer pain to the teeth, teeth may also refer pain to other teeth as well as to other anatomic areas of the head and neck (see Chapter 3). This may create a diagnostic challenge, in that the patient may insist that the pain is from a certain tooth or even from an earache when, in fact, it is originating from a distant tooth with pulpal pathosis. Using electronic pulp testers, investigators found that patients could localize which tooth was being stimulated only 37.2% of the time and could narrow the location to three teeth only 79.5% of the time, illustrating that patients may have a difficult time discriminating the location of pulpal pain.

Referred pain from a tooth is usually provoked by an intense stimulation of pulpal C-fibers, the slow conducting nerves that when stimulated cause an intense, slow, dull pain. Referred pain always radiates to the ipsilateral side of the tooth involved. Anterior teeth seldom refer pain to other teeth or to opposite arches, whereas posterior teeth may refer pain to the opposite arch or to the periauricular area but seldom to the anterior teeth. Mandibular posterior teeth tend to transmit referred pain to the periauricular area more often than maxillary posterior teeth. One study showed that when second molars were stimulated with an electric pulp tester, patients could discriminate accurately which arch the sensation was coming from only 85% of the time, compared with an accuracy level of 95% with first molars and 100% with anterior teeth. The authors also pointed out that when patients first feel the sensation of pain, they are more likely to accurately discriminate the origin of the pain. With higher levels of discomfort, patients have less ability to accurately determine the source of the pain. Therefore, in cases of diffuse or referred pain, the history of where the patient first felt the pain may be very significant.

Since referred pain can complicate a dental diagnosis, the clinician must be sure to make an accurate diagnosis to protect the patient from unnecessary dental or medical treatment.
CLINICAL CLASSIFICATION OF PULPAL AND PERIAPICAL DISEASES

Many attempts have been made over the years to develop classifications of pulpal and periapical disease. However, many studies have shown that there is not a great correlation between clinical signs and symptoms and what is actually present histologically. Since removal of the questionable tissues for histologic examination is not practical, clinical classifications have been developed in order to formulate treatment plan options. In the most general terms, the objective and subjective findings are used to classify the suspected pathosis, with the assigned designations merely representing the presence of healthy or nonhealthy tissue. These resulting classifications are used in determining whether to provide endodontic treatment.

Pulpal Disease

Normal Pulp

Teeth with normal pulp do not exhibit any spontaneous symptoms. The pulp will respond to pulp tests, and the symptoms produced from such tests are mild, do not cause the patient distress, and result in transient sensation reversing in seconds. Radiographically, there may be varying degrees of pulpal calcification but no evidence of resorption, caries, or mechanical pulp exposure. No endodontic treatment is indicated for these teeth.

Reversible Pulpitis

When the pulp within the tooth is irritated so that the stimulation is uncomfortable to the patient but reverses quickly after irritation, it is said to have a reversible pulpitis. Causative factors include caries, exposed dentin, recent dental treatment, and defective restorations. Conservative removal of the irritant will resolve the symptoms. However, sometimes this is easier said than done. Exposed dentin that has no other form of dental pathosis can sometimes have a sharp, quickly reversible pain when subjected to thermal, evaporative, tactile, mechanical, osmotic or chemical stimuli. This is known as dentin (or dentinal) hypersensitivity. Areas of cervically exposed dentin account for much of the observed dentin hypersensitivity.

As will be described in later chapters, the fluid movement within dentinal tubules stimulates the odontoblasts and its associated fast-conducting A-delta nerve fibers, which in turn produce dental pain. The more open these tubules are (for example, from a newly exposed preparation, dentin decalcification, dental scaling, tooth bleaching materials, or fractures), the more the tubule fluid will move and, subsequently, the more the tooth is predisposed to dentin hypersensitivity. When making a diagnosis of pulpal pathosis, it is important to discriminate this sensation from that of a reversible pulpitis, which would be secondary to caries, trauma, or new or defective restorations. Detailed questioning of recent dental treatment, not to mention a thorough clinical and radiographic examination, will help to separate dentin hypersensitivity from other dental pathosis, as the treatment modalities for each are completely different.
Irreversible Pulpitis

As the disease state of the pulp progresses into an *irreversible pulpitis*, treatment will be necessary. This classification may be divided into symptomatic or asymptomatic irreversible pulpitis, with the degree of clinical symptoms escalating over time.

**Symptomatic Irreversible Pulpitis**

Teeth that are characterized as having *symptomatic irreversible pulpitis* exhibit intermittent or spontaneous pain, whereby rapid exposure to dramatic temperature changes (especially to cold stimuli) will elicit heightened and prolonged episodes of pain even after the source of the pain is removed. The pain may be sharp or dull, localized or referred. Typically there are minimal changes in the radiographic appearance of the periradicular bone. With advanced irreversible pulpitis a thickening of the periodontal ligament may be evident, and there may be some suggestion of pulpal irritation by virtue of extensive canal calcification. Deep restorations, caries, pulp exposure, or any other direct or indirect insult to the pulp, recently or historically, may be present and may be seen radiographically or clinically or be suggested from a complete dental history. Typically, when a symptomatic irreversible pulpitis remains untreated, the tooth will eventually succumb to necrosis.

**Asymptomatic Irreversible Pulpitis**

Occasionally, deep caries will not produce any symptoms, even though clinically or radiographically the caries may be well into the pulp. Left untreated, the tooth may become symptomatic or even necrotic. In cases of *asymptomatic irreversible pulpitis*, endodontic treatment should be performed as soon as possible so that this conversion does not take place and cause the patient distress.

**Necrosis**

When pulpal necrosis (or nonvital pulp) occurs, the pulpal blood supply is nonexistent and the pulpal nerves are nonfunctional. It is the only clinical classification that directly attempts to describe the histologic status of the pulp (or lack thereof). This condition is subsequent to symptomatic or asymptomatic irreversible pulpitis. Under complete necrosis and before any pathosis extends into the periodontium, the tooth is typically asymptomatic. It will not respond to electric pulp tests or to cold stimulation. However, if heat is applied for too long, the tooth may respond, possibly relating to remnants of pulpal fluid or gases expanding and extending into the periapical region. As previously discussed, a traumatic injury to a tooth may prevent the lack of a response to pulp tests and mimic that of pulpal necrosis; therefore a good dental history is imperative. Pulpal necrosis may be partial or complete and it may not involve all of the canals in a multirooted tooth. For this reason, the tooth may present with confusing symptoms, whereby pulp testing over one root may give no response and pulp testing over another root may give a vital response, and the tooth may exhibit symptoms of
an irreversible pulpitis.

After the pulp becomes necrotic, bacterial growth can be sustained within the canal. When this infection (or the bacterial toxins from this infection) extends into the periodontal ligament space, the tooth may become symptomatic to percussion or exhibit spontaneous pain. Radiographic changes may occur, ranging from a thickening of the periodontal ligament space to the appearance of a periapical radiolucent lesion. The tooth may become very hypersensitive to heat, even to the warmth of the oral cavity, and is often relieved by applications of cold. As previously discussed, this may be very helpful in attempting to localize a necrotic tooth when the pain is referred or nonlocalized.

**Periapical Disease**

**Periradicular Periodontitis**

A tooth with *acute periradicular periodontitis* will have a very painful response to biting pressure or percussion. This tooth may or may not respond to pulp vitality tests, and the radiograph or image of this tooth will generally exhibit a widened periodontal ligament space but no periradicular radiolucency.

A tooth with *chronic periradicular periodontitis* generally presents with no clinical symptoms. This tooth does not respond to pulp vitality tests, and the radiograph or image will exhibit a periradicular radiolucency, usually around the apical third of the root. This tooth is generally not sensitive to biting pressure but can “feel different” to the patient upon percussion.

**Periradicular Abscess**

A tooth with an *acute periradicular abscess* will be very painful to biting pressure, percussion, and palpation. This tooth will not respond to any pulp vitality tests and will exhibit varying degrees of mobility, and the radiograph or image can exhibit anything from a widened periodontal ligament space to a periradicular radiolucency. Swelling will be present in the mucobuccal fold and facial tissues adjacent to the tooth. The patient will frequently be febrile, and the cervical and submandibular lymph nodes will be tender to palpation.

A tooth with a *chronic periradicular abscess (suppurative periradicular periodontitis)* will not generally present with clinical symptoms. This tooth will not respond to pulp vitality tests and the radiograph or image will exhibit a periradicular radiolucency. The tooth is generally not sensitive to biting pressure but can “feel different” to the patient upon percussion. This entity is distinguished from chronic periradicular periodontitis because it will exhibit intermittent drainage through an associated sinus tract.
SUMMARY

Endodontics is a multifaceted specialty, with much emphasis on how cases are clinically treated. Clinicians have increased their ability to more accurately perform endodontic procedures by way of an increased visualization using DOMs, precise apical foramen detection using electronic apex locators, enhanced imaging techniques using digital radiography, and more. Practices have incorporated more refined canal cleaning and shaping with ultrasonics and rotary-driven nickel titanium files facilitated with computer-assisted electronic handpieces. There have been many other recent advancements—all for the sake of achieving an optimal result during endodontic treatment. However, these advancements are useless if an incorrect diagnosis is made. Before the clinician ever considers performing any endodontic treatment, the following questions must be answered:

- Is the existing problem of dental origin?
- Are the pulpal tissues within the tooth pathologically involved?
- Why is the pulpal pathosis present?
- What is the appropriate form of treatment?

Testing, questioning, and reasoning are together combined in order to achieve an accurate diagnosis and to ultimately form an appropriate treatment plan. The art and science of making this diagnosis are the first steps that must be taken before initiating any treatment.
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During recent years, the gold standard metaphor for something painful has become “a root canal.” Journalists have embraced this expression and use it freely to describe how something is equal to or, if it is really horrible, worse than a “root canal.” Since root canal treatment often is performed to rid the patient of pain, it is very unfortunate that the misleading use of this “pain standard” causes anxiety and even sleepless nights. Not only is this expression used too freely, but also this misuse of a treatment method’s name seriously affects patients who need root canal therapy since fear of dental treatment leads to avoidance of care. A toothache is bad enough, but anticipating a treatment that the media use as an example of excruciating pain is even worse for the patient.

Many people consider pain to be closely related to dental treatment. Even though dental treatment often rids the patient of preexisting pain, it can also hurt. For example, injections for anesthesia hurt. Thus, from a patient’s vantage point, pain is a reason for seeking dental treatment just as it is a reason for avoiding dental treatment. Pains of dental origin are common. Every year about 15 million working days are lost because of dental pain in the United States. In addition to the direct costs for absenteeism, the actual costs must be considerably higher because of pain affecting function as well as quality of life.

One third of all dental emergencies are endodontic. In approximately 90% of emergencies with pain as a symptom, the pain is pulpal or periapical. Of course, all these teeth do not need endodontic therapy. If the tooth cannot be restored or it has no value for the whole dentition, then extraction becomes the treatment of choice. Still, endodontic emergency treatment is a major part of the work of the clinician on call. Pain in the oral cavity can have many causes although pulpal and periapical diseases are the most common.

Temporomandibular joint (TMJ) disorders, sinusitis, tooth eruption problems, and neurologic disorders are among conditions to consider in the differential diagnosis of a toothache (see Chapter 3 for details). In most instances, differentiation among different diagnoses or causes of pain takes seconds or minutes. However, sometimes the process to eliminate multiple causes during the search for the underlying etiology for the pain is time consuming. One of the most important skills in pain diagnosis is to listen to the patient. Very often patients can tell the clinician about the cause even though they may not be aware of it. Listening to a patient with pain that is difficult to diagnose is time consuming. However, listening and examination are necessary to solve the mystery. If a diagnosis cannot be made or a cause cannot be found, then treatment must not be started.

ENDODONTIC PAIN DIAGNOSIS

Generally, pain is conceptualized as a psychobiologic phenomenon with two components: perception of pain, which is influenced by anesthesia, and reaction to pain (e.g., fear, anxiety, anguish, depression, crying), which is influenced by drugs and emotions. These emotional states vary from patient to patient and, coupled with the development of hyperalgesia (see Chapter 20), can exaggerate the perception of pain. Thus patients in pain provide inaccurate information. Pain is a personal experience described by analogies. The patient may be using words that are incomprehensible to the clinician. The clinician must not only listen to the patient but also try to comprehend what the patient is attempting to say. Given a patient’s discomfort and apprehension it is tempting to rush through the diagnosis to institute treatment. The urgency of the situation, however, should not preclude a thorough clinical evaluation of the patient.

Systematic Diagnosis of Pain

One’s ability to diagnose different orofacial pain disorders depends on understanding that dental pain, real or not, can be of systemic or odontogenic origin; dental pain can be associated with numerous diseases that manifest with pain. Pain can be referred from one part of the body to another (see Chapter 3). Evaluation of
the dental history, particularly the history of pain in the same tooth before the present pain experience, is important in rendering proper treatment. The cause must be reliably differentiated as odontogenic or nonodontogenic. Identifying orofacial pain as a pain of odontogenic origin becomes increasingly difficult as the focus shifts away from localized tooth pain to a wider area of the face (see Chapter 3). Numerous orofacial diseases can mimic endodontic pain and produce sensory misperception as a result of overlap between sensory fibers of the trigeminal nerve and adjacent cranial and cervical innervation. To properly manage the patient in pain the clinician must remember that the pain may not be of dental origin. Thus, while systematically sorting through the findings, the clinician should attempt to uncover signs and symptoms produced exclusively by inflammatory pulpal and periradicular diseases. Further, the clinician must remember that even in a true endodontic emergency, most likely only one tooth is responsible.

**Records**

To provide a precise, structured appraisal of a patient’s chief complaint, details of the clinical and dental examination must be recorded. Forms allow the clinician to keep an efficient record and quantify diagnostic data (Figs. 2–1, 2–2, 2–3). The process of diagnosis of the endodontic emergency, as set forth in this chapter, concentrates on the acute endodontic emergency. The clinician must collect the appropriate data (e.g., the set of signs, symptoms, and test results) that will lead to a diagnosis (see Chapters 1, 3, and 10 for further information).

**Figure 2-1** Example of a medical systems review common to a comprehensive dental record. AIDS, Acquired immunodeficiency syndrome; HIV, human immunodeficiency virus.
Critical medical information about the patient may easily be overlooked in an emergency situation. Thus the basic examination of the patient must include a comprehensive evaluation of the patient’s medical history, an intraoral cancer screening, and taking the patient’s blood pressure. Completion of a preprinted, succinct, comprehensive medical history form is mandatory, and it represents the standard of care. An individual’s physical condition, medical history including allergies, and current medications can affect the treatment course or prognosis. Only the patient’s medical history enables the clinician to determine the need for a medical consultation, premedication of the patient, or modification of therapy.

The medical history can identify hypertensive patients who may require modification of anesthetic procedures. The vast majority of medical emergencies in the dental office are associated with anesthesia, which is not surprising since local anesthetics are the most common systemic medicine routinely administered in the dental office. The idea that the relatively small amounts of epinephrine administered during routine dental procedures are not clinically significant has been shown to be incorrect. The increased epinephrine load in the bloodstream during a dental procedure is due to the epinephrine contained in the local anesthetic injection, not due to surgical stress. Further, it also seems prudent to avoid the use of norepinephrine and levonordefrin in patients with hypertension because of their unopposed alpha1 stimulation.

Antibiotic prophylaxis may be indicated for patients with congenital or rheumatic heart disease as well as those at risk because of implanted prosthetic devices, hemodialysis, or impaired host defenses. Patients receiving chemotherapy or who are immunocompromised may also require antibiotic prophylaxis.

The medical history can identify patients for whom healing and repair of periradicular pathosis could be complicated or delayed, such as those who have uncontrolled diabetes or acquired immunodeficiency syndrome (AIDS). In addition, the dentist should identify any patient with a bleeding disorder so that appropriate precautions may be taken before any dental treatment.

Also, possible drug interactions between currently prescribed medications and those prescribed for the endodontic emergency must be understood by the dentist and noted in the patient’s record.

Although a medical history questionnaire provides the clinician with valuable information about the physical and psychologic condition of the patient, any medical history questionnaire can also prove to be entirely worthless. The ultimate value of the questionnaire rests in the ability of the clinician to interpret the significance of the answers and elicit additional information through physical examination and dialogue.
The physical examination should include the taking of blood pressure. This can be easily accomplished by the assistant after seating the patient. Vital signs obtained at this preliminary appointment, known as baseline vital signs, serve two functions. First, they help determine a patient’s ability to tolerate the stress involved in the planned treatment. Second, baseline vital signs are used as a standard during the management of emergency situations in comparison with readings obtained during the emergency. Also, dealing with a patient in pain directly indicates one of the vital signs, the pain itself. Although pain is a subjective sensation, it can be measured on a 0 to 10 scale and documented in the chart. Indeed, pain assessment is recognized as the “fifth vital sign.” Although a screaming 3-year-old or a difficult-to-manage disabled adult may present difficulties, the clinician should make every effort to record vital signs for each patient. Abnormal readings may require further investigation or referral.

Finally, any concerns or questions raised by the medical history may be further elucidated by consulting the appropriate physician.

**Interview and Initial Work-up**

Orofacial pain of dental origin requires a careful examination and diagnosis. About 33% of all emergencies are of endodontic origin, and 90% of emergency cases with pain are endodontic. Still, many nonodontogenic pain conditions may appear as toothache to the patient, including eruption pain, sinusitis, periodontal disease, neurologic disorders, and others. It is most embarrassing to start an endodontic procedure and have the patient later report that the original symptoms still remain. The risk of initiating procedures on the wrong teeth needs to be minimized. Through diagnosis, the problem will be identified, and only then can treatment be initiated and success obtained.

The prognosis of an emergency procedure depends on (1) the ability to determine a correct diagnosis and (2) the ability of the therapist to deliver the optimal emergency treatment. Treating the patient with the prescription plan is not enough. Making the diagnosis so that emergency treatment procedures can be instituted is paramount for the clinician to achieve comfort for the patient and one’s own peace of mind.

In the words of the great physician Sir William Osler, “Listen to your patient and the patient will give you the diagnosis.” A significant amount of diagnostic information can be obtained through an interview and a series of questions. In many instances, these questions can be asked by the staff over the telephone. This will also allow the clinician to determine if the patient needs an immediate appointment or can be seen on another date.

*The patient interview includes the following questions.*

**The Four Questions Plus One**

1. Why is this pain different from any other pain? Is the pain spontaneous or present all the time? Spontaneous pain usually indicates endodontic problems. Differentiation of the following is determined:
   - Is the pain from a pulpal inflammation?
   - Is the pain from a periapical infection?
   - Is the pain of nonodontogenic (including psychogenic) origin?

Depending on how long the pain has been present, it might be from another source. Emergency-type pain from an odontogenic origin often comes on quickly and is seldom something that has been present for several months. If pain is from pulpal or periapical tissues, then additional questions are asked.

2. What re-creates or initiates the pain?

This question allows the clinician to focus on what tests should be used to perform a differential diagnosis. Does it hurt to chew (Fig. 2–4)? If the pain is created following the ingestion of hot coffee, then a hot test is required. This question also gives the clinician information to rule out other problems.
3. What drugs have you taken for the pain?

If the patient has had the pain for several weeks or months, has seen several dentists and physicians, and occasionally takes medication for the pain, this pain is probably from a nonodontogenic source. If, on the other hand, the pain keeps the patient awake all night and the patient took a potent pain medication with no effect, then this patient has emergency needs and must be seen that day.

Another category of patient is the drug addict. These patients often call, usually before a weekend or holiday, saying they took their last pain pill or that they have taken any suggested antiinflammatory medicine. They are usually manipulative and are looking for drugs. The referral source of this patient should be carefully screened. The introduction might even include a fabricated story of a fictional previous appointment with the clinician taking the call or another doctor.

4. Does pain awaken the patient?

Odontogenic pain awakens a patient from sleep. The patient who can sleep through the night may have pain of psychogenic origin. A true endodontic emergency keeps the patient from sleeping. The patient can be disoriented from the lack of sleep or ingestion of analgesics. These patients must be seen that day and, if possible, should be accompanied to the office.

5. Where does it hurt, and where does the pain radiate to?
This question focuses on whether the pain is of pulpal origin (pain may be hard to exactly localize) or of periapical origin (pain is specifically localized). It also contributes to a differential diagnosis helping to locate the origin of the pain (Fig. 2–5).

**Dental History**

A patient who presents in pain is usually an emergency appointment fit into an already scheduled day. The patient in acute pain wants immediate relief, and the clinician wants to make a quick diagnosis. Both the patient and the clinician desire the same outcome, namely, to relieve the patient of pain with a procedure. Once this is done, the patient can be given another scheduled time to complete the needed treatment.

During this emergency appointment, one should never lose the organized and systematic approach to patient care. A careful review of the following does not add much time to this emergency appointment but can add much to the patient’s care (Fig. 2–6).
AAE Endodontic Case Difficulty Assessment Form and Guidelines

PATIENT INFORMATION

Name: ____________________________
Address: __________________________
City/State/Zip: ______________________
Phone: ____________________________

DISPOSITION

Treat in Office: Yes ☐ No ☐
Refer Patient to: ____________________
Date: ____________________________

Guidelines for Using the AAE Endodontic Case Difficulty Assessment Form

The AAE designed the Endodontic Case Difficulty Assessment form for use in endodontic curricula. The Assessment Form makes case selection more efficient, more consistent and easier to document. Dentists may also choose to use the Assessment Form to help with referral decision making and record keeping.

Conditions listed in this form should be considered potential risk factors that may complicate treatment and adversely affect the outcome. Levels of difficulty are sets of conditions that may not be controllable by the dentist. Risk factors can influence the ability to provide care at a consistently predictable level and impact the appropriate provision of care and quality assurance.

The Assessment Form enables a practitioner to assign a level of difficulty to a particular case.

LEVELS OF DIFFICULTY

MINIMAL DIFFICULTY Preoperative condition indicates routine complexity (uncomplicated). These types of cases would exhibit only those factors listed in the MINIMAL DIFFICULTY category. Achieving a predictable treatment outcome should be attainable by a competent practitioner with limited experience.

MODERATE DIFFICULTY Preoperative condition is complicated, exhibiting one or more patient or treatment factors listed in the MODERATE DIFFICULTY category. Achieving a predictable treatment outcome will be challenging for a competent, experienced practitioner.

HIGH DIFFICULTY Preoperative condition is exceptionally complicated, exhibiting severe factors listed in the MODERATE DIFFICULTY category or at least one in the HIGH DIFFICULTY category. Achieving a predictable treatment outcome will be challenging for even the most experienced practitioner with an extensive history of favorable outcomes.

Review your assessment of each case to determine the level of difficulty if the level of difficulty exceeds your experience and comfort, you might consider referral to an endodontist.

The AAE Endodontic Case Difficulty Assessment Form is designed to aid the practitioner in determining appropriate case disposition. The American Association of Endodontists neither expressly nor implicitly warrants any positive results associated with use of this form. This form may be reproduced but may not be amended or altered in any way.

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On seating the patient, the chairside assistant takes the patient’s blood pressure and temperature. Baumgartner suggests that temperature is a quick and easy screening tool to evaluate systemic involvement of an infection that might help in the treatment of the patient. With intractable pain, it is not unusual to see an elevated blood pressure, which may be checked and observed during subsequent appointments.

1. Review the medical history. Focus on allergies, medications taken, and systemic conditions. Contraindications to drugs or treatment are noted on the patient’s record. This review also allows the clinician to establish a rapport with the patient.

2. Review the consent form, and ask if there are any questions. The clinician might institute treatment, and consent is needed. (In addition, the patient must understand that problems can be encountered, such as fractured porcelain during access preparation through a crown.)

3. Perform an intraoral soft tissue cancer screen. This also gives the clinician the opportunity to observe the dental needs and history of the patient. A good reference for reviewing the steps involved in an intraoral exam is given at www.niocr.nih.gov/healthinformation/diseasesandconditions/oralcancer/detectingoralcancer.htm.

4. Review the patient’s dental history. Focus is on the patient; questions might be needed to determine the desire of the patient to pursue saving the dentition or just eliminating the pain. A treatment plan timeline must be obtained for those involved cases that require multiple disciplines. This can be obtained while scheduling or at subsequent appointments. A notation should be made in the chart.

All these steps are important and necessary. Still, they do not have to be carried out in this order. A patient in
pain first and foremost wants to talk about the pain. Therefore it is often good for the patient-clinician rapport to start with the chief complaint and then deal with the histories.

Pain History

Pain can be separated into two categories depending on its duration. This will also help in the differential diagnosis. Acute pain and chronic pain represent two separate problems and are treated differently.

Several signs and symptoms of pulpal and periapical lesions allow acute pain and chronic pain to be distinguished and will help in the differential diagnosis of the pain source.

Acute Pain

Pain of odontogenic origin is usually acute in onset and severe. Acute pain occurs from the irreversible inflammation of the dental pulp or from an inflamed pulp that has infected the periapical environment, creating an acute periapical periodontitis or abscess. It can occur spontaneously during the early stages of pulpal inflammation when there is poor localization of the pain because of the relative lack of pulpal proprioceptors. Moreover, the pain may be referred to other sites. Pain intensifies and localizes once the inflammation spreads to the periodontal ligament and surrounding osseous structures. Pain is easier to localize at this time because of the higher innervation of proprioceptors in the periodontal ligament. Often, potent analgesics are not adequate to control endodontic pain, which can awaken the person from sleep. Odontogenic pain is eliminated with root canal treatment or tooth extraction. Additional details are given in Chapter 18, “Analgesics in Endodontics,” and Chapter 19, “Local Anesthesia in Endodontics.”

Chronic Pain

Chronic pain can be of odontogenic origin but is usually from a different source and is mimicking an odontogenic problem. Chronic pain has been present for more than 6 months. This can include periodontal, [13][101] systemic, or psychogenic problems. Occasionally, chronic pain can originate from a pulpitis that is the result of a previous pulp cap, restorative exposure, cracks, or caries.

If the chronic pain is odontogenic, then tests performed on the tooth will reveal vitality or necrosis. Treatment should begin only when the pain can be duplicated.
MANAGEMENT OF THE DENTAL EMERGENCY PATIENT

Because pain is a psychobiologic entity, in an acute pain emergency, both the physical problem and the emotional state of the patient should be considered. The clinician’s reactions to the patient are important for both pain and patient management. The patient’s needs, fears, and coping mechanisms must be compassionately understood. This assessment and the clinician’s ability to build rapport with the patient are key factors in successful patient management.[46][59][106]

Anesthesia

Obtaining deep anesthesia of inflamed painful tissue is a challenge (see Chapter 19 for full detailed information). Suppression of the nociceptive action potential is hampered by the numerous inflammatory pathways that are operating in the area. It is postulated that when local anesthesia is not pronounced, local acidic byproducts of inflammation or infection lower the pH at the injection site and result in local anesthetic failure. One reason for this occurrence is that most local anesthetic molecules remain in the relatively inactive cationic form.[57] Of course, if changes in this ionic equilibrium were the only factors contributing to anesthesia difficulties in patients with local inflammation or infection, then simply using nerve block injections central to the lesion would predictably overcome this problem. However, this strategy is not always successful. It has been reported that local mediators of inflammation, such as prostaglandins and bradykinin, can antagonize the effects of local anesthetics.[21][59][54] In addition, morphologic changes in the nerve trunk central to the inflammatory process may contribute to local anesthetic resistance in selected cases.[85]

Further, there is a special class of sodium channels on C fibers, known as tetrodotoxin resistant (TTXr).[48] Sodium channel expression shifts from TTX sensitive to TTXr during neuroinflammatory reactions, and the TTXr sodium channels play a role in sensitizing C fibers and creating inflammatory hyperalgesia.

A clinically significant characteristic of these sodium channels is that they are relatively resistant to lidocaine. [107] Researchers have found these channels to be five times more resistant to anesthetic than TTX-sensitive channels. To avoid this problem, the practitioner might need to select alternate and supplementary sites for injecting anesthetic solution. Consideration must be given to the type and amount of anesthetic solution required for the conditions. Importantly, bupivacaine was found to be more potent than lidocaine in blocking TTXr channels and may be the anesthetic of choice when treating these teeth.[89] Anatomic limitations, such as dense, bony plates, aberrant distribution of neural bundles, or accessory innervation, especially in the mandible, may be present. Supplemental intraligamentary or intraosseous injections are most helpful to ensure profound local anesthesia.[89]

Inability to obtain complete local anesthesia may also result from not allowing enough time for the anesthesia to take. Mandibular blocks, for example, can take a full 15 minutes for complete anesthesia. Maxillary infiltrations take much less time. The clinician should be skilled in all anesthetic techniques that may be required. (This issue is fully discussed in Chapter 19.)
TREATMENT

Vital Teeth

Pain emanating from teeth can have three origins: exposed dentin, pulpal inflammation, and periapical inflammation. Dentin and pulp are closely related and function as one unit. In other words, all procedures performed in dentin are essentially performed in dentin and pulp, the pulpodentin complex.

Exposed Sensitive Dentin

Different hypotheses have been proposed in an attempt to explain the sensitivity of dentin. Historically there have been three main hypotheses:

1. Presence of nerves in dentin
2. Direct effect on mechanoreceptors in pulp
3. Transduction of a stimulus from the odontoblast process to nerve endings

Presence of Nerves in Dentin

Historically, researchers had found nerves in all other tissues that are sensitive so a logical conclusion was that dentin also should contain nerves. Early studies reported the presence of nerves from the pulp to the dentinoenamel junction. However, since the then-used staining techniques stained for both nerves and mineral, many findings of nerve presence were artifacts. In an elegant light microscopic study on nerve staining and artifacts, Langeland and Yagi showed that nerves are only present in the inner part of the dentin. The same has been found when transmission electron microscopy was used. Byers and Kisch and Lilja found nerve fibers only in the innermost part of dentin tubules in circumpulpal dentin. A common clinical finding is that dentin is very sensitive at the border to the enamel. However, the hypothesis that nerve endings are present at the dentinoenamel junction has not been corroborated.

Direct Effect on Mechanoreceptors

Brännström showed in a series of publications that rapid movement of dentin fluid causes pain whether the stimuli are osmotic, chemical, mechanical, or thermal modalities. According to findings by Matthews et al. these external stimuli cause movement of the dentinal fluid, creating shear forces in the inner part of the dentin tubules. It has been proposed that mechanoreceptors detect these movements leading to generation of action potentials and, ultimately, the perception of pain. The movement of intratubular liquid influencing mechanoreceptors has been called the hydrodynamic theory and has become generally accepted as an explanation for exposed dentin sensitivity. It explains most situations involving pain and exposed dentin. However, there may be other or additional explanations for pain responses to stimulus of open tubules. Theoretically, movement of fluid in a capillary tubule may in addition give rise to an electric current, streaming potential that could markedly enhance the effect on nerve endings.

Transduction of a Stimulus from the Odontoblast Process to Nerve Endings in the Tubule or at the Predentin Border

Many pulpal nerve endings are in close proximity to odontoblasts, and both A-delta and A-beta fibers form large endings in close apposition with odontoblasts. It may be possible that sensory fibers can detect and respond to current fluctuations in odontoblasts. Dental nerve fibers and odontoblasts may influence each other’s activity levels. Findings of receptors for neuropeptides and neurotrophin on odontoblasts support this concept. The arrangements of microtubules in the odontoblast process and in axons appear to be similar, suggesting a function for odontoblasts related to that of nerve fibers. Protein surfaces in the body are surrounded by clustered water that behaves differently from regular "bulk water." Currents can travel directly through the clustered water, and this has been referred to as water wires (for a review, see reference ). It has recently been proposed that microtubules in odontoblast processes can receive signals via...
currents in the clustered water of dentin tubules. This could emphasize the role of the odontoblast in the transfer of signals to nerve endings.

A complete explanation for dentin sensitivity may not have been reached yet, which may explain the many treatments for sensitive dentin—no method is absolutely perfect. Still, the most efficient way to treat sensitive dentin is to block the dentinal tubules, thereby preventing stimuli from reaching nerve endings in the pulp. Blocking can be done in many ways. Restorative materials have been used with mixed results, but the introduction of hydrophilic bonding agents has markedly improved the adhesion to dentin. Many different noninvasive ways of blocking dentin tubules have been attempted. In clinical trials oxalate salts have been shown to be superior to other methods. The oxalate ion reacts with calcium ions in dentin fluid, resulting in a precipitation of calcium oxalate in the tubule. This reduces the functional diameter, thereby limiting fluid movement. Potassium oxalate solutions are commercially available for treatment of sensitive dentin. The potassium ion can reduce nerve activity and should therefore add a beneficial effect to the preparation.

Pulpal Inflammation

The causes for pulpal pain are not fully understood. Studies have shown that teeth with caries into dentin have pulpal inflammation. Still, the majority of teeth with pulpal inflammations are free from symptoms. Two teeth with similar histologic features may show different clinical symptoms, thus undermining an understanding of the true state of a pulp.

The duration of pain is used as a yardstick for determining whether there is sensitive dentin or an irreversible pulpal inflammation. If a cold test results in pain that lasts for a few seconds, the cause is considered to be sensitive dentin. Lingering pain is taken as an indication of irreversible pulpal inflammation. This clinical rule of thumb is crude and probably often inexact, but no better method presently exists.

Hypersensitive Teeth

Hypersensitive teeth are sensitive to changes in temperature, usually cold. The duration of pain is mostly a few seconds. It has been common to label such teeth “hyperemic.” This term is a misnomer because there may be increased blood flow in these teeth. Exposed dentin, leakage under restorations, or preparation without sufficient water coolant may cause the symptoms. In most instances endodontic therapy is not indicated. Treatment of exposed dentin with potassium oxalate or replacement of fillings usually solves the problem.

Pulpal Inflammation and Pain

Unless a pulp is exposed, pulpal diagnosis is based on clinical findings. Caries must be removed, and in teeth with symptoms of pulpal pain, old fillings should be removed. Experiences from endodontic emergency clinics show that old fillings often serve as barriers, hiding old pulp cappings or unexcavated caries. It is therefore essential to remove fillings in symptomatic teeth. When no pulp exposure exists following excavation, the clinician must make the decision whether to access the tooth. In most instances the removal of infection (caries, leaking filling) and the placement of a temporary filling will make the symptoms subside. Still, in severe pain cases the patient has an intense, constant pain and endodontic treatment is indicated.

Irreversible Pulpitis

Emergency management for painful, irreversible pulpitis involves initiating root canal treatment to alleviate the pain. Complete removal of the pulp and total cleaning and shaping of the root canal system are the treatment of choice for emergent irreversible pulpitis. Unfortunately, in an emergency situation time for treatment is often an issue. Given the potential time constraints and inevitable differences of each clinician’s skill level it may not be feasible to complete the cleaning and shaping at the initial visit. Subsequently, in multirooted teeth, a pulpotomy (removal of the coronal pulp or tissue from the widest canal) has been advocated for emergency treatment of irreversible pulpitis.

Because it is impossible to detect clinically the apical extent of the inflamed pulp and provide predictable pain relief, it is important to clean and shape root canal systems to the fullest extent possible. A file should not be introduced into any canal unless a pulpectomy is anticipated. Often inflamed vital pulp tissue that is lacerated with endodontic files will result in increased discomfort, because the pulp has become inflamed, shredded,
and traumatized. Pain symptoms can persist or worsen if inflamed pulp remains in the root canals, because the inflammatory process will extend into the periradicular tissues.

Historically, the idea that intracanal medicaments helped control or prevent additional pain was very popular. However, the literature shows this to be an unfounded belief. In fact, a dry cotton pellet has been shown to be as effective in relieving pain as a pellet moistened with camphorated monochlorophenol (CMCP), cresatin, eugenol, or saline. Complete removal of the pulp is the best treatment of irreversible pulpitis.

Single-visit endodontic treatment for teeth diagnosed with irreversible pulpitis is not contraindicated. Postoperative pain and the long-term prognosis after single-visit endodontics are similar to root canal treatment completed in multiple visits. Because temporary restorations eventually leak, filling in one visit eliminates the possibility of interappointment bacterial contamination of the root canal system. However, time constraints at the emergency visit often make the single-visit treatment option difficult. If root canal therapy is to be completed at a later date, medicating the canal with calcium hydroxide is indicated to reduce the chances of bacterial growth in the canal between appointments. Sources of infection, such as caries and leaky fillings, should be completely removed to prevent recontamination of the root canal system between appointments. Occlusal reduction is not indicated in these cases without periapical involvement.

Irreversible Pulpitis with Acute Apical Periodontitis

In irreversible pulpitis with apical periodontitis, pulpal inflammation has spread to the periradicular tissues, resulting in a combination of pulpal and periapical symptoms. Between visits, the canals should be medicated with calcium hydroxide to prevent bacterial regrowth. Occlusal reduction has been reported to reduce postoperative pain in patients whose teeth initially exhibit pulpal vitality, percussion sensitivity, and preoperative pain.

Apical periodontitis caused by traumatic occlusion often results in pain on biting, eating, or ‘when the teeth come together.’ Often a recent restoration or the clinician’s own temporary access repair has been placed with a high contact. Treatment includes occlusal adjustment to remove the premature contact. Apical periodontitis caused by traumatic occlusion can also be seen in cases of bruxism, a common phenomenon during college exam times.

After root canal treatment, apical periodontitis can develop as a result of trauma to the periradicular tissues or from the inflammatory response to debris extruded beyond the confines of the root canal system. If all tissue has been removed from the root canal system, and traumatic occlusion has been ruled out, apical periodontitis is best managed with oral analgesics.

Antibiotics are not recommended for irreversible pulpitis or acute apical periodontitis (see Chapter 20 for additional information). In these situations, when the risk/benefit ratio is considered, antibiotics may put the patient at risk for the side effects of the antimicrobial agent and select for resistant organisms. Moreover, placebo-controlled clinical trials demonstrate that antibiotics have no effect on pain levels in patients with irreversible pulpitis.

Finally, teeth with irreversible pulpitis should not be left open between visits because bacterial contamination of the cleansed canal will occur.

Pulpal Necrosis (and Previously Treated Teeth) with Acute Periradicular Abscess

No Swelling

The treatment of pulpal necrosis with periapical symptoms should involve thorough removal of necrotic pulp tissue from the root canal system. Complete cleaning and shaping of the root canals and placement of a calcium hydroxide dressing are the goals of emergency treatment. Some clinicians believe that if necrotic debris is not pushed beyond the apex, the patient will have less postoperative discomfort. If possible and time permits, then complete instrumentation of the canal or canals is appropriate, at the emergency visit, to remove as much of the canal contents as possible. This is facilitated by improvements in technology, such as electronic apex locators that can quickly and predictably determine an accurate working length. Taking it a step further, one school of thought proposes introducing a file slightly beyond the apex to ensure patency of the canal. This may also establish drainage from the periapical tissues and is especially useful when the clinician has diagnosed pulpal necrosis with acute periradicular abscess but no drainage has
been achieved by access into the root canals. Because of the possibility of iatrogenic damage (i.e., apical transportation), care must be taken to prevent aggressive extension with large files past the apical foramen.

Emergency treatment of previously root-treated teeth that are symptomatic and have extensive restorations (including posts and cores, crowns, and bridgework) can be difficult and time consuming. However, the goal remains the same: removing contaminants from the root canal system and establishing patency to achieve drainage. Gaining access to the periapical tissues through the root canals may require removal of posts and failing root canal fillings, as well as negotiation of blocked or ledged canals. On occasion the canal may be obstructed with blockages or ledges that prevent canal negotiation. Failure to complete root canal debridement and achieve periapical drainage may result in continued painful symptoms.

Historically, trephination, the surgical perforation of the alveolar cortical plate to release accumulated tissue exudate causing pain, was advocated to provide pain relief in patients with severe and recalcitrant periradicular pain. The technique involved an engine-driven perforator entering the medullary bone without the need for an incision and thus providing a pathway for drainage from the periradicular tissues. However, recent studies have failed to show a benefit of trephination not only in patients with irreversible pulpitis with acute periradicular periodontitis but also in patients with symptomatic necrotic teeth with radiolucencies.

Trauma of the surgical procedure may add to the pain process and also to inadvertent and possible irreversible injury to the tooth or surrounding structures. However, one very real use for trephination is with an acute alveolar abscess when the area is large and almost perforating the buccal bone, such as usually occurs with maxillary teeth. A sterile root canal instrument can be manipulated into the area, and an artificial sinus tract will be created.

Although single-visit endodontic treatment for teeth diagnosed with irreversible pulpitis is not contraindicated, treatment of necrotic and previously treated teeth is not so cut and dried. Research has indicated that postoperative pain differs little in cases of pulpal necrosis filled at the time of the emergency versus at a later date. Whereas some recent studies show no difference between the outcome of one-visit versus two-visit treatment, other recent studies have questioned the long-term prognosis of such treatment, especially in cases of acute periodontitis. Appropriate treatment in multiple visits will permit elimination of bacteria in the root canal system.

With Swelling

Tissue swelling associated with an acute periradicular abscess may be seen at the initial emergency visit, as an interappointment flare-up, or as a postendodontic complication. Swellings may be localized or diffuse, fluctuant or firm. Localized swellings are confined within the oral cavity. A diffuse swelling or cellulitis is characterized by its spread through adjacent soft tissues, dissecting tissue spaces along fascial planes.

Three avenues can address swelling and infection:
1. Establish drainage through the root canal
2. Establish drainage by incising a fluctuant swelling
3. Antibiotic treatment

The cardinal rule for managing all these infections is to achieve drainage and remove the source of the infection. When the swelling is localized the preferred avenue is drainage through the root canal. Cleaning and shaping are paramount to success regardless of drainage, because bacteria remaining within the root canal system compromise resolution of the acute condition. Copious irrigation is performed throughout the cleaning and shaping of the canal.

The drainage should be allowed to stop; then the root canals should be dried, medicated with calcium hydroxide, and closed. Gentle finger pressure to the mucosa overlying the swelling may aid drainage. On very rare occasions, drainage may continue and the clinician may opt to step away from the patient for some time. As a rule, teeth should not be left open between appointments. If good drainage is achieved by access and instrumentation of the root canal system, then no incision and drainage procedure is needed.

The prescription of antibiotics should be adjunctive to appropriate clinical treatment (see Chapter 13 for details). Antibiotics are not indicated for localized swelling; rather, they are indicated when signs and symptoms are associated with systemic involvement, for patients with progressive infections, or for patients who are immunocompromised. The objective is to aid the elimination of pus from the tissue

spaces. Generally the use of antibiotics alone (without concurrent cleaning and shaping) is not considered appropriate treatment.\[50][61]

With localized swelling the practitioner is dealing with an abscess that is confined within the oral cavity. A diffuse swelling indicates an advanced infection that is potentially dangerous for the patient (see Chapter 13 for further information on how these infections are managed). More aggressive treatment is necessary to minimize the possibility of the infection spreading.

**Incision for drainage**

Management of a localized soft tissue swelling can be facilitated through incision for drainage of the area. Incision for drainage is indicated whether the cellulitis is indurated or fluctuant. A pathway for drainage is needed to prevent further spread of the abscess or cellulitis. An incision for drainage allows decompression of the increased tissue pressure associated with edema and provides significant pain relief for the patient. The incision also provides a pathway not only for bacteria and bacterial byproducts but also for the inflammatory mediators associated with the spread of cellulitis.

The basic principles of incision for drainage are as follows:
1. Make the incision at the site of greatest fluctuance.
2. Dissect gently, through the deeper tissues, and thoroughly explore all parts of the abscess cavity, eventually extending to the roots of the teeth responsible for the pathosis. This will allow compartmentalized areas of pus to be disrupted and evacuated.
3. To promote drainage, the wound should be kept clean with hot saltwater mouth rinses. Intraoral heat application to infected tissues results in a dilation of small vessels, intensifying host defenses through increased vascular flow.\[50][61]

A diffuse swelling can turn into a medical emergency with potentially life-threatening complications. One determining factor that directs the spread of the infection is the muscle attachments. A patient under the care of a dentist should be contacted every 8 to 12 hours until the swelling starts to resolve. In addition, the patient should be able to contact the dentist at any time for additional instructions or an alternative course of action if the situation worsens. Analgesics should be prescribed, and the patient should be monitored closely for the next several days until there is improvement. Individuals who show signs of toxicity, elevation of body temperature, lethargy, central nervous system (CNS) changes, or airway compromise should be referred to an oral surgeon for immediate hospitalization, with aggressive medical and surgical intervention. This team will no doubt include members of a department for infectious disease.

**Laboratory diagnostic adjuncts**

Chapter 15 discusses culturing techniques and indications. Culturing for anaerobic bacteria usually requires at least 1 to 2 weeks. With this in mind, culturing is not a normal aspect of emergency treatment. Thus, in an emergency, regardless of whether or not a culture is taken, antibiotic treatment should begin immediately, because oral infections progress rapidly and the patient’s condition may deteriorate while waiting for the laboratory results.

**Cracked Teeth**

Cracked teeth can be difficult to locate and diagnose (see also Chapter 1). In the beginning cracks are small and hard to find. Removal of filling materials, dye solutions, selective loading of cusps, fiberoptic light producing transillumination, and magnification are helpful in the search for suspected cracks. As time goes by a crack increases and often becomes stained. Still it can take a long time before a crack becomes detectable. Because cracks are hard to find and their symptoms can be confusing, the name *cracked tooth syndrome* has been suggested.\[26\]

Cracks are not radiographically visible unless the beams are in the same direction as the crack. Therefore a “negative radiographic finding” does not necessarily mean that a crack is not present.

Cracks in vital teeth often exhibit sudden sharp pain attacks, especially during chewing. In order to deal with this “syndrome” one must, as always, listen to the patient and keep in mind that cracks in vital and nonvital teeth will cause different signs and symptoms.
**Cracks in Vital Teeth**

A sharp, intense pain of short duration during chewing and on release of food may indicate a crack in a vital tooth. A slight movement in the fracture line involves dentin tubules and causes signals to reach pain receptors in the pulp. Teeth with cracks that do not reach the pulp exhibit these symptoms until the crack becomes a fracture and the undermined piece falls off. If a crack reaches the pulp it becomes an avenue for infection. The pulp then develops symptoms of pulp inflammation, such as sensitivity to temperature changes.

Detection of the crack is performed using a bite stick. If the tooth responds normally to cold and percussion and a crack is diagnosed, then a full coverage restoration is indicated. If the pain with mastication is relieved and the tooth still responds normally to cold, then endodontic treatment is not needed.

**Cracks in Root-Filled or Nonvital Teeth**

Cracks in teeth without a living pulp give vague symptoms, and the origin of the pain is often difficult to locate. Pain receptors in the periodontal ligament may be involved, or bacteria may invade through the craze line. Symptoms may include tenderness to percussion or palpation. During late stages when a crack or fracture has reached the root surface, the advancing infection will cause a periodontal inflammation. Once this inflammation is established it can usually be detected radiographically. The radiolucency is often J shaped, involving the apex as well as the root surface affected by the crack or fracture. In late stages it is frequently possible to probe along a crack or fracture in the root surface. A sudden increase in periodontal probing often indicates a crack or fracture from local periodontitis caused by bacteria accumulating in the crack or fracture.

Treatment of cracked teeth involves locating the crack or fracture and determining, by exposing the crack, if the tooth can be saved. Depending on location, exposing a crack can be done surgically or by means of drilling away the crack.

**Pharmacologic Treatment of Pulpal and Periapical Pain**

Because a more thorough description of pain medications can be found in Chapter 19, this recommendation list is short. Additional reviews are given in reference [38].

Since pulpal and periapical pain involves inflammatory processes, the first choice of analgesics is nonsteroidal antiinflammatory drugs (NSAIDs). However, no pain medication can replace the cleaning of the root canal to rid the tooth of the cause of infection in order to prevent or treat pain of endodontic origin.

Aspirin has been used as an analgesic for more than 100 years. It is more efficient than codeine, 60 mg. Its analgesic and antipyretic effects are equal to acetaminophen, and its antiinflammatory effect is stronger. However, aspirin’s side effects include epigastric distress, nausea, and ulceration. In addition, its analgesic effect is inferior to that of ibuprofen, 400 mg.

Acetaminophen as a pain medication is equal to aspirin, but it does not have its side effects. When NSAIDs and aspirin are contraindicated, such as because of gastrointestinal problems, acetaminophen is the preferred analgesic. A maximal dose of 4 g in a 24-hour period should not be exceeded.

Ibuprofen, an NSAID, has been found to be superior to aspirin (650 mg) and acetaminophen (600 mg) with or without codeine, 60 mg. Also, ibuprofen has fewer side effects than the combinations with opioid. A maximal dose of 3.2 g in a 24-hour period should not be exceeded. Patients who take daily doses of aspirin for its cardioprotective effect can take occasional doses of ibuprofen; however, it would be prudent to advise patients to avoid regular doses of ibuprofen. These patients would do better taking a selective COX-2 inhibitor, such as diclofenac, rofecoxib, or celecoxib.

Because of NSAIDs’ antiinflammatory effect they also to a certain degree suppress swelling after surgical procedures. The good analgesic effect and the additional antiinflammatory effect make NSAIDs, especially ibuprofen, the drug of choice for acute dental pain unless the patient has a contraindication to their use. Ibuprofen has been used for more than 30 years and has been thoroughly evaluated if the NSAID alone does not have a satisfactory effect the addition of an opioid may provide additional analgesia. However, it will increase the risk for side effects.

An ideal pain reliever combination is to alternate between ibuprofen and acetaminophen. The
antiinflammatory response of ibuprofen coupled with the CNS effect of acetaminophen will eliminate pain, reduce inflammation, and preclude the need for opioids. There seems to be a cumulative effect, and dosing instructions are to alternate every 2 hours between 400 to 600 mg of ibuprofen and 1 g of acetaminophen, never exceeding 4 g of acetaminophen every 24 hours (see Chapter 15).

When dealing with patients in pain it is important to remember the placebo effect. A few positive words regarding the pain medication will often have a desired effect.

**Analgesics for Endodontics Summary**

**NSAIDs**

Ibuprofen superior to aspirin, acetaminophen, or combinations of these with opioids.
Optimal dosage: 400 mg.
NSAIDs should not be given to patients with aspirin allergy.
*Prolonged duration:* diflunisal and naproxen are alternatives to other NSAIDs when prolonged duration is beneficial.

**Acetaminophen**

Equal to aspirin but with fewer side effects. The preferred analgesic when salicylates or NSAIDs are contraindicated.
Optimal dosage: 600 mg.

**Opioids**

Combinations of opioids with other analgesics may give increased analgesia but will also increase side effects.
Nonopioid analgesics should primarily be used at optimal dosage before considering any addition of opioids.
ENDODONTIC LIMITATIONS FOR THE GENERAL PRACTITIONER

Endodontic treatment and referral of the endodontic patient depend on a multitude of factors. Clinical experience and expertise, judgment, and ego all play roles in this process. Referral can do much for the patient and the general practitioner. Judicious case selection for treatment versus referral can elevate patient care, with responsibility for the care of a patient shared, and it can elevate the standard of care and technical expertise that the patient experiences in endodontics.

Diagnosis and treatment planning can yield success and can also help the practitioner select cases to treat or not to treat. To review case assessment, the most difficult endodontic procedures that should be considered for referral to an endodontist are the following:

1. Necrotic or infected endodontic problems
2. Abnormal anatomy
   a. Mandibular anterior teeth with two canals
   b. Premolars with more than one canal
   c. Severe curves
   d. Calcifications
   e. Long roots
   f. Maxillary first molar
   g. Mandibular first molars

3. Access through crowns or more complex restorations
4. Surgical procedures
5. Patient management
   a. When the patient will experience pain
   b. Chronic lesions
   c. When the patient might experience a failure
   d. Local anesthetic considerations
      (1) Vasoconstrictor contraindication
      (2) Anesthetic allergy
      (3) History of anesthesia difficulty
   e. Personal factors and general considerations
   f. Limited opening
   g. Gagger
   h. Fear
   i. Motivation to preserve teeth
   j. Cannot hold film
   k. Cannot recline
   l. Small mouth or trismus

6. Medically compromised patients
   a. Cardiovascular diseases
   b. Cerebrovascular considerations
   c. Bleeding disorders
   d. Renal dysfunction
From the endodontist’s vantage point, an important aspect of the referral is communication to the specialist regarding the patient and to the patient regarding the specialist. This rapport develops a team approach toward patient care. In addition, it introduces and prepares the patient for the specialist and the needed procedure or opinion. It can serve to psychologically prepare the patient for a good and positive experience. The ideal referring source will also acknowledge help with the treatment plan from the endodontist even if it simply is the prognostication of the individual procedure.

e. Medical prostheses
f. Host/defense abnormalities
g. Diabetes
h. Mental impairment
i. Acute systemic disease
j. Pregnancy
k. Need to premedicate
l. Other systemic conditions

7. Restorative abutments
8. Diagnostic dilemmas
   a. Inconclusive or contradictory findings
   b. Radiographic findings
   c. Difficulty in obtaining films of diagnostic value

9. Foreseeable technical difficulties
   a. Restorability
   b. Existing restoration
c. Fractured tooth
d. Resorptions
e. Endodontic-periodontal lesion
f. Trauma
g. Avulsion
h. Luxation
i. Previous endodontic treatment
j. Perforations
k. Radiographic findings
l. Pulpal space
m. Root morphology
n. Apical morphology
o. Malpositioned teeth
p. Buccal version
q. Rotated or tipped
r. Too far distally
Occasionally, the endodontist must formulate a team and refer a patient to one or several individuals. This can include the restorative dentist, periodontist, oral medicine specialist, or oral surgeon. If a tooth needs to be extracted, the help of an oral surgeon may be required. This might be in preparation for an intentional replantation. However, some infections and lesions extend beyond the scope of the endodontist.

Many of these clinical problems exist in patients who have neglected themselves and their needs. The treatment that they seek has allowed enough time to elapse so that the infection has penetrated additional facial spaces. Therefore a team including an oral surgeon, an infectious disease specialist, and sometimes an otolaryngologist might be needed. Once patients reach this point, their fever is elevated, and they are truly sick, weak, and debilitated.

Another group of team players and source of help will be a psychologist, psychiatrist, and neurologist. In addition, an oral medicine specialist might be of great help. These specialists represent a group that is helpful for patients whose diagnosis is not dental but who fall into the category of oral-facial pain of psychogenic origin.

The diagnosis of odontogenic pain can be obvious and routine, or it might proceed like a detective story—complicated and long to figure out. Dr. I.B. Bender, the great sage and teacher of endodontics, once said that if the diagnosis cannot be made, “tincture of time” is the appropriate treatment. Eventually, if an odontogenic problem exists, it will often localize when inflammation spreads to the periapical tissues richly innervated with proprioceptors.

The authors have seen multiple diagnostic problems in their years of clinical practice. Three instances come to mind. One involved a president of a university, one a provost of a different university, and the third a chief executive officer (CEO) of a communications giant. The common theme in each case was focus and great concern by their family dentists and physicians to solve their chief complaint of severe pain. In each instance, attention was paid to the area that exhibited the pain. No one was wrong, but each person was so concerned for the patient and tried so hard that no one stepped back to see the forest for the trees. Once the diagnosis was made by the endodontic specialist, treatment relieved the pain.

Diagnosis of odontogenic pain is a skill. Each clinician must be adept at determining if a patient is in need of his or her services or must be referred elsewhere. Those situations when diagnosis becomes an intellectual pursuit and combines all of the clinician’s knowledge and concentration can be the most worthwhile and satisfying exercises in dental medicine.
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Chapter 3 - The Nonodontogenic Toothache

Donna Mattscheck  Alan Law

“An unthinking dentist is a bad dentist. Perfect technique misapplied is at least as unconscionable as sloppy work.”

—Marjorie Jeffcoat, D.M.D.

A nonodontogenic toothache is, of course, an oxymoron. How can one have a toothache that is not odontogenic in etiology? The answer lies in the differentiation of the perception of a pain source and the pain’s true origin.

Figure 3-1 Pantomograph of a patient who has undergone several endodontic procedures without resolution of her chief complaint. (Courtesy Dr. Jeffrey Okeson.)

Pain is common. It causes human suffering and has significant socioeconomic effects. Pain is a motivator that provokes individuals to seek care, but protracted chronic pain debilitates and can significantly impair the quality and productivity of a person’s life. One survey revealed that 66% of respondents experienced pain or discomfort over a 6-month period. Significantly, 40% of respondents reported that this pain affected them to a "high degree." A 2003 study estimated the lost productive work time attributed to common pain conditions among active workers to cost $61.2 billion per year. One investigator reported that over a 6-month period 22% of Americans experienced at least one of five types of facial pain, the most common of which (12.2%) was toothache.

Although toothache is the most common pain entity in the facial region, many other types of pain can occur in the same general area. A primary responsibility of a clinician is to diagnose pathologic entities associated with the oral cavity and masticatory apparatus. Many of these pathologic entities have pain as a primary component. Although dental clinicians are sought out daily for the alleviation of odontogenic pain, they must have a basic working knowledge of other types of facial pain to make an accurate diagnosis and properly select care for patients. Not all pains that present as toothache are of odontogenic origin. The presenting toothache may be a heterotopic symptom of another disorder; that is, it is perceived to originate from a site different from the tissue that is actually the source of the pain. This differs from primary pain, in which the perceived site of pain is the actual tissue from which the pain originates. Before discussing pain entities that mimic toothache, it is helpful to understand the neurobiologic mechanisms of orofacial pain.

SOMATIC STRUCTURES

To understand the pathways by which orofacial pain occurs, one must first understand the structures involved in its transmission to higher brain centers. Structures of the orofacial region can be divided into two broad categories: somatic and neural structures. Somatic structures make up the different nonneural tissues and
organ. The somatic structures can be further anatomically divided into superficial and deep. Superficial structures include the skin, mucosa, and gingiva, and pain that arises from these superficial structures is usually well localized (e.g., a sharp explorer penetrating the gingiva results in a well-localized pain). Deep structures include musculoskeletal and visceral tissues. Pain from these deep structures is typically poorly localized and diffuse.
NEURAL STRUCTURES

Neural structures are involved in the efferent (away from the brain) and afferent (toward the brain) regulation of somatic structures. The pathway by which pain is transmitted from orofacial structures to the brain can be divided into the (1) primary afferent system, (2) central nervous system (CNS), and (3) autonomic nervous system.

Peripheral Nervous System

Pain arises as a result of tissue damage or the potential for tissue damage and is transmitted via terminal nerve fibers known as primary afferent nerve fibers. The two major classes of nociceptive (pain-sensing) primary afferent nerve fibers that can detect potentially damaging noxious stimuli are the A-delta and C fibers. Both fiber types have a wide distribution throughout the skin, oral mucosa, and tooth pulp. In addition, separate classes of nerve fibers exist that are involved in detecting nonnoxious stimuli, such as vibration and proprioception. Such fibers can be found in the periodontal ligament (PDL), skin, and oral mucosa and include the A-beta fibers.

Primary Afferent Neuron

Detection and encoding of noxious stimuli for the orofacial region are conveyed primarily by the trigeminal, or fifth cranial, nerve. The majority of cell bodies of the trigeminal sensory fibers are located in the trigeminal ganglia on the floor of the middle cranial fossa. The peripheral axons of the trigeminal ganglion run in three divisions—the ophthalmic (V1), maxillary (V2), and mandibular (V3), which innervate most of the oral mucosa, the temporomandibular joint (TMJ), anterior two thirds of the tongue, dura of the anterior and middle cranial fossae, tooth pulp, gingiva, and periodontal membrane.

In the peripheral nervous system these neurons or nerves are referred to as primary afferent (e.g., sensory) fibers. The primary afferent fibers can broadly be divided into A-beta fibers, which transmit light touch or proprioceptive information, and A-delta and C fibers, which encode pain. The tooth is densely innervated by afferent nerve fibers that are believed to transmit mainly pain in response to thermal, mechanical, or chemical stimuli. The vast majority of dental nerves are C fibers that innervate the central pulp, most of which terminate beneath the odontoblasts.[11]

A-Beta Fibers

The rapidly conducting myelinated neurons that respond to light touch are called A-beta fibers. Under normal conditions, activation of the A-beta fibers by high-intensity stimulation results in low-frequency output in the CNS. Although activation for the A-beta fibers normally is interpreted as nonpainful mechanical stimulation[47] or “pre-pain,”[19] A-beta fibers have been shown to undergo phenotypic changes that allow them to encode painful stimuli under inflammatory conditions.[46]

A-Delta Fibers

The A-delta fibers are lightly myelinated, have a faster conduction velocity than C fibers, and are believed to transmit a sharp or pricking sensation. A-delta fibers primarily respond to noxious mechanical stimuli rather than chemical or thermal stimuli. Other A-delta fibers may be polymodal (responding to mechanical, chemical, and thermal stimuli)[4] or respond only to cold/mechanical[30] or hot/mechanical[15] noxious stimuli.

In the tooth pulp, A-delta fibers traverse the odontoblastic layer and terminate in the dentinal tubules.[11] Because of their location and their sensitivity to mechanical stimulation, A-delta fibers are believed to respond to stimuli that result in movement of fluid within the dentinal tubules (e.g., osmotic, mechanical probing, or thermal stimuli applied to the external surface of the tooth).[11] Consistent with the hypothesized mechanism of dentinal pain is the fact that the stimuli that cause dentinal fluid movement result in a sharp pain associated with A-delta fiber activation.[13] When intense noxious stimuli activate the A-delta fibers, the input to the CNS
consists of high-frequency action potentials.

C Fibers

The C fibers are unmyelinated, have slower conduction velocity, and are associated with a dull, aching, or burning sensation. Most C fibers are polymodal, responding to mechanical, thermal, and chemical stimuli. Because of the difference in conduction velocities, A-delta fibers are believed to transmit early, shooting pain, whereas C fibers transmit late, dull pain. Noxious stimuli that exceed the receptor threshold of these nociceptive primary afferent terminals result in action potentials that travel centrally, signaling tissue damage. In the pulp tissue, the more centrally located C fibers respond to thermal, mechanical, and chemical stimuli and are believed to be sensitized by inflammation. All visceral structures are primarily innervated by afferent fibers conducting nociceptive information, such as that carried by A-delta and C fibers.

Central Nervous System

The primary afferent fibers are responsible for the transduction and transmission of sensory information to higher brain centers by forming synapses on neurons located within the trigeminal nucleus, which spans the midbrain and cervical spinal cord. This point marks the beginning of the CNS and is the point at which processing of pain information begins (Fig. 3-2).

Figure 3-2 The trigeminal nerve entering the brainstem. The primary afferent neuron (1st N) forms a synapse with a second-order neuron (2nd N) in the trigeminal nucleus. The second-order neuron carries pain information to the thalamus (Th) from which it is sent to the cerebral cortex for interpretation. (Redrawn from Okenon JP: Bell’s orofacial pains, ed 5, Chicago, 1995, Quintessence Publishing Co.)

Just as the periphery has different types of sensory neurons, the trigeminal nucleus also has different types of neurons that receive nociceptive input from the periphery. The neurons located in the trigeminal nuclei are known collectively as second-order or projection neurons and can be subdivided into three distinct groups on the basis of the type of information they receive: (1) low-threshold mechanoreceptors, (2) nociceptor-specific neurons, and (3) wide-dynamic range neurons.

The primary central site of termination for nociceptive fibers is the subnucleus caudalis located in the most
caudal region of the trigeminal nucleus, which anatomically and functionally resembles the dorsal horn of the spinal cord and has been referred to as the medullary dorsal horn. Four major components of nociceptive processing are located in the dorsal horn of the subnucleus caudalis: central terminals of afferents, local circuit neurons (interneurons), projection neurons, and descending neurons. Within the subnucleus caudalis, the A-delta and C fibers terminate primarily in the outer laminae (I and IIa) and lamina V. Local circuit neurons are composed of islet cells (thought to be inhibitory) and stalked cells (believed to be excitatory). Combined, the local circuit neurons may modulate nociceptive transmission from the primary afferents to the projection neurons.

The fourth component of the dorsal horn is comprised of the terminal endings of descending neurons. The descending neurons originate in the nucleus raphe magnus (NRM), the medullary reticular nuclei, and the locus ceruleus (LC). Descending brainstem neurons release serotonin (from the NRM) and/or norepinephrine (from the LC), which may inhibit the activity of projection neurons directly or by activating local opioid interneurons. These neurons are responsible for the endogenous abatement of pain; blockade of their activity results in increased pain transmission and reduced pain thresholds.

**Second-Order Neuron**

Projection neurons have axons that cross to the contralateral medulla to ascend in the trigeminothalamic tract and project to the ventral posterior medial and intralaminar nuclei of the thalamus, where additional neurons project to the cortex. Projection neurons involved in the transmission of painful stimuli can be divided into two classes: wide–dynamic range and nociceptive-specific neurons. Wide–dynamic range neurons receive input from mechanoreceptors, thermoreceptors, and nociceptors, whereas nociceptive-specific neurons are excited solely by nociceptors. These two types of projection neurons may be responsible for signaling the severity and location of pain, respectively.

Multiple primary afferent neurons may form synapses on a single projection (i.e., convergence). This occurs to a much greater degree in deep tissues as opposed to cutaneous tissues. Primary afferent fibers of nontrigeminal origin, such as those derived from vagus, glossopharyngeal, facial, and cervical spinal ganglia, have been shown to converge and form synapses on trigeminal projection neurons located as far caudal as spinal level C4. This phenomenon of convergence may result in the clinical finding of pain that radiates beyond an area of tissue injury. Convergence may also explain why pain appears to be associated with a site other than the injured area. Interestingly, when projection neurons receive input from superficial and deep structures, the more superficial inputs usually predominate. Thus pain originating from deep structures would typically be referred to superficial areas (e.g., pain originating from the jaw muscles would typically be referred to the face rather than deeper structures).

**Autonomic Nervous System**

The entire sympathetic innervation of the orofacial region is supplied by the stellate ganglia that are located bilaterally at the level of the seventh cervical vertebra. Under normal conditions sympathetic stimulation has no influence on sensory function. However, afferent sympathetic fibers in an area of trauma may become involved in the response to pain and may also play a role in chronic pain states. Specifically, C fibers in the area of partial nerve injury may become responsive to sympathetic nerve stimulation. The modulation of nociception by the sympathetic nervous system has been shown such that release of pain neurotransmitters may be altered in the presence of sympathetic agonists and by blockade of the sympathetic nervous system using antagonists. Whether the effects of sympathetic nerve fibers on pain transmission are direct (by hemostatic regulation) or indirect remain unclear. The parasympathetic division of the autonomic nervous system has not been shown to be involved in the development or modulation of pain.

**Review of Neurophysiology**

**Peripheral Sensitization**

An inflammatory reaction that often produces pain follows tissue insult. The severity of the pain is related to several conditions of the injury, such as the type, extent, location, innervation of the tissue, and phase of the inflammation. In the nociceptive system, tissue injury can manifest as increased responsiveness or reduced thresholds to a noxious stimulus, referred to as hyperalgesia. Hyperalgesia can be partially accounted for by sensitization of nociceptors (primary hyperalgesia) and by CNS mechanisms (secondary hyperalgesia).
In the absence of tissue damage, activation of C or A-delta fibers produces a transient pain that is believed to serve as a physiologic warning. When there is tissue injury, afferent fibers may be activated by lower-intensity stimuli than usual, and the quality of pain may be more persistent and intense. This phenomenon is due in part to sensitization of nociceptors, including an increase in spontaneous activity.

At the site of tissue injury a number of inflammatory mediators can directly or indirectly sensitize primary afferent nociceptors. These inflammatory mediators may be released from the local tissue cells, circulating and resident immune cells, vasculature and endothelial smooth muscle cells, and peripheral nervous system cells.

Central Sensitization

Following peripheral tissue injury an afferent barrage from C fibers results from peripheral tissue inflammation, decreased afferent thresholds, and spontaneous firing of afferent fibers. When a second-order neuron receives a prolonged barrage of nociceptive input, it may also become sensitized. This results in a phenomenon referred to as central sensitization. The result of central sensitization is enhanced processing (i.e., amplification) of neural impulses that are being transmitted to higher brain centers. Two effects of central sensitization are secondary hyperalgesia and referred pain.

Secondary hyperalgesia is an increased response to painful stimulation at the site of pain resulting from CNS changes. This contrasts with primary hyperalgesia, which is a lowered pain threshold resulting from sensitization of peripheral neurons. Secondary hyperalgesia might be felt in superficial (e.g., gingiva, skin) or deep (e.g., muscles, teeth) structures.
HETEROTOPIC PAIN

Any pain felt in an area other than its true source is a heterotopic pain. The three types of heterotopic pain are referred, central, and projected. Referred pain is pain felt in an area innervated by a different nerve from the one that mediates the primary pain. Referred pain cannot be provoked by stimulation of the area where the pain is felt; rather it is brought on by manipulation of the primary source of pain (Fig. 3-3). In addition, referred pain cannot be arrested unless the primary source of pain is anesthetized. The referral of pain tends to occur in a laminated fashion (Fig. 3-4) because peripheral nociceptors enter the spinal trigeminal tract in a laminated fashion. As a result general referral patterns exist in the face. In addition, the referral of pain is usually in a cephalad or upward direction. This is evidenced clinically in that pain from mandibular molars typically is referred to maxillary molars, as opposed to premolars or incisors.

Figure 3-3 Pain that is referred from an area innervated by one nerve (C2) to an area innervated by a different nerve (V3). Note that this phenomenon occurs secondary to the convergence of different neurons onto the same second-order neuron in the trigeminal nucleus. The sensory cortex perceives two locations of pain. One area is the trapezius region that represents the source of pain. The second area of perceived pain is felt in the temporomandibular joint area, which is only a site of pain, not a source of pain. This pain is heterotopic (referred). (Redrawn from Okeson JP: Bell’s orofacial pains, ed 5, Chicago, 1995, Quintessence Publishing Co.)
Central pain is pain that emanates from structures of the CNS and is perceived as being from peripheral structures. An example would be pain caused by a CNS tumor that impinges on intracranial structures (Fig. 3-5). Although the structure in the CNS may be insensitive to the pressure from the tumor, pain may be felt in structures that are in the peripheral distribution of the structure being impinged on. Projected pain is felt in peripheral distribution of the same nerve that mediates primary nociceptive input and is the result of the stimulation of the sensory nerve trunk or root in the anatomic location of the nerve. An example of projected pain is the pain associated with postherpetic neuralgia, which follows the dermatome mapping of the nerve affected by the herpetic infection.

Figure 3-4  The laminated pattern of innervation from orofacial structures into the trigeminal nucleus. These laminated patterns commonly reflect the patterns of referred pains felt in the orofacial structures. (Redrawn from Okeson JP: Bell’s orofacial pains, ed 5, Chicago, 1995, Quintessence Publishing Co.)

Figure 3-5  Magnetic resonance (MR) scan of a 35-year-old woman presenting with pain in her anterior maxilla. She was diagnosed with an adenocarcinoma in the midbrain near the pons. This tumor was compressing the trigeminal nucleus, resulting in pain of central origin that was felt as pain in the face. (Courtesy Dr. James Fricton.)
Sources of Odontogenic Toothache

Before considering heterotopic pains, it is important to fully understand odontogenic pain as a primary source for toothache. Only two structures serve as sources for primary odontogenic pain. These structures are the pulp/dentin complex and the periradicular tissues. The innervation of the pulp is similar to that of other deep visceral tissues and in various states of pathosis will have pain characteristics similar to deep visceral tissues. The primary nociceptors of the pulp that respond to inflammation are the slow-conducting, high-threshold C fibers. Because their threshold is high, C fibers do not respond to normal or nonpathologic dentinal stimulation. C fibers typically conduct pain that is associated with tissue damage. In addition, the frequency of firing of C fibers is not proportional to the input intensity (i.e., C fibers do not encode stimuli intensity, only stimuli onset and offset). For example, a slightly cold stimulus that is below the C fiber threshold will fail to produce any sensation. Only when a stimulus is intense enough to reach the threshold will the C fiber fire, resulting in the sensation of pain.

Pulpal pain is mediated by C fibers and is dull, aching, or throbbing in nature. This contrasts with the quick, short, sharp sensation produced by A-delta fibers that mediate dentinal pain. Therefore, when the clinician is pulp testing, it is meaningful to note not only whether the patient perceived the stimulus but also the nature of the stimulus perceived. A simple notation of “s” (short) can indicate a response more typical of an A-delta fiber (dentinal pain), or “p” (prolonged) can indicate the response was more indicative of a C fiber response (pulpal pain).

Tissue inflammation can result in sensitization of nerve fibers. When peripheral nociceptors (pulpal C fibers) are sensitized, the threshold of firing in response to a given stimulus (e.g., temperature, pressure) is lowered. In states of sensitization these nociceptors can be provoked with a less intense stimulus. The threshold for excitation is still “all or nothing,” but the required level of stimulation has decreased. These fibers can become so sensitized that they may fire at as low a temperature threshold as body temperature, which is normally not sufficient to stimulate a C fiber. In fact, C fibers can become so sensitized that they will fire in response to the normal pulse pressure of cardiac contraction, eliciting a complaint of “I can feel my heartbeat in my tooth” or “my tooth is throbbing.” Sensitized C fibers thermal thresholds can fall below 37°C (body temperature) and therefore fire without provocation, resulting in spontaneous pain.

Typical of deep visceral tissues, the pulpal nociceptors demonstrate a high degree of convergence in the CNS. In a study of cat brain, 74% of the neurons tested in the subnucleus caudalis showed convergence from multiple tooth pulps. In addition, the dental pulp lacks proprioceptive neurons. The high degree of convergence from pulp tissue and the lack of proprioceptive information provided are the key factors in why purely pulpal pain can be so difficult for patients to localize. In addition to reducing localization of pain, convergence increases the referral of pain to tissues not actually affected by the inflammation. The fact that there is convergence of neurons from the pulps of mandibular teeth with those of maxillary teeth can result in pain from a mandibular pulpitis being referred to the maxillary arch. Because pulpal pain may be poorly localized by the patient, it is important for the clinician to localize the source of the pain. This is often accomplished through tests that attempt to either reproduce the eliciting stimulus of a patient’s pain or eliminate the pain. For example, pulpal pain should be aggravated with hot or cold stimulation and should be eliminated or significantly reduced with local anesthetic.

Unlike pulpal pain, pain of periradicular origin is easier to localize. Mechanoreceptors are numerous in the periodontal ligament (PDL) and are most densely concentrated in the apical one third. Once inflammation from pulp disease extends into the PDL, patients are able to locate the source of the pain much more readily. As a musculoskeletal structure, the PDL responds to noxious stimulation in a graded fashion. That is, the degree of discomfort a patient feels in relation to periradicular pain depends on the degree of peripheral sensitization and the amount of provocation to this structure. Sensitized PDL will be uncomfortable to a patient if percussed lightly but more uncomfortable if percussed heavily. This is known as a graded response. It is therefore appropriate to record periradicular testing such as percussion and palpation in terms of degrees of tenderness (versus “all or nothing”). As with pulpal pain, pain of periradicular origin should also have an identifiable etiology. Periradicular pain tends to be dull, aching, or throbbing and should resolve completely.
with local anesthesia. Pain of suspected periradicular origin that does not respond to local anesthetic strongly indicates a nonodontogenic origin.

The tooth is unique in the human body in that it has a visceral component—the pulp, and a musculoskeletal component—the periodontal ligament. Therefore odontogenic pain can vary widely in presentation. Tooth pain can be diffuse or well localized, mild or intense, spontaneous or provoked with various stimuli applied at various intensities. The quality can vary between sharp and dull and between aching or throbbing. This potential for extreme variability makes it possible for toothaches to mimic or be mimicked by many other types of pain that occur in the head and neck. In addition, because both the pulp tissue and PDL can be categorized as deep somatic tissue, continued nociceptive input from odontogenic pain has a great propensity to produce central excitatory effects, such as secondary hyperalgesia, referred pain, secondary co-contraction of muscles, myofascial trigger points, and autonomic changes. These effects add to the complexity of diagnosing odontogenic pain and differentiating tooth pain from other sources in the region.

**Sources of Nonodontogenic Toothache**

This chapter provides information for the dental clinician to aid in the identification of toothaches with a nonodontogenic etiology. The clinician must have a thorough knowledge of all possible causes of orofacial pain, which includes both odontogenic and nonodontogenic conditions. This knowledge will prevent misdiagnosis and allow for proper treatment selection and referral if necessary. For information on treatment of these disorders other references should be used.

**Myofascial Sources**

Although any deep somatic tissue type in the head and neck has the propensity to induce central excitatory effects and therefore cause referral of pains to teeth, pains of muscular origin appear to be the most common. Myofascial pain (MFP) emanates from small foci of hyperexcitable muscle tissue. Clinically these areas feel like taut bands or knots and are termed *trigger points*. Typically the pain is described as a diffuse, constant, dull, aching sensation, which may lead the clinician to a misdiagnosis of pulpal pain. Another potentially misleading characteristic of masticatory muscle pain is that patients may report pain when chewing. This feature is similar to pain that is periradicular, not pulpal, in origin. On further investigation, it should become clear that the pain is triggered by contraction of masticatory muscles rather than loading of PDLs. Palpation of the muscles of mastication should reproduce the pain whereas percussion of the teeth should not. The intensity of the pain will increase and can be perceived in a distant site. MFP that is perceived to emanate from a tooth is a referred type of heterotopic pain. That is, the pain is felt in an area other than the nerve branch that innervates the trigger point. Typically, muscles that refer pain to teeth are the masseter, temporalis, medial pterygoid, lateral pterygoid, and anterior digastric.

Although the definitive pathogenesis of MFP is unknown, authors have theorized that muscles may become disturbed through injury or sustained contraction such as clenching. Clinically this muscular contraction might occur as a parafunctional habit or as a protective response by localized muscle to an ongoing deep noxious input such as dental pain. Considering this theory and what is witnessed clinically, trigger points appear to be induced or aggravated by toothache. It also appears that trigger points can persist after the toothache has been resolved, which can be confusing for the clinician and frustrating for the patient. It is important to realize the relationship of these two entities: MFP can mimic toothache, and toothaches may induce the development of MFP.

Toothaches of myofascial origin may arise with or without evidence of pulpal or periapical pathosis. Definitive diagnosis is based on lack of symptoms after pulp testing and percussion or palpation sensitivity, or failure to resolve symptoms with local anesthetic blockade. In contrast, jaw function and palpation of the masticatory muscles will elicit toothaches of myofascial origin. Typically, local anesthetic infiltration into the trigger points will lead to resolution of symptoms.

Some common therapeutic modalities utilized to treat MFP include deep massage, relaxation techniques, “spray and stretch,” muscle relaxants, and trigger point injections. Deep massage and relaxation techniques are noninvasive and easily administered. Spray and stretch involves application of a vapor coolant spray to the skin overlying the trigger point followed by a gentle stretching of the muscle. Trigger point injections are used for both the diagnosis and treatment of MFP. Specifically, if the pain complaint is diminished on injection of the trigger points, then the source of the pain has been confirmed. The therapeutic efficacy of a trigger point injection varies. Some patients might experience lasting relief with one injection or several, whereas others may not. See “Additional Tests” for further information on trigger point injections.
Sinus/Nasal Mucosal Sources

Sinus/nasal mucosal pain is another common source that can mimic toothache. Sinus pain can exhibit symptoms of fullness or pressure below the eyes but is generally not very painful unless the nasal mucosa is also affected.[13] Pain from the nasal mucosa tends to be dull and aching and can also have a burning quality typical of visceral mucosal pain. Generally these pains are of viral, bacterial, or allergic etiology. Other symptoms consistent with these types of disease (e.g., congestion, nasal drainage) should be noted in the patient history.

Typical of deep visceral tissues, sinus/nasal mucosal pain can induce central excitatory effects such as secondary hyperalgesia, referral of pain, and autonomic changes. This tendency gives sinus/nasal pain the ability to masquerade as toothache. Secondary hyperalgesia, seen clinically as a concentric spread of pain beyond the area of tissue injury, will result in tenderness of the mucosa in the area of the maxillary sinuses as well as tenderness to percussion of several maxillary teeth. Teeth tender to percussion and palpation suggest periapical inflammation. Autonomic sequelae might present as edema or erythema in the area that could suggest a dental abscess. However, when an etiology for pulpal and therefore periapical pathosis is absent, sinus/nasal mucosal disease should be suspected. Other symptoms of sinus disease include sensitivity to palpation of structures overlying sinuses (i.e., paranasal tenderness) and a throbbing or increased pain sensation when the head is placed lower than the heart. Dental local anesthetic blockade will not abate sinus/nasal mucosa pain, although topical nasal anesthetic will.

Patients with suspected sinus/nasal mucosal disease should be referred to an otolaryngologist for further diagnosis and treatment. Physical exam as well as adjunctive tests may be necessary for definitive diagnosis. Tests may include nasal cytologic and ultrasound studies and the use of nasal endoscopes in addition to imaging tests such as radiology and computed tomography imaging.[12] Treatment of the sinus/nasal mucosa depends on the etiology (e.g., bacterial, viral, allergic, obstructive).

Neurovascular Sources

Neurovascular pains have qualities very similar to pulpal pain. These can be intense, are often pulsatile, and frequently present as headache. These headaches are sometimes referred to as neurovascular disorders since they appear to have a neurologic etiology and a vascular target. The International Headache Society recognizes three major subdivisions of primary headaches: (1) migraine, (2) tension-type headache, and (3) cluster headache and other trigeminal autonomic cephalgias. Tension-type headache will not be discussed here, because it does not tend to mimic toothache.

Individuals who experience neurovascular headache generally have headache as the main symptom. Although other pains such as toothache can occur along with headache, the headache is usually the most severe. Thus, when headache is accompanied by tooth pain it is typically distinguishable from a genuine toothache because the toothache is perceived as secondary to the headache.

The most common type of migraine lasts between 4 and 72 hours. Migraines tend to be unilateral, pulsatile, and moderately to severely intense. Patients may also experience nausea or vomiting as well as photophobia or phonophobia. The headache is likely to be aggravated with routine physical activity. Caffeine/ergotamine compounds have been used widely in the past to abort migraine headache. More recent and popular approaches include the administration of one of the triptans, such as sumatriptan or almotriptan.[36] Cluster headaches are episodic, last 15 minutes to 2 hours, and vary in frequency from one every other day up to eight per day. They occur in young men (20 to 40 years) and consist of strictly unilateral, excruciating orbital and supraorbital or temporal pain. Ipsilateral autonomic symptoms of nasal congestion, rhinorrhea, conjunctival injection, and lacrimation are commonly present. The standard treatment to abort acute attacks of cluster headache is inhalation of 100% oxygen.[20]

Elimination of pain following a 10-minute inhalation of 100% oxygen is diagnostic for cluster headache. Sublingual ergotamine and sumatriptan are also effective and well tolerated in the acute treatment for cluster headache.[16]

Paroxysmal hemicranias present with similar characteristics to cluster headaches with some exceptions. They are shorter lasting and more frequent, and they occur more commonly in females. A favorable response to indomethacin is diagnostic for paroxysmal hemicrania.
A review of cases in the literature shows that pain of neurovascular origin presenting primarily as toothache is more likely to be a cluster headache or other subtypes of trigeminal autonomic cephalgias. A typical referral pattern would be to the maxillary anterior or premolar teeth. Concurrent autonomic features, such as discoloration or swelling, might compound the diagnostic problem by suggesting abscess. It is important to note that neurovascular headaches tend to be episodic with complete remission between episodes, whereas toothache pain usually has at least some background discomfort between any aggravating episodes. Provocation of the tooth should not increase the pain. Local anesthetic is unpredictable in these cases and can mislead the clinician in the diagnosis. Previously mentioned abortive methods, such as administration of oxygen to rule out cluster headache or indomethacin to rule out paroxysmal hemicrania, would be appropriate. After ensuring that the patient’s pain is not odontogenic, referral to an appropriate care provider is in order.

**Neuropathic Pain Disorders**

All previously described pain entities can be classified as somatic pain. That is, they are a result of noxious stimulation to somatic structures. These impulses are transmitted by normal neural structures, and their clinical characteristics are related to stimulation of normal neural structures. Neuropathic pain actually arises from abnormalities in the neural structures themselves. The clinical examination generally reveals no somatic tissue damage, and the response to stimulation of the tissue is disproportionate to the stimulus. Thus neuropathic pains can be misdiagnosed as psychogenic pain simply because a local cause cannot be visualized. Neuropathic pain in the orofacial region can be categorized in many ways. For the purposes of this chapter and ease of discussion, neuropathic pain is divided into four subcategories: neuralgia, neuroma, neuritis, and neuropathy.

**Neuralgia**

Because of its varied presentation and distressing nature, trigeminal neuralgia, or tic douloureux, can be particularly challenging to the clinician. Although deviations are common, trigeminal neuralgia is characteristically an intense, sharp, shooting pain that is most often unilateral. On stimulation such as light touch, an area, called the trigger zone, ipsilateral to the perceived location of the symptoms elicits sharp, shooting pain. Most but not all patients present with a characteristic trigger zone. In trigger zones the response to the stimulus is not proportional to the intensity of the stimulus. That is, slight pressure on a trigger zone results in severe pain. In addition, once triggered, pain typically subsides within a few minutes until triggered again. This contrasts with odontogenic pain, which may come and go but does not do so in such a predictable and repeatable manner. Finally, the trigger is an area that has no sensory abnormalities (e.g., dysesthesia, paresthesia).

Trigger zones for trigeminal neuralgia may be intraoral and may be triggered by chewing. Thus the patient and clinician may be led to a diagnosis of odontogenic pain. In addition, because the trigger involves peripheral input, anesthetizing the trigger zone may result in a diminution of symptoms, which can be very misleading to the clinician if the assumption is that local anesthetic blocks only odontogenic pain.

Because symptoms can be quite severe patients may consent to or even insist on treatment even though the clinical findings do not definitively support an odontogenic etiology. The possibly misleading symptoms, along with the willingness of the patient to consent to what may seem to be desperate measures, emphasize the importance of a thorough history and clinical evaluation. The absence of a dental etiology for the symptoms (e.g., large restorations, dental trauma, recent dental treatment) in the presence of the characteristic sharp, shooting pain should alert the clinician to consider neuralgia in the differential diagnosis. Generally these individuals should be referred to a neurologist.

Trigeminal neuralgia typically presents in individuals over the age of 50 years. The etiology is thought to be inflammation in one trunk of the gasserian ganglion, possibly as a result of carotid artery pressure. Individuals with multiple sclerosis will develop trigeminal neuralgia more frequently than the general population. For this reason, a person under the age of 40 years who develops trigeminal neuralgia should also be screened for multiple sclerosis or other intracranial pathosis. The two general treatment options for trigeminal neuralgia are pharmacologic and surgical procedures. Because of the possible complications associated with surgery, it is usually considered only after attempting pharmacologic therapies. Several medications, including carbamazepine, baclofen, and more recently gabapentin, have been used for treatment of trigeminal neuralgia. Drugs aimed at relieving nociception, such as nonsteroidal antiinflammatory agents, have no significant benefit in patients with trigeminal neuralgia. Narcotics are also not beneficial in treating trigeminal neuralgia. Clinical trials support carbamazepine as a first-line drug for treating trigeminal neuralgia. In patients who experience pain relief from carbamazepine, the effect is usually rapid; most will report a
Another neuralgia that may mimic toothache is pretrigeminal neuralgia. Pretrigeminal neuralgia is a syndrome of dull, aching, or burning pain, often in the oral cavity or teeth. It has been characterized as a toothachelike or sinuslike pain that precedes true paroxysmal trigeminal neuralgia. The pain episodes may be triggered by jaw movements or by drinking hot or cold liquids and may last from hours to months, with variable periods of remission. The subsequent onset of true neuralgic pain may be quite sudden or may appear several years later. Pretrigeminal neuralgia patients respond favorably to medications used to treat trigeminal neuralgia.

**Neuroma**

The term *neuroma* has been around for many years and is often overused to describe other types of neuropathic pain. A traumatic neuroma, also known as an *amputation neuroma*, is a proliferative mass of disorganized neural tissue at the site of a traumatically or surgically transected nerve. A part of the diagnosis therefore is confirmation of a significant event that would account for the damage to the nerve. Symptoms will not develop until the neural tissue on the proximal stump has had time to proliferate, typically about 10 days after the event. Tapping over the area of a neuroma elicits volleys of sharp electrical pain similar to trigeminal neuralgia (i.e., Tinel’s sign). In contrast to trigeminal neuralgia, there should be a zone of anesthesia peripheral to the area of the neuroma. Treatment involves surgical coaptation of the nerve with prognosis being variable and dependent on adequate distal nerve tissue and time interval between injury and reconstruction. Therefore early recognition and referral are key before significant distal nerve degeneration occurs. Although neuromas most commonly develop in the area of the mental foramen, lower lip, and tongue, they can also form in extraction sites. Neuromas were found to form in extraction sites between 4 and 6 months after removal of the tooth in an experimental animal model. Although not all neuromas that form are painful, this could explain the ongoing pain in extraction sites after healing has appeared to occur. It is interesting to ponder the possibility of neuroma formation in deafferentation injuries such as pulpectomy and the implications this might have on continued PDL sensitivity after adequate root canal treatment. For treatment of neuromas that are not amenable to surgical correction, see “Neuropathy.”

**Neuritis**

Neuritis is a condition caused by inflammation of a nerve or nerves secondary to injury or viral or bacterial infection. Generally pain from a virally induced neuritis such as recurrent herpes simplex or herpes zoster will be associated with skin or mucosal lesions. This presentation is not much of a diagnostic challenge, but pain can precede the vesicular outbreak by many days or even weeks. Since these disorders are caused by a reactivation of a virus that has been dormant in the trigeminal ganglion, it is considered projected pain with its distribution within the dermatomes innervated by the affected peripheral nerves. The nerves affected by the virus may solely supply deeper tissues and therefore may not produce any cutaneous lesions. In the absence of skin or mucosal lesions a viral neuritis can be very difficult to diagnose. Bacterial infection of the sinuses or dental abscess can also cause neural inflammation that may result in pain. This pain occurs simultaneously with pain of the infected tissues and usually dissipates once the etiology is addressed. In susceptible individuals, virally or bacterially induced neuritis may produce a postinfection neuropathy of the infected nerve. The pain is fairly constant and can be dull, aching, or burning. Also, the pain may be accompanied by allodynia, a painful response to normally nonnoxious stimulation, such as light brushing of the skin. Oral acyclovir is the most common treatment for acute herpetic outbreaks and is efficacious in decreasing the duration and severity of pain following herpes zoster. Efficacy is only based on administration in the prevesicular but not the vesicular stage. Addition of prednisolone to acyclovir produces only slight benefits over acyclovir alone. Neither acyclovir alone nor its combination with prednisolone appears to reduce the frequency of postherpetic neuralgia.

Localized traumatic injury can also induce a neuritis. This injury can be chemical, thermal, or mechanical. A classic endodontic example of a chemical injury to a nerve is the overextension of a highly neurotoxic paraformaldehyde-containing paste (e.g., Sargent) paste) onto the inferior alveolar nerve. Chemical trauma can be due to certain toxic components of the endodontic filling materials such as eugenol, irrigating solutions such as sodium hypochlorite, or intracanal medicaments such as formocresol. Mechanical compression in addition to thermal trauma may be a factor when thermoplasticized material is overextended using an injectable or carrier-based technique. Mechanical nerve trauma is more commonly associated with oral surgical procedures such as orthognathic surgery and third molar extraction. Neuropathic complications have also been documented following mandibular implant surgery at a rate of 5% to 15% with permanent neuropathies resulting in approximately 8% of these cases. Unfortunately, traumatic neuritis is often
misdiagnosed as a postoperative chronic infection, and the area is reentered and debrided. Additional surgical insult further traumatizes the nerve, prolonging the already present nociceptive barrage, which puts the patient at an increased risk of developing central hyperalgesia. Undiagnosed and mistreated cases of acute neuritis not only lead to unnecessary dental procedures but also act as additional aggravating factors of the neuritis, and therefore the neuritis has a greater chance of becoming chronic.

Neuritis pain typically is a persistent, nonpulsatile burning and is often associated with sensory aberrations, such as paresthesia, dysesthesia, or anesthesia. The pain can vary in intensity, but when stimulated, the pain provoked is disproportionate to the stimulus.

Treatment of acute neuritis is based on its etiology. In instances of chemical trauma (e.g., Sargenti paste) where there is obvious irritant present, surgical debridement of the nerve to remove any substance that can continue to irritate the nerve is an important aspect of treatment. With a neuritis secondary to mechanical compression (e.g., implant placement) of a nerve, nerve decompression by removal of the implant fixture is indicated. Such localized, acute, traumatically induced neuritis is inflammatory in nature and therefore can also benefit from supportive pharmacotherapies, such as steroids. For management of neuritis that is not responsive to the preceding treatments, medications used to treat neuropathic pain may be used (see “Neuropathy”).

Neuropathy

This chapter uses the word neuropathy as the preferred term for localized, sustained, nonepisodic pain secondary to an injury or change in a neural structure. Historically other terms have been used, including atypical facial pain. This term suggests pain that is felt in a branch of the trigeminal nerve that does not fit any other pain category. If pain from an unknown source is perceived in a tooth it may be labeled atypical odontalgia. If the pain persists after the tooth has been extracted it is referred to as phantoms tooth pain. This term implies a psychogenic component. The major limitation in the use of all these terms is that they merely suggest an area where a pain of unknown etiology exists and completely lack any information regarding pathophysiology. Although each of these terms has been extensively described in the literature, probably none of them actually represents one discrete condition but rather a collection of various conditions. Currently, a task force of the IASP (International Association for the Study of Pain) has been charged to look at classification of orofacial neuropathic pain. The task force is reporting at the SIG (special interest group) business meeting during the IASP World Congress on Pain in Sydney, Australia in August 2005.

Once a nerve has been sensitized by injury or disease it may remain so and present as a peripherally sensitized nerve. This peripheral sensitization and the ongoing pain (nociceptive barrage) that accompanies it can induce changes in the central or sympathetic nervous systems. Peripheral sensitization, central sensitization, and sympathetic enhancement all can potentially impact the clinical presentation of a neuropathy. A typical clinical course of someone with an undiagnosed neuropathy might consist of treatment for a toothache. When the pain does not resolve with nonsurgical root canal treatment (NS RCT), it might then be followed by apical surgery and perhaps an extraction. The extraction site might then be explored and debrided in a misguided attempt to remove any potential source of the patient’s ongoing pain. After each treatment, pain tends to be reduced for a short time and then return to its original, or even increased, intensity level. This is probably a result of a new neural injury consisting of reorganization and resprouting that increases the inhibition of nerve firing for a time. Surgical approaches to neuropathies are not effective because they do not desensitize the nerve. On the contrary, surgical intervention may aggravate the situation by inflicting an addition neural injury in the periphery and contributing to the already present nociceptive input. This intervention therefore puts the patient at an increased risk of developing a central or sympathetic component to the pain. This statement is not meant to refer to situations with concurrent nerve trunk compression or other type of physical or chemical irritation present.

The diagnosis of neuropathy is based primarily on history and examination. The history should reveal some inflammation-inducing event (see “Neuritis” and “Neuroma”) although the nature of the initial insult is not always identified. Typically, the examination is grossly unremarkable with no evidence of local tissue damage. However, constant pain of varying degrees of intensity will be reported in a focal area. This area may show hyperalgesia or allodynia. That is, noxious stimulation to the area will be perceived as more painful, or hyperalgesia or allodynia. That is, noxious stimulation to the area will be perceived as more painful, or hyperalgesia. This intervention therefore puts the patient at an increased risk of developing central hyperalgesia. Undiagnosed and mistreated cases of acute neuritis not only lead to unnecessary dental procedures but also act as additional aggravating factors of the neuritis, and therefore the neuritis has a greater chance of becoming chronic.

Neuropathies can be classified on the basis of their clinical presentation and response to therapies. Peripheral neuropathy may develop following sensitization of a peripheral nerve and presents clinically as
described earlier. Diagnosis of peripheral neuropathy is based on its favorable response to peripheral neural blockade. Treatment is directed at decreasing the sensitization of the peripheral nerves and reducing the ectopic neuronal firing. Topical as well as systemic medications can be used for treatment of cutaneous peripheral neuropathies. Some topical medications include topical anesthetics and capsaicin-containing compounds as well as transdermal preparations of nonsteroidal antiinflammatory drugs (NSAIDs), sympathomimetic agents, and neuromuscular depolarizing agent (NMDA) blocking agents.

The clinical presentation of a central neuropathy is very similar to a peripheral neuropathy. Following sensitization of peripheral nerves and the nociceptive barrage that accompanies it, pain is nonremitting and lacks evidence of tissue insult. Unlike its peripheral counterpart, allodynia and secondary hyperalgesia are clearly present. That is, the area of pain is much larger than the initial site of injury. The most telling sign that a neuropathy has taken on a more central component is that local anesthetics are no longer effective. Therefore the treatment must be directed toward the central processing of pain. This is done with medications such as NMDA receptor agonists (ketamine), gabapentin, tricyclic antidepressants, and opioids. The prognosis for a central neuropathy is not as good as for a peripheral neuropathy because central neuropathic pain tends to become more refractory with time. Treatment is based on the management of pain rather than its cure.

The last variation of neuropathic pain is sympathetically enhanced or maintained pain. In cases of sympathetically maintained pain (SMP), peripheral nerve fibers up regulate the expression of adrenergic receptors, making them responsive and sensitive to sympathetic input. SMP may also have a central component whereby constant sympathetic drive alters neuronal excitability. Neuronal injury may induce sprouting of sympathetic axons into the trigeminal spinal nucleus since basketlike formations of sympathetic fibers have been reported around the cell bodies of sensory neurons in the dorsal root ganglia. Increases in sympathetic drive, such as from stress and fevers, may aggravate SMP. Diagnosis of SMP is based on blocking sympathetic outflow to the affected region with a sympathetic nerve block. In the orofacial region this would require a stellate ganglion block (see later discussion for greater detail). The block is considered diagnostic for SMP if the block is effective in decreasing the patient’s pain. Multiple blocks can also be utilized as a form of therapy. Other therapies include drugs that target peripheral alpha2 adrenoceptors (agonists) or alpha1 adrenoceptors (antagonists), such as guanethidine, phentolamine, and clonidine.

Cardiac Sources

Cardiac pain classically presents as a substernal pain that most commonly radiates to the left arm, shoulder, neck, and face. Although not as common, anginal pain may present solely as dental pain, generally felt in the lower left jaw. Similar to pain of pulpal origin, cardiac pain can be spontaneous and diffuse with a cyclic pattern that fluctuates in intensity from mild to severe. The pain can also be intermittent and completely asymptomatic at times. The quality of cardiac pain when referred to the mandible is chiefly aching and sometimes pulsatile. Cardiac pain may be spontaneous or increased with physical exertion, emotional upset, or even the ingestion of food.

Cardiac pain cannot be aggravated by local provocation of teeth. Anesthetizing the lower jaw or providing dental treatment will not reduce the pain. It can be decreased with rest or a dose of sublingual nitroglycerin. Diagnosis of cardiac pain along with immediate referral is mandatory to avoid impending myocardial infarction.

Psychogenic Sources

Psychogenic toothache falls under a group of mental disorders known as somatoform. The name is derived from the fact that the patient has somatic complaints yet lacks a physical cause. Since these patients lack a physical cause for pain they will also present without local tissue changes. In somatoform disorder the patient is not fabricating the symptoms nor seeking conscious benefit. Somatoform disorders differ from factitious or malingering disorders. In factitious disorders, physical or psychologic symptoms are produced by the individual and are under voluntary control. Malingering is similar to factitious disorder with the added characteristic that the symptoms are presented for obvious and recognizable benefit. This diagnostic category poses a significant diagnostic challenge. Lacking evidence of local tissue damage is typical of heterotopic pain entities previously discussed in this chapter. It is important to emphasize that psychogenic pain is rare. All other potential diagnoses must be ruled out before making the diagnosis of psychogenic pain. The diagnosis of psychogenic toothache is one of exclusion and is based on the practitioner’s awareness of other heterotopic pain characteristics and behavior. Of particular note are centrally emanating pains, cardiac pain, neurovascular pain, and neuropathic pain.
Psychogenic pain is known to be precipitated by severe psychologic stress. This pain differs from any other pain condition. That is, it may not fit a normal anatomic distribution or physiologic pattern. The pain may be felt in multiple teeth, and the pain may move from one tooth to another. Patients’ reported intensity of pain tends to be more severe than their amount of concern for their condition. Their response to therapy varies but can include a lack of response or an unusual or expected response. Early identification of psychogenic pain and referral to a psychologist or psychiatrist are necessary to avoid irreversible and unnecessary dental treatment.
TAKING A PAIN HISTORY

Pain diagnosis is largely based on the patient’s subjective history; however, a patient rarely gives all pertinent diagnostic information about the pain voluntarily. Often one must carefully extract the details of the patient’s pain complaint through systematic and thorough questioning. This is known as “taking a history,” and it involves both careful listening and astute questioning. The beginning of Box 3–1 gives an example of a basic diagnostic work-up for odontogenic pain. It can be used easily for pain histories of typical odontogenic pain by circling all descriptors that apply and then filling in the remaining blanks. As the details of the patient’s pain complaint are gathered, the clinician should mentally progress through an algorithm of possible diagnoses since each detail should lead to one type of pain over another. After completing a thorough and accurate history of the complaint or complaints (see the second half of Box 3–1), often the diagnosis has already been narrowed down to a particular pain entity. This is particularly true with odontogenic pain. The only question that will remain is “Which tooth is it?” Whereas a patient will provide information as to the perceived site of pain, the clinician’s examination will reveal the true source of the pain. With more complicated pain complaints the clinician may have a list of possible diagnoses, known as a differential diagnosis. This differential diagnosis will serve to guide the examination and testing in an effort to confirm one diagnosis while ruling out all others. If, after completing the subjective examination, all items on the differential diagnosis are outside the clinician’s scope of practice, then the clinician should continue the examination until he or she has a firm idea of the possible diagnosis so that a proper referral can be made. In addition, it is paramount that all odontogenic sources have been ruled out and that this information is communicated to the health care provider to which the patient is referred. If no differential diagnosis can be formulated after the history, then the history should be redirected to the patient to confirm that the information is complete and accurate. If the patient is unable to provide sufficient information regarding the pain complaint then it may be helpful to have the patient keep a pain history, detailing the aspects of the pain on a daily basis. Treatment must be avoided when the diagnosis is uncertain. Diagnostic therapy (i.e., “Let’s do a root canal treatment and see if it helps”) may result in costly treatment that does not improve the patient’s condition and could be a factor in aggravating and perpetuating a patient’s pain. Treatment should always specifically address a diagnosis.

Box 3-1

<table>
<thead>
<tr>
<th>Pain History</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Diagnostic Work-up for Pain of Odontogenic Origin</strong></td>
</tr>
<tr>
<td><strong>Subjective: Pain (circle all appropriate)</strong></td>
</tr>
<tr>
<td>Level (0 – 10) ____</td>
</tr>
<tr>
<td>Well localized</td>
</tr>
<tr>
<td>Spontaneous</td>
</tr>
<tr>
<td>Constant</td>
</tr>
<tr>
<td>Dull ache</td>
</tr>
<tr>
<td>Onset ____</td>
</tr>
<tr>
<td>Progression (frequency/intensity/duration) ____</td>
</tr>
<tr>
<td>Aggravating factors ____</td>
</tr>
<tr>
<td>Relieving factors ____</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>History of the Complaint</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chief Complaint</strong></td>
</tr>
<tr>
<td>Prioritize complaints</td>
</tr>
<tr>
<td>Specify location</td>
</tr>
<tr>
<td>VAS 0 – 10</td>
</tr>
</tbody>
</table>
A complete medical history along with current medications and drug allergies should always be ascertained. It is also important to note demographic information because certain genders and ages are more at risk for some disorders as opposed to others.

Recording a patient’s chief complaint in the patient’s own words is a medical and legal necessity but falls

<table>
<thead>
<tr>
<th><strong>Initial Onset</strong></th>
<th>When did you first notice this?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Progression</strong></td>
<td><strong>Frequency</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Intensity</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Duration</strong></td>
</tr>
<tr>
<td><strong>Previous Similar Complaints</strong></td>
<td>Have you ever had this type of pain before?</td>
</tr>
<tr>
<td><strong>Complaint Characteristics</strong></td>
<td>Daily</td>
</tr>
<tr>
<td></td>
<td>Constant</td>
</tr>
<tr>
<td>Duration</td>
<td>Temporal pattern</td>
</tr>
<tr>
<td><strong>Aggravating Factors</strong></td>
<td>What makes this pain worse? Be specific!</td>
</tr>
<tr>
<td><strong>Alleviating Factors</strong></td>
<td>What makes this pain better?</td>
</tr>
<tr>
<td></td>
<td>How much better?</td>
</tr>
<tr>
<td><strong>Associated Factors</strong></td>
<td>Swelling</td>
</tr>
<tr>
<td></td>
<td>Discoloration</td>
</tr>
<tr>
<td></td>
<td>Numbness</td>
</tr>
<tr>
<td><strong>Relationship to Other Complaints</strong></td>
<td>Would your jaw hurt if your tooth didn’t hurt?</td>
</tr>
<tr>
<td></td>
<td><strong>Prior Consults/Treatment</strong></td>
</tr>
<tr>
<td></td>
<td>Who?</td>
</tr>
<tr>
<td></td>
<td>When?</td>
</tr>
<tr>
<td></td>
<td>What was the diagnosis?</td>
</tr>
<tr>
<td></td>
<td>What was done?</td>
</tr>
<tr>
<td></td>
<td>How did it affect the pain?</td>
</tr>
</tbody>
</table>
short of comprising a thorough pain history. A complete history begins with a patient’s general pain complaint; for example, “My tooth hurts.” Patients may have more than one pain complaint; for example, “My tooth hurts, and it is starting to make my jaw hurt.” All pain complaints should be noted and investigated separately. Understanding the specific components of the complaints makes it possible to discern the relationship between the complaints. That is, either the complaints are wholly separate and there are two types of pathosis present, or one source of pain is merely creating a heterotopic pain that is wholly secondary to the first.

The clinician begins with determining the **location** in which the patient perceives the pain. Aspects of the location involve localization and migration. Pain should be definable as either well localized or diffuse and either superficial or deep. Easily localized superficial pain tends to be cutaneous or neurogenic. Musculoskeletal pain is felt deeply and is more localizable once it is provoked. Deep, diffuse pain suggests a deep somatic visceral or musculoskeletal origin. Both tissue types are involved in a high degree of nociceptor convergence into the trigeminal nucleus and therefore are much more likely to be involved in creating heterotopic pain. Typical referral patterns of deep somatic pain tend to follow peripheral dermatomes that reflect the laminations in the trigeminal nucleus. Referred pain also tends to occur in a cephalad direction. Therefore referred pain from a deep somatic tissue such as tooth pulp, cardiac tissue, or skeletal muscle will respect this pattern. Pain that spreads distally along a nerve branch is much more indicative of a projected type of heterotopic pain. Projected pains imply a neurogenic source and possibly one that is secondary to impingement from intracranial pathosis. Since superficial sources of pain are not likely to be involved in referral, if a patient indicates that the pain is superficial and spreading, this is highly suggestive of a neurogenic rather than a cutaneous source.

Assessment of the **intensity** of pain is easily accomplished using a verbal analog scale. This question is best phrased, “On a scale of 0 to 10, with 0 being no pain and 10 being the worst pain you can imagine, how bad is your pain?” Intensity not only can provide insight on pain type but also can help guide postoperative pain management as well as provide a baseline for response to therapies.

Identifying the **onset** of pain may provide information regarding etiology. The clinician should ask if the onset followed a particular event, such as a dental appointment or a traumatic injury; however, these relationships can be misleading. Having a temporal correlation does not necessarily ensure a cause and effect relationship. The onset of pain may be either gradual or sudden. Severe pain of sudden onset can signal a more serious problem. Pain that has been present over a protracted period, particularly if the pain has been unchanging, is highly suggestive of a nonodontogenic source.

Other **temporal** aspects of pain include frequency and duration. The question should be asked: “How often does the pain occur, and how long does it last?” These temporal aspects may establish patterns that point more clearly to one condition over another.

**Progression** of the patient’s pain over time should be noted. Whether a pain is better, worse, or unchanging since the onset should be broken down into three factors: frequency, intensity, and duration. Static pains that do not change over time are typically not odontogenic.

The **quality** of a pain or “what it feels like” is a critical aspect of a pain history. Knowledge of pain characteristics as they relate to tissue types is essential. Pain quality can be difficult for patients to describe, and it is often necessary to provide them with a list of descriptors to choose from. In instances of odontogenic pain the list is fairly short. The deep visceral and musculoskeletal components of a tooth limit true odontogenic pain to being either dull aching or throbbing. If there is an aspect of sharpness to the pain it is helpful to understand if the sharpness is more stabbing, which would be more indicative of A-delta fiber – mediated dentinal pain, or if it is more electrical, which would be more indicative of a neuralgia. Table 3–1 lists some common examples of pain descriptors and their respective pain types.

<table>
<thead>
<tr>
<th>ORIGIN</th>
<th>QUALITY OF PAIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muscular</td>
<td>Dull, aching</td>
</tr>
<tr>
<td>Neurogenic</td>
<td>Shocking, burning</td>
</tr>
<tr>
<td>Vascular</td>
<td>Throbbing, pulsatile</td>
</tr>
</tbody>
</table>

Factors that precipitate or aggravate the patient’s pain complaint are key to diagnosis. Aggravating factors not only suggest different tissue types that are involved but also aid in directing objective tests. When gathering information, it is important to be specific. If a patient reports pain while eating, the clinician must
remember that many structures are stimulated during mastication, such as muscles, TMJs, mucosa, PDLs, and potentially pulps, and ask the patient to be specific as to the aggravating factor. The lack of any aggravating factors indicates that the pain is not odontogenic.

**Alleviating factors** can provide insight as to the nature of the pain. If the pain is relieved by a medication it is critical to know the specific medication, its dosage, and the degree to which the pain was attenuated. It is equally important to know what has no effect on the intensity of the pain. For example, a pain that is mid-level in intensity yet completely unresponsive to antiinflammatory drugs suggests a noninflammatory origin.

**Associated factors** such as swelling, discoloration, and numbness must be ascertained, as well as their correlation with symptoms. Swelling of acute onset suggests an infection, and its concurrent pain would be of inflammatory origin. Swelling that comes and goes with the intensity of pain suggests an autonomic component. The same can be said for discoloration, such as redness. Numbness or any other type of sensory aberrations should be recorded. If the altered sensation is a major component of the pain complaint then it should be investigated separately and its relationship to the pain determined. Pains that occur with sensory aberrations tend to have a strong neurogenic component.

If the patient has more than one pain complaint, an effort should be made during the subjective history to determine the **relationship of the complaints**. One pain might serve as an aggravating factor to the other. There may be a correlation as to the onset, intensity, or progression of the complaints. Also, the clinician must remember that patients may actually have more than one type of pathosis occurring concurrently and there may be no relationship whatsoever. The clinician needs to ask about any **previous similar complaints** and what happened. Recurrence of similar pains might reveal a pattern that lends itself to a particular pain diagnosis.

It is critical to learn about any prior consultations. Details regarding the type of clinician, actual work-up performed, and diagnosis rendered will help in narrowing down a differential diagnosis. Any treatment that was performed and its effect on the chief complaint should be ascertained.
PATIENT EXAMINATION

As stated previously, the history gathers information about the patient’s pain complaint in order to formulate a list of possible diagnoses based on specific pain characteristics. Poor or improper symptom analysis will lead to a false differential diagnosis, and any testing will therefore have limited meaning. Performing a general examination including extraoral, intraoral, and hard and soft tissue assessment is required to confirm the health of various structures and to identify possible pain-producing etiologies. When a patient presents with a toothache, the pain is usually of odontogenic origin. Diagnostic procedures are often limited to confirming a suspect tooth rather than identifying a nonodontogenic source of pain. Standard pulpal and periradicular tests serve to aid in ruling in odontogenic pain and therefore ruling out nonodontogenic pain as a diagnosis. The site of pain is determined by patient history, but the true source of pain should be revealed with testing. If the chief complaint cannot be reproduced with standard tests then additional tests may be necessary to narrow down a differential diagnosis. For details on a general examination and standard tests, see Chapter 1.

Additional Tests

Further tests should be chosen with forethought in an effort to develop a workable differential diagnosis that can guide the clinician toward a meaningful consultation or an appropriate referral for the patient. These tests may consist of palpation or provocation of various structures, sensory testing, or diagnostic blocks. This chapter will not cover the application of these tests in detail. For more information on the application and interpretation of these tests, other sources should be consulted.

Palpation and percussion are common tests to differentiate odontogenic pain from pain of sinus origin. Palpation of the sinuses consists of firm pressure placed over the involved sinus (usually maxillary). In addition, pain of sinus origin may be provoked with a lowering of the patient’s head.

If pain of muscular origin is suspected then an attempt to reproduce this pain can be done with palpation of the muscles of mastication or provocation by functional manipulation. The temporalis, deep and superficial masseter, medial pterygoid, and digastic muscles should be palpated in an effort to discover tenderness or trigger points that reproduce the pain complaint. The medial pterygoid is only partially accessible to palpation and may need to be functionally tested by stretching the muscle (opening wide) or contracting the muscle (biting firmly). The lateral pterygoid may be difficult if not impossible to palpate intraorally and therefore is more appropriately assessed with functional manipulation. Pain emanating from this muscle may be increased by protruding the jaw against resistance. Exacerbating the chief complaint with muscular function provides a strong indication of a myofascial source of pain.

Because of the complexity of innervation and the occurrence of heterotopic pain in the orofacial region, it may be difficult to definitively determine the origin of the pain with testing alone. It cannot be stressed enough that primary pain should not only be provoked with local manipulation but also relieved with anesthetic blocking. Important factors surrounding diagnostic anesthesia include relief of pain having a typical onset and duration for the particular anesthetic used. In addition, the pain should be diminished completely, or suspicion of a central component or a co-existing disorder should arise. The use of diagnostic anesthesia may be necessary and useful in augmenting the diagnostic work-up (Fig. 3–6). Topical anesthetic can be helpful in the investigation of cutaneous pain and peripheral neuropathies. Anesthetic injection including peripheral nerve blocks can be used to determine if the etiology of the pathosis is peripheral to the area of the block. Pain that persists after the onset of usual signs of anesthesia suggests a central component to the patient’s pain. The patient’s history and general examination are key in differentiating the pain from a central neuropathy versus a central pain emanating from an intracranial mass.
Pain that is thought to be primarily muscular where trigger points have been discovered on examination can be further investigated with local anesthetic injection into the trigger point. Trigger point injections are typically performed with either a 27- or 25-gauge needle and a minimally myotoxic anesthetic, such as 2% lidocaine or 3% mepivacaine without a vasoconstrictor. Myofascial trigger point injections may result in abolishment of pain at the trigger point as well as the site of referral.

Sympathetic efferent activity can play a role in the enhancement or maintenance of chronic pain. In the head and neck, sympathetic activity flows through the stellate ganglion located bilaterally near the first rib. In patients with a suspicion of a sympathetic component to their pain a stellate ganglion block can be used to provide diagnostic insight. This is usually done by a trained anesthesiologist. An effective block delivered to the stellate ganglion will interrupt sympathetic outflow to the ipsilateral side of the face resulting in partial Horner’s syndrome, evidenced by flushing, congestion, lacrimation, miosis of the pulpal ptosis, and anhidrosis.[28] A sympathetic blockade that diminishes or eliminates a pain state may serve to guide future treatment, such as repeated blocks or systemic treatment with sympathetically active drugs (e.g., clonidine, prazosin).[44]

Both peripheral and central neurologic conditions can present as pain in the orofacial region. One role of the clinician is to help rule out gross neurologic conditions secondary to intracranial pathosis. Patients with systemic complaints such as nausea, dizziness, or changes in one of the special senses should raise suspicion of intracranial pathosis. A neurologic screening examination, including a gross sensory and motor evaluation of cranial nerves II to XII, should be performed. For details on cranial nerve examination please refer to Bates’ Guide to Physical Examination and History Taking, ed 7. Investigation of sharp/dull differentiation as well as light touch discrimination between the different branches of the trigeminal nerve can provide insight as to location and etiology of pathosis.

**Case Studies**

**Case 1**

A 56-year-old man presents with a chief complaint that “This tooth still hurts, and it’s getting worse. It even hurts when I smile.” His medical history reveals a history of angina secondary to a 70% occlusion of his right coronary artery. He also reports a history of hypercholesterolemia. He has no history of myocardial infarction and denies any other significant medical history. Patient is taking lovastatin (Mevacor), 400 mg per day, nifedipine (Procardia), 60 mg once daily, and atenolol 50 mg once daily. He has no known drug allergies.

The patient was referred by a periodontist for evaluation of continued pain associated with tooth #3. He had been on periodontal maintenance therapy for generalized moderate adult periodontitis for more than 5 years. He had root canal treatment and a mesiobuccal root amputation of #3 as treatment for a localized area of advanced periodontitis 6 months ago.

**Subjective History**
After careful questioning, it became apparent that the patient was experiencing pain with two different qualities: an intermittent ache associated with #3 and an intermittent, sharp, shooting pain associated with tooth #3. The intermittent dull ache was of gradual onset 9 months ago. This pain was unaffected by the nonsurgical root canal treatment and root amputation. This pain had increased in frequency, intensity, and duration over the last 3 months. There was no temporal component. The dull ache was aggravated by biting and by the occurrence of the sharp, shooting pain. The sharp, shooting pain had a sudden onset 6 months ago. It had also increased in frequency, intensity, and duration without a temporal component. It could occur spontaneously or when “smiling big.” The patient reported the sharp, shooting pain could also be aggravated by pressing lightly on his face in the area overlying #3 but not by pressing intraorally on #3.
Examination

The coronal portion of the amputated mesiobuccal root was restored with intermediate restorative material (IRM). No cracks, fractures, sinus tracts, or swelling was detected. There were generalized probing depths of 4 mm throughout the upper right sextant. Tooth #3 has an 8 mm broad probing defect mesially with bleeding on probing. Box 3-2 gives the results of clinical testing.

Box 3-2

<table>
<thead>
<tr>
<th>Tests:</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endo ice:</td>
<td>+ (s)</td>
<td>-</td>
<td>+ (s)</td>
</tr>
<tr>
<td>Percussion:</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Palpation:</td>
<td>-</td>
<td>-</td>
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</table>

A periapical radiograph (Fig. 3-8) showed evidence of prior nonsurgical root canal treatment and mesiobuccal root amputation of tooth #3. Mild to moderate horizontal bone loss was evident in the quadrant. No radiographic evidence of caries or apical radiolucencies was noted.
Additional Tests

In the absence of a clear etiology, a more extensive extraoral examination was performed. Cranial nerves II to XII were intact. The sharp, shooting pain was predictably produced with light brushing of the skin over the area of #3. This examination increased the patient’s subjective complaint of a dull ache associated with #3. With the likelihood of two possible sources of pain existing, a diagnostic anesthetic block of #3 was performed. Buccal infiltration of #3 with 27 mg 3% mepivacaine without epinephrine was done. After 3 minutes the patient no longer reported a dull ache with #3, and he was nontender to percussion. The sharp, shooting pain could still be initiated with light brushing of the skin over the area of #3 and continued to cause a dull ache in the area of #3. Diagnoses of trigeminal neuralgia and advanced localized adult periodontitis of #3 were made. The patient was referred to a neurologist for evaluation and treatment. The diagnosis of trigeminal neuralgia was confirmed, and he was prescribed carbamazepine, 100 mg per day.

Case 2

A 28-year-old male has a chief complaint of “My teeth on the right side hurt.” His past medical history is not significant. He denies any systemic disease and has no known drug allergies. He is currently taking 600 mg of ibuprofen as needed for pain. He is taking no other medications. The patient was referred by his general dentist for evaluation of pain associated with his teeth on the right side.

Subjective History

After careful questioning, it was determined that the patient was experiencing pain of two different types. The most distressing pain to the patient was a diffuse, right-sided, constant low-grade dull ache (3/10 on verbal analog scale [VAS]). The onset was gradual, beginning 2 years ago. The pain had recently increased in intensity and duration. This pain was aggravated by opening wide. Additionally, this low-grade dull ache would increase in intensity after the occurrence of a sharp pain that was induced with biting down. There was no notable temporal component, and no attempts had been made by the patient to obtund the pain.

His other pain type had a sudden onset approximately 4 months ago. This pain was localized to the area of the right first molars. It was an intermittent, sharp, shooting pain (8/10 VAS) that occurred when biting.

Examination

Tooth #3 had an occlusal amalgam with cracks evident on the mesial marginal ridge and the buccal groove. Tooth #30 had an occlusal amalgam, and cracks were noted on the mesial and distal marginal ridges of tooth. There were no swellings or sinus tracts and no probing greater than 4 mm on the right side. Periapical radiograph demonstrated no evidence of caries or apical radiolucencies. The patient’s sharp pain was reproduced with a bite test applied to the mesiobuccal cusp of #30. Following the bite test, the patient reported an intensifying of his dull ache. Box 3 – 3 gives the results of clinical testing.

Box 3-3

<table>
<thead>
<tr>
<th>Tests:</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>31</th>
<th>30</th>
<th>29</th>
</tr>
</thead>
</table>

Figure 3-8 Periapical radiograph showing prior NS RCT and mesiobuccal root amputation of tooth #3.

Clinical Results of Testing: Case 2
Thirty seconds after completing pulp testing, the patient again reported an intensifying of his dull ache.

**Additional Tests**

In consideration of an uncertain diagnosis, a more extensive examination was performed. Palpation and provocation tests of the muscles of mastication revealed a trigger point in the patient’s right deep masseter. Palpation of this trigger point resulted in immediate intensifying of his “toothache.” A trigger point injection of 3% mepivacaine without epinephrine was done in an effort to clarify a diagnosis. Following a trigger point injection all tests were repeated. Palpation of the trigger point no longer produced pain. The bite test and cold test still produced a short, sharp pain but were no longer followed by a dull ache.

Diagnoses of reversible pulpitis secondary to cracked #31 and myofascial pain of the right masseter were made. The patient was given home care instructions for treatment of his myofascial pain, and he was referred to his general dentist for cuspal coverage of both #3 and #30.
SUMMARY

Clinicians are frequently called on to diagnose and treat complaints of orofacial pain, and thus a thorough knowledge of odontogenic and nonodontogenic causes of orofacial pain is necessary. The basis for this knowledge begins with an understanding of the anatomy and physiology of the pain system and how alterations in this system can result in pain that is poorly localized and therefore misdiagnosed. A realization that pain does not always originate in structures in which the pain is felt, along with an understanding of the neurobiologic basis of heterotopic pain, is necessary to ensure accurate diagnosis of orofacial pain.

There are several indicators that a toothache may be nonodontogenic in origin. Red flags for nonodontogenic pain include toothaches that have no apparent etiology for pulpal or periradicular pathosis; pain that is spontaneous, poorly localized, or migratory; and pain that is constant and nonvariable. In addition, quality of pain that is described as burning, pricking, or "shocklike" is less likely to be pulpal or periradicular.

A thorough pain history and examination of dental and nondental structures are essential to differentiate between odontogenic and nonodontogenic sources of pain. Examples of key components of the pain history and examination are included in this chapter for reference. In addition, the chapter has focused on the more common nonodontogenic sources of orofacial pain. As stated earlier the role of the dental clinician is to diagnose and treat disorders of the oral cavity and masticatory structures. In the event that a nondental pathosis is suspected, a differential diagnosis of probable disorders is essential as part of a referral to a more appropriate health care provider. In addition, an understanding of any potential role or interaction of dental structures in the patient’s pain complaint should be communicated as part of the referral.
References


Chapter 4 - Case Selection and Treatment Planning

Paul A. Rosenberg

The process of case selection and treatment planning begins after a clinician has diagnosed an endodontic problem. The clinician must determine if the patient’s oral health needs are best met by providing endodontic treatment and maintaining the tooth or by advising extraction. This question is more complex than ever before because of the wide array of treatment modalities. The use of ultrasonics and microscopy as well as new materials has made it possible to predictably retain teeth that previously could not have been treated. Even teeth that have failed initial endodontic treatment can often be successfully retreated using nonsurgical or surgical procedures.

Increased knowledge about the importance of anxiety control, nonsteroidal antiinflammatory drug (NSAID) premedication, profound local anesthesia, occlusion, and biologically based clinical procedures enables clinicians to complete endodontic procedures in the absence of intraoperative or postoperative pain (see Chapters 19 and 20 for more information on pain control and anesthesia). Thus preoperative pain should not influence treatment selection because modern techniques for profound local anesthesia can provide complete comfort for the great majority of patients receiving endodontic treatment (see Chapter 19, “Local Anesthesia in Endodontics,” for details).

Questions concerning tooth retention and possible referral can be answered only after a complete patient evaluation. The evaluation must include assessment of medical, psychosocial, and dental factors as well as a consideration of the relative complexity of the endodontic procedure. Although most medical conditions do not contraindicate endodontic treatment, some can influence the course of treatment and require specific modifications. A number of valuable texts are available that review the subject of dental care for the medically compromised patient.[6][31][47][53] An excellent website is also available and can be used to elicit information.[4]

Perhaps the most important advice for a clinician who plans to treat a medically compromised patient is to be prepared to communicate with the patient’s physician. The proposed treatment can be reviewed, and medical recommendations should be documented. Fig. 4-1 depicts a sample medical consultation letter that can be modified as necessary.
The American Society of Anesthesiologists (ASA) Physical Status Classification was devised in 1941 and revised to its present form in 1983. The ASA website lists the following:

ASA I - Normal, healthy patient; no dental management alterations required.

ASA II- A patient with mild systemic disease that does not interfere with daily activity or who has significant health risk factor (e.g., smoking, alcohol abuse, gross obesity); may or may not need dental management alterations.

Examples: Stage I or II hypertension, type 2 diabetes, allergy, well-controlled asthma.

ASA III- A patient with moderate to severe systemic disease that is not incapacitating but may alter daily activity; may have significant drug concerns; may require special patient care; would generally require dental management alterations.

Examples: Type 1 diabetes, stage 3 hypertension, unstable angina pectoris, recent myocardial infarction, poorly controlled congestive heart failure, AIDS, chronic obstructive pulmonary disease, hemophilia.

ASA IV- A patient with severe systemic disease that is a constant threat to life; definitely requires dental management alterations; best treated in special facility.

Example: Kidney failure, liver failure, advanced AIDS.


The ASA classification remains the most widely used assessment method for preanesthetic patients despite some inherent limitations to its use as a perioperative risk predictor. This is a generally accepted and useful guide for preoperative assessment of relative risk. However, the prudent clinician should also take into account other factors not considered in the classification scheme, such as age, obesity, and skill of the health care provider. Other systems have been proposed that would better reflect the increasing number of medically complex patients treated by clinicians as Americans live longer.
COMMON MEDICAL FINDINGS THAT MAY INFLUENCE ENDODONTIC TREATMENT PLANNING

Pregnancy

Although pregnancy is not a contraindication to endodontics, it does modify treatment planning. An extensive body of literature exists concerning the use of radiographs and drugs while treating pregnant patients. Protection of the fetus is a concern when administration of ionizing radiation or drugs is considered. Of all the safety aids associated with dental radiography, such as high-speed film, digital imaging, filtration and collimation, the most important is the protective lead apron with thyroid collar. Drug administration during pregnancy is a controversial subject. A major concern is that a drug may cross the placenta and be toxic or teratogenic to the fetus. In addition, any drug that is a respiratory depressant can cause maternal hypoxia, resulting in fetal hypoxia, injury, or death. Ideally, no drug should be administered during pregnancy, especially during the first trimester. If a specific situation makes adherence to this rule impossible, then that clinician should review the appropriate literature and discuss the case with the physician and patient.

Further considerations exist during the postpartum period if the mother breast feeds her infant. Although most drugs are only minimally transmitted from the maternal serum to the breast milk and the infant’s exposure is not significant, the clinician should avoid using any drug known to be harmful to the infant. A dentist should consult the responsible physician before using any medications for the nursing mother. Alternative considerations include using minimal dosages of drugs, having the mother bank her milk before treatment, having her feed the child before treatment, or suggesting the use of a formula for the infant until the drug regimen is completed. The U.S. Food and Drug Administration (FDA) and the American Academy of Pediatrics have issued a list of drugs that are thought to be compatible with breastfeeding (see http://www.fda.gov/fdac/features/895_brstfeed.html). Box 4-1 summarizes this list.

Box 4-1

Partial List of Drugs Usually Compatible with Breast Feeding

- Acetaminophen
- Many antibiotics
- Aspirin (should be used with caution)
- Codeine
- Ibuprofen
- Insulin
- Quinine
- Thyroid medications


In terms of treatment planning, elective dental care is best avoided during the first trimester because of the potential vulnerability of the fetus. The second trimester is the safest period in which to provide routine dental care. Significant surgical procedures are best postponed until after delivery.

Cardiovascular Disease

Patients with some forms of cardiovascular disease are vulnerable to physical or emotional stress that may be encountered during dental treatment, including endodontics. Patients may be confused or ill informed concerning the specifics of their particular cardiovascular problem. In these situations, consultation with the patient’s physician is mandatory before the initiation of endodontic treatment. Patients who have had a myocardial infarction (i.e., “heart attack”) within the past 6 months should not have elective dental care. This is because patients have increased susceptibility to repeat infarctions and other cardiovascular complications and may be taking medications that could potentially interact with the vasoconstrictor in the local anesthetic. In addition, vasoconstrictor should not be administered to patients with unstable angina pectoris or to patients with uncontrolled hypertension, refractory arrhythmias, recent myocardial infarctions
A patient who has a heart murmur as a result of a pathologic condition may be susceptible to an infection on or near the heart valves, which is caused by a bacteremia. This infection is called infective or bacterial endocarditis and is potentially fatal. Patients who have a history of murmur or mitral valve prolapse with regurgitation, rheumatic fever, or a congenital heart defect must be given antibiotic therapy prophylactically before endodontic therapy to minimize the risk of bacterial endocarditis. Because the American Heart Association periodically revises its recommended antibiotic prophylactic regimen for dental procedures, it is essential for the clinician to stay current concerning this important issue. A low compliance rate exists among at-risk patients regarding their use of the suggested antibiotic coverage before dental procedures. Therefore the clinician must question patients concerning their compliance with the prescribed prophylactic antibiotic coverage before endodontic therapy. If the patient has not taken the antibiotic, the procedure must be delayed.

Patients with artificial heart valves are considered highly susceptible to bacterial endocarditis. Therefore consulting this patient’s physician regarding antibiotic premedication is essential. Some physicians elect to administer parenteral antibiotics in addition to or in place of the oral regimen. The coronary artery bypass graft is a common form of cardiac surgery. Ideally, vasoconstrictors should be minimized during the first 3 months after surgery to avoid the possibility of precipitating arrhythmias. Ordinarily these patients do not require antibiotic prophylaxis after the first few months of recovery unless there are other complications. The clinician can play an important role in the detection of hypertension. The clinician may be the first to detect an elevated blood pressure. Further, patients receiving treatment for hypertension may not be controlled adequately because of poor compliance or inappropriate drug therapy. Abnormal blood pressure readings become the basis for physician referral. Few conditions exist in which there is a possibility that dental treatment could seriously injure or even result in the death of a patient. However, acute heart failure during a stressful dental procedure in a patient with significant valvular disease and heart failure or the development of infectious endocarditis represent two such life-threatening disorders. Careful evaluation of patients’ medical histories including the cardiac status of patients, the use of appropriate prophylactic antibiotics, and stress reduction strategies will minimize the risk of serious cardiac sequelae.

Cancer

Some cancers may metastasize to the jaws and mimic endodontic pathosis, whereas others can be primary lesions (Fig. 4–2). A panoramic radiograph is useful in providing an overall view of all dental structures. When a clinician begins an endodontic procedure with a well-defined apical radiolucency, it might be assumed to result from an extension of infectious agents from a nonvital pulp. Careful examination of preoperative radiographs from different angulations is important since lesions of endodontic origin would not be expected to be shifted away from the radiographic apex in the different images. If a local anesthetic is not administered and if the patient experiences pain during access or canal instrumentation, it is advisable to reconsider the original diagnosis because the radiolucency may be a lesion of nonodontogenic origin. A useful website for the differential diagnosis of radiographic lesions (ORAD II) was created by Dr. Stuart White and is available on-line at http://www.orad.org/difDiag.html. A definitive diagnosis of a periradicular osteitis can be made only after biopsy. When a discrepancy exists between the initial diagnosis and clinical findings, consultation with an endodontist is advisable. Patients undergoing chemotherapy or radiation to the head and neck may have impaired healing responses. Treatment should be initiated only after the patient’s physician has been consulted. Resolving the question of endodontic treatment or extraction for preradiation patients often requires a dialogue between the dentist and physician.
The effect of the external beam of radiation therapy on normal bone is to decrease the number of osteocytes, osteoblasts, and endothelial cells, thus decreasing blood flow. Pulps may become necrotic from this impaired condition. Toxic reactions during and after radiation and chemotherapy are directly proportional to the amount of radiation or dosage of cytotoxic drug to which the tissues are exposed. Delayed toxicities can occur several months to years after radiation therapy. The outcome of endodontic treatment should be evaluated within the framework of the toxic results of radiation and drug therapy. The cancer patient’s white blood cell (WBC) count and platelet status should also be reviewed before endodontic treatment. In general, routine dental procedures can be performed if the granulocyte count is greater than 2000/mm³ and the platelet count is greater than 50,000/mm. If urgent care is needed and the platelet count is below 50,000/mm, consultation with the patient’s oncologist is required.

**Human Immunodeficiency Virus and Acquired Immunodeficiency Syndrome**

It is important for clinicians treating acquired immunodeficiency syndrome (AIDS) patients to understand their patient’s level of immunosuppression, drug therapies, and potential for opportunistic infections. Although the effect of human immunodeficiency virus (HIV) infection on long-term prognosis of endodontic therapy is unknown, studies have shown that HIV patients do not have increased risk for postoperative pain or inflammation after endodontic treatment. The clinical team must also minimize the possibility of transmission of HIV from an infected patient, and this is accomplished by adherence to universal precautions (see [http://www.cdc.gov/ncidod/hip/BLOOD/UNIVERSA.HTM](http://www.cdc.gov/ncidod/hip/BLOOD/UNIVERSA.HTM) for details). Although saliva has not been demonstrated to have transmitted the virus in a dental situation, the potential for it to do so exists. Infected blood can transmit HIV, and during some procedures it may become mixed with saliva. Latex gloves and eye protection are essential for the clinician and staff. HIV can be transmitted by needlestick or an instrument wound, but the frequency of such transmission is low, especially with small-gauge needles.

A vital aspect of treatment planning for the patient with HIV/AIDS is determining the current CD4 lymphocyte count and level of immunosuppression. Generally patients having a CD4 count of more than 400 mm³ may receive all indicated dental treatment. Patients with a CD4 count of less than 200 mm³ will have increased.

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**Figure 4-2**  
A. Essentially normal periradicular appearance of #29 following endodontic treatment. Treatment was due to a diagnosis of irreversible pulpitis. B. Rapid periradicular breakdown of #29 and new periradicular radiolucencies associated with #30 four months after endodontic treatment of #29. The patient’s complaints now included pain isolated to #30 as well as lip and chin paresthesia. C. Nonsurgical endodontics of #30. D. Surgical postoperative radiograph of #30 and #29. Biopsy results following endodontic surgery were positive for metastatic breast cancer. (Courtesy Dr. Robert Sadowsky, Dr. Lee Adamo, and Dr. Jeffrey Burkes.)

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susceptibility to opportunistic infections and may be effectively medicated with prophylactic drugs. Medical consultation is advisable before surgical procedures and before initiating complex treatment plans.

**End-Stage Renal Disease**

Consultation with the patient’s physician is suggested before dental care is initiated for patients being treated for end-stage renal disease. Depending on the patient’s status and the presence of other diseases common to renal failure (e.g., diabetes mellitus, hypertension, systemic lupus erythematosus), dental treatment may be best provided in a hospital setting. The goal of dental care for patients being treated for end-stage renal disease is to restore and maintain the mouth to a healthy state and prevent infection.

**Dialysis**

The most recent American Heart Association guidelines do not include a recommendation for prophylactic antibiotics before invasive dental procedures for patients with intravascular access devices. However, other investigators advise that prophylactic antibiotics are prudent for hemodialysis patients with arteriovenous shunts/grafts when invasive dental procedures are performed. Although controversy exists, antibiotic prophylaxis should be provided for patients receiving hemodialysis who have known cardiac risk factors. For patients undergoing hemodialysis who do not have known cardiac risk factors, consultation with the managing physician or nephrologist is advised. When prophylaxis is used, the standard regimen of the American Heart Association is recommended. Some drugs frequently used during endodontic treatment are affected by dialysis. Drugs metabolized by the kidneys or nephrotoxic drugs should be avoided.

Both aspirin and acetaminophen are removed by dialysis and require a dosage increase in patients with renal failure. Amoxicillin and penicillin V also require a dosage adjustment following hemodialysis. It is advisable to consult the patient’s physician concerning specific drug requirements during endodontic treatment. Endodontic treatment is best scheduled on the day following dialysis, since on the day of dialysis patients are generally fatigued and could have a bleeding tendency.

**Diabetes**

The Centers for Disease Control and Prevention (CDC) reported a 6% increase in the incidence of diabetes mellitus in the United States in the year 2001. The dramatic increase has been linked to a remarkable 57% increase in obesity among Americans during the last 10 years. Twenty percent of Americans are classified as obese. It has been estimated that 15.7 million persons in the United States representing 5.9% of the population have diabetes. It is likely that diabetic patients requiring endodontic treatment will be increasingly common. Diabetes mellitus appears to have multiple causes and several mechanisms of pathophysiology. Diabetes mellitus can be thought of as a combination of diseases that share the key clinical feature of glucose intolerance. Patients with diabetes, even those who are well controlled, require special consideration during endodontic treatment. The patient with diabetes who is well controlled medically and free of serious complications, such as renal disease, hypertension, or coronary atherosclerotic disease, is a candidate for endodontic treatment. However, special considerations exist in the presence of acute infections. The non-insulin-controlled patient may require insulin, or the insulin dose of some insulin-dependent patients may have to be increased. In cases in which surgery is required, consultation with the patient’s physician is advisable to consider adjustment of the patient’s insulin and dosage, antibiotic prophylaxis, and dietary needs during the postoperative period. A source of glucose (orange juice, soda, Glucola) should be available if symptoms of an insulin reaction occur. Acute infections in the diabetic patient should be managed using the standard approach of: incision and drainage, pulpectomy, antibiotics, and warm rinses.

Appointments should be scheduled with consideration given to the patient’s normal meal and insulin schedule. The patient with diabetes who is well managed medically and is under good glycemic control without serious complications such as renal disease, hypertension, or coronary atherosclerotic heart disease can receive any indicated dental treatment. However, patients with diabetes who have serious medical complications may need a modified dental treatment plan. Moreover, recent studies suggest that diabetes is associated with a decrease in the success of endodontic treatment in cases with preoperative periradicular lesions. These patients may require referral to an endodontist for alternative treatment considerations.

**Prosthetic Implants**
Patients with prosthetic implants are frequently being treated in dental practices. The question concerning the need for antibiotic prophylaxis to prevent infection of the prosthesis has been debated for many years. A lack of scientific data has resulted in empiric recommendations to give dental patients prophylactic antibiotics. A statement was issued jointly in 1997 by the American Dental Association and the American Academy of Orthopedic Surgeons in an attempt to clarify the issue. The statement concluded that scientific evidence does not support the need for antibiotic prophylaxis for dental procedures to prevent prosthetic joint infections. It went on to state that antibiotic prophylaxis is not indicated for dental patients with pins, plates, and screws, nor is it routinely indicated for most patients with total joint replacements. However, the statement indicated that some “high risk patients” who are at increased risk for infection and undergoing dental procedures likely to cause significant bleeding should receive antibiotic prophylactic treatment. Such patients would include those who are immunocompromised or immunosuppressed, who have insulin-dependent (type I) diabetes, who are in the first 2 years following joint replacement, or who have previous joint infections, malnourishment, or hemophilia. The advisory statement concludes that the final decision on whether to provide antibiotic prophylaxis is the responsibility of the clinician who must consider potential benefits against the risk. It should be noted that endodontics has been shown to be an unlikely cause of bacteremia in contrast to extractions, periodontal surgery, scaling, and prophylaxis. Consultation with the patient’s physician on a case-by-case basis is advisable to establish the need for prophylaxis.

**Behavioral and Psychiatric Disorders**

Stress reduction is an important factor in the treatment of patients with behavioral and psychiatric disorders. Sensitivity to the patient’s needs must be part of the dental team’s approach. Significant drug interactions and side effects are associated with tricyclic antidepressants, monoamine oxidase inhibitors, and antianxiety drugs. Consultation with the patient’s physician is essential before using sedatives, hypnotics, antihistamines, and opioids.

**Psychosocial Evaluation**

The initial visit, during which medical and dental histories are gathered, provides an opportunity to consider the patient’s psychosocial status. Although some patients may want to maintain a tooth with a questionable prognosis, others may lack the necessary sophistication to comprehend the potential risks and benefits. It would be a mistake to lead patients beyond what they can appreciate, and patients should not be allowed to dictate treatment that has a poor prognosis.

The clinician should also assess the patient’s level of anxiety as an important part of preparation for the procedure to follow. It is reasonable to assume that most patients are anxious to some degree, especially when they are about to have endodontic treatment. A conversation describing the procedure and what the patient can expect is an important part of an anxiety reduction protocol. It is well documented that a high level of anxiety is a predictor of poor anesthesia and postoperative pain. More than 200 studies indicate that behavioral intervention for the highly anxious patient before treatment decreases anxiety before and after surgery, reduces postoperative pain, and accelerates recovery.

**Recent Medical Research: Dental Implications**

Patients with Hodgkin’s disease or breast cancer often receive irradiation to the chest as an element of treatment. Although the therapy often cures the malignancy, it has been implicated in causing late-onset heart disease that may influence the development of a treatment plan and subsequent treatment. Therapeutic irradiation of the chest results in the inadvertent inclusion of the heart within the irradiation field. Some patients may experience pathologic changes of the heart valves that could predispose them to endocarditis, accelerated atherosclerosis of the coronary artery that increases their risk of experiencing a fatal myocardial infarction, or both. Clinicians need to identify patients who have received irradiation to the chest and consult with patients’ physicians to determine whether therapy has damaged the heart valves or coronary arteries. Patients with irradiation-induced valvular disease may require prophylactic antibiotics when undergoing specific dental procedures that are known to cause a bacteremia and a heightened risk of developing endocarditis. Patients with radiation-induced coronary artery disease should be administered only limited amounts of local anesthetic agents containing a vasoconstrictor; they may require the administration of sedative agents and cardiac medications to preclude ischemic episodes. Consultation with the patient’s physician is an appropriate response to a history that includes prior radiation to the chest.

There is a widespread belief among dentists and physicians that oral anticoagulation therapy in which patients...
receive drugs such as warfarin sodium (Coumadin) must be discontinued before dental treatment to prevent serious hemorrhagic complications, especially during and after surgical procedures. Aspirin is a commonly used drug as an anticoagulant on a daily basis without the supervision of a physician. Clinical studies published within the past 5 years do not support the routine withdrawal of anticoagulant therapy before dental treatment for patients who are taking such medications.[26] When patients report that they are receiving an anticoagulant medication, dentists and patients can benefit from using the following guidelines:

- Identify the reason the patient is receiving anticoagulant therapy.
- Assess the potential risk versus benefit of altering the drug’s regimen.
- Know the laboratory tests used to assess anticoagulation levels.
- Be familiar with local methods of obtaining hemostasis both intraoperatively and postoperatively.
- Be familiar with the potential complications associated with prolonged or uncontrolled bleeding.
- Consult the patient’s physician to discuss the proposed dental treatment and determine the need to alter the anticoagulant regimen.
DENTAL EVALUATION

The strategic value of the tooth in question should be considered before presenting alternative treatment plans to the patient. Although a final decision may be straightforward, the consideration of alternative treatment options can also be challenging as the clinician considers multiple factors that will play a role in determining the ultimate success or failure of a case. Referral of the patient to a specialist should be considered when the complexity of the procedure is beyond the ability of the clinician. Factors that affect endodontic prognosis, including periodontal and restorative, must be considered (see Chapter 2 for additional information). The alternative of a dental implant offers another choice when the endodontic prognosis is poor.

Case Selection: Endodontics or a Dental Implant

Prognosis of Endodontic Treatment

The prognosis of endodontic therapy has been extensively studied. The study designs are marked by their diversity and vary in their case selection, numbers of subjects, operative techniques, follow-up periods, definitions of success, and who provided the treatment. Many studies have demonstrated that the success rate is significantly influenced by a preexisting periradicular radiographic lesion.[5] Teeth with a preexisting apical radiolucency have been shown to have a lower success rate than teeth without such lesions. In a classic study, Strindberg[54] found that remineralization of periapical lesions could take up to 9 years after treatment. More recently, Sjogren and associates[52] noted that uncertainty exists concerning the influence of the size of the preoperative periapical lesion on clinical success. Results of studies with short follow-up periods may be skewed and not reflect the true prognosis. Cohort studies of 3 or 4 years may be required to record a stable treatment outcome.[9][28][38]

The objective of a recent study, established in 1993, is to prospectively assess the 4- to 6-year outcome of endodontic treatment performed in a university graduate clinic environment.[21] The project is designed to provide cumulative data with the completion of each phase that will be used to determine the influence of potential prognostic factors on the outcome of treatment. The initial phase of the project studied 450 teeth. The “healed” rate was significantly higher for teeth treated without apical periodontitis (92%) than with apical periodontitis (74%). The overall “healed” rate was 81%. This study confirmed apical periodontitis as the main prognostic factor in initial treatment cases. The patient’s systemic resistance and the quality of instrumentation, obturation, and final restoration also play an important role in the ultimate outcome of endodontic treatment (Fig. 4–3).[5] The scope of modern endodontics has been enhanced by the use of ultrasonics and microscopy as well as improved instruments and new materials. Teeth can be retained today that would not have been treated in the past. Biologically, it has become increasingly clear that elimination of intraradicular infection is the key to endodontic success.
An important advantage of providing endodontic therapy is to allow rapid return of the patient’s compromised dentition to full function and aesthetics. This rapid return is in marked contrast to the use of provisional restorations associated with dental implants while waiting for osseous integration.

Dental Implants

The advent of dental implants as a predictable alternative provides the clinician with new treatment options. Although research on the long-term efficacy and success of dental implants is ongoing, it seems clear that when appropriately utilized they offer a valuable alternative when preservation of the natural dentition is not possible. Currently, perspective randomized clinical trails are lacking that compare tooth retention with endodontic treatment with replacement of a tooth with an implant. Such a study would have to recognize, among a long list of variables, patients’ systemic health, periodontal status, restorative treatment, type of implant used, and pretreatment status of the endodontically treated tooth.

Patients benefit when clinicians consider the entire range of treatment options. The options considered should be based on sound biologic principles and individually selected on a case-by-case basis.

Periodontal Considerations

Extensive periodontal lesions frequently complicate the endodontic procedure being considered. Such lesions may necessitate consultation with an endodontist or periodontist or both to gather more information about the tooth’s prognosis. Periodontal probing is an essential element in endodontic case selection. Multirooted teeth with periodontal complications offer a variety of multidisciplinary complexities and treatment possibilities. A tooth with a poor periodontal prognosis may have to be sacrificed, despite the probability of a favorable endodontic prognosis. In some situations it may not be clear if the primary problem is periodontal or endodontic. This fact can influence the treatment plan; the pathogenesis can be better understood after vitality testing, periodontal probing, radiographic assessment, and evaluating the dental history. The risk to the total
treatment plan should be kept in mind when questionable procedures are considered. It is not prudent to incorporate a chronic problem into a new complex prosthesis (Figs. 4-4 and 4-5).

**Figure 4-4** Tooth #19 has a poor prognosis. Periodontal probing reached the apex of the distal root. Extraction is indicated and should be done as soon as possible to prevent further damage to the mesial bone associated with tooth #18. There are restorative questions concerning the ultimate treatment plan: Should the mesial root of tooth #19 be retained? Should tooth #20 be used as an abutment? Should an implant be placed? (Courtesy Dr. Brian Lican.)
Surgical Considerations

Surgical evaluations are particularly valuable in the diagnosis of lesions that may be nonodontogenic. Biopsy is the only definitive means of diagnosing such a lesion. When retreatment is being considered, the clinician must determine if nonsurgical, surgical, or combined treatment is appropriate. This decision is influenced by the presence of complex restorations, posts, and the radiographic assessment of prior endodontic therapy.

Restorative Considerations

A satisfactory restoration may be jeopardized by a number of factors. Subosseous root caries (perhaps requiring crown lengthening), poor crown/root ratio, and extensive periodontal defects or misalignment of teeth may have serious effects on the final restoration. Therefore these problems must be recognized before endodontic treatment is initiated. For nonemergency complicated cases, a restorative treatment plan should be in place before starting endodontic treatment. Some teeth may be endodontically treatable but nonrestorable, or they may represent a potential restorative complication in a large prosthesis. Further, reduced coronal tooth structure under a full-coverage restoration makes endodontic access more difficult because of reduced visibility and lack of radiographic information about the anatomy of the chamber (see also Chapter 7). Thus it is not unusual for restorations to be compromised during endodontic access (Fig. 4–6). Whenever possible, restorations should be removed before endodontic treatment.

Other Factors That May Influence Endodontic Case Selection

A variety of factors may complicate proposed endodontic therapy. Calcifications, dilacerations, and resorptive defects may compromise endodontic treatment of a tooth with potentially strategic value (Fig. 4–7). The inability to isolate a tooth is also a problem and may result in bacterial contamination of the root canal system. Extra roots and canals pose a particular anatomic challenge that radiographs do not always reveal (Fig. 4–8). Retreatment cases offer particular mechanical challenges (Fig. 4–9) and are discussed in detail in Chapter 25. Ledges, perforations, or a post may be present, all of which complicate treatment and alter the prognosis. The dentist should recognize these potential problems and be able to manage and factor them into the decision concerning the tooth’s prognosis, including the possibility that the patient should be referred to a specialist. An approach has been suggested that permits a clinician to evaluate each patient to determine the level of anticipated difficulty and helps the generalist to identify which cases should be referred for specialty care.[46]
Figure 4-7  Resorptive defects can be successfully treated. Early intervention, before there is perforation of the root, increases the chance of success. (Courtesy Dr. Leon Schertzer.)

Figure 4-8  Radiographs do not always demonstrate canal complexities. A, Initial radiograph. B, Highly magnified view of the pulp chamber. C, Completed endodontic treatment. (Courtesy Dr. Lee Adamo.)
Some clinicians use a simple formula for determining which endodontic cases they treat and which they refer to a specialist. The number of roots may be the determining factor in a decision concerning referral, or the key factor may be the chronic or acute status of the case. Having specific goals at each visit helps to organize the treatment. For example, in an uncomplicated molar or premolar, some clinicians will set a specific goal for the first visit that includes access and thorough instrumentation, while deferring the obturation to a second visit. Uncomplicated single-rooted, vital teeth may be planned for a single-visit approach. It is important that ample time be allowed so that the procedure can be completed without stress. These recommendations have a biologic basis. It is not biologically sound to partially instrument root canal systems, thereby leaving residual inflamed pulpal remnants or necrotic debris in the canal, since such remnants may cause pain and be susceptible to infection. The clinician would be well advised to begin canal instrumentation only if time permits for the extirpation of all pulp tissue.

The most important variables in determining whether to refer a patient to a specialist are the skills of the clinician and the complexity of the case.

Recently the American Association of Endodontists (AAE) developed guidelines for assessing endodontic case difficulty. The AAE Endodontic Case Difficulty Assessment Form enables a clinician to assign a level of difficulty to a particular case. The form describes cases of minimum, moderate, and high degrees of difficulty. This form lists criteria that can be used to identify when a clinician should refer a patient to a specialist (see Fig. 2–6). The use of surgical operating microscopes, endoscopes, and ultrasonics enable the specialist to predictably treat teeth that would not have been treatable before.
DEVELOPMENT OF THE ENDODONTIC TREATMENT PLAN

Vital Case

The acute vital case is best managed using a biologically based approach. Pain in such cases may be due to increased intrapulpal pressure and inflammatory mediators such as prostaglandins. The challenge for the clinician is to painlessly treat inflamed and well-innervated tissue. Performing a complete pulpotomy or, if time permits, establishing measurement control and completing a pulpectomy have a high degree of predictability in alleviating pain. It has been shown that simply debriding the pulp chamber is also a highly predictable method of providing pain relief. When a canal has been entered the clinician is committed to removing all tissue. Partial instrumentation (i.e., leaving tissue remnants in the canal) may result in increased postoperative pain. Teeth should be closed with a temporary filling at the conclusion of the visit.

Nonvital Case

The acute nonvital case represents a microbiologic challenge for the clinician. A tooth that has had a nonvital pulp for some time may suddenly become acutely painful (see Chapter 2 for managing these emergency cases). The cause of this dramatic change is due to an imbalance in the host-parasite relationship. These changes can be due to an increase in the virulence of bacteria, a change in the flora, or a reduced host defense mechanism. These changes can be initiated simply by opening the tooth and changing the environment of the bacterial flora. The therapeutic goals in such cases are to reduce as much as possible the bacterial content in the root canal system and to promote decompression of the periradicular tissues by instrumentation and irrigation of the canal. Calcium hydroxide should be temporarily sealed into the root canal or canals with a cotton pellet in the pulp chamber. Teeth should be closed and the endodontic treatment completed as soon as possible to prevent continued bacterial penetration into the canal. When a fluctuant swelling exists, incision and drainage may be performed in conjunction with canal instrumentation (Fig. 4-10).

Retreatment Cases

Retreatment cases offer a particular set of challenges to the clinician, and this topic is covered extensively in Chapter 25. Leading questions to be considered before retreatment include the following:

Figure 4-10 Incision and drainage should be performed on this fluctuant swelling (arrow) in conjunction with canal instrumentation.
A retreatment plan should be developed after the clinician has determined the cause of failure and weighed other factors that may affect the prognosis (e.g., root fracture, defective restoration) (Figs. 4–11, 4–12, 4–13, 4–14). Retreatment cases may require surgical endodontics in combination with nonsurgical retreatment. Referral to a specialist is often helpful when planning treatment for complex cases.

- Why did the case fail?
- Are prior radiographs available for review?
- Is there an obvious procedural problem that can be corrected?
- Is the canal system readily accessible for reentry?
- Are there additional factors (other than endodontic) that may have contributed to the failure?
- Is the tooth critical to the treatment plan?
- Does the patient understand the prognosis for the tooth and want to attempt retreatment?

Figure 4-11 Two years after endodontic therapy on tooth #8, the patient returned with pain and swelling. A dentist mistakenly began endodontic access on tooth #7, without confirming the apparent radiographic diagnosis with vitality testing. Tooth #7 was vital, and tooth #8 was successfully retreated after removal of the post. (Courtesy Dr. Leon Schertzer.)
Many years after endodontic treatment of tooth #30, the patient returned with a chief complaint of pain and an inability to chew on the tooth. Despite the radiographic appearance of excellent endodontic treatment, the tooth was retreated and the patient’s pain disappeared. Note the unusual distal root anatomy, which was not apparent during the initial procedure. A. Initial radiograph. B. Completion of initial endodontic therapy. C. Retreatment.

Retreatment of tooth #26 resulted in healing of the periradicular lesion. The initial radiograph was misleading and implicated tooth #25 and tooth #26. Pulp testing indicated a vital pulp in tooth #25, so it was not treated. (Courtesy Dr. Leon Schertzer.)
Immature Teeth

Primary and immature permanent teeth may have pulpal pathosis caused by caries or trauma; preserving these young teeth is essential. Premature loss of an anterior tooth can lead to malocclusion, predispose the patient to tongue habits, impair aesthetics, and damage the self-esteem of the patient. The reader is referred to Chapter 22 for further information.

Endodontic and Periodontic Considerations

The relationship between the pulpal and the periodontal tissue complex begins during the embryonic stage of dental development. The richly vascularized dental papillae and the surrounding, future periodontal tissues have a shared circulation. This interrelationship provides the anatomic basis for potential pathosis as described in Chapter 17.

Endodontic Surgery

Endodontic surgery may be performed as an initial treatment or as a retreatment procedure. Before considering the actual treatment, the clinician should consider the most prudent measure to prevent recurrence of the problem. For example, if the cause of failure is a leaking coronal restoration, then apical surgery will probably fail. As a primary treatment modality, apical surgery may be performed when there is a completely calcified canal. As a retreatment procedure, apical surgery is performed as a secondary effort to salvage failed endodontic treatment. The primary reason for apical surgery is to improve the quality of the apical seal. In recent years dramatic changes have occurred in the techniques and materials used for surgical resolution of complex cases as discussed in Chapter 20.

Figure 4-14 Nonsurgical retreatment of tooth #30. Note additional root located and treated. A, Note inadequate endodontic treatment and large periapical lesion. B, Bite wing radiograph. C, Retreatment after post removal. D, Eighteen-month recall radiograph indicates periapical healing.
Single-Visit Versus Multivisit Treatment

Debate is ongoing about the merits of a single-visit or multivisit approach to endodontic treatment. An extensive body of research has sought to determine relative success rates, pain associated with each approach, and its relationship to pulp vitality and the presence of periapical osteitis. [15][24][41][44]

Vital Cases

Vital cases are often suitable for single-visit treatment. The number of roots, time available, and the clinician’s skills are factors to be considered. Severity of the patient’s symptoms is another important consideration. For example, a patient in severe pain should not experience a long visit including access, instrumentation, and obturation. Treatment in such cases may be directed at alleviating pain, with filling of the canal postponed for a later visit. The clinician’s judgment of what the patient can comfortably tolerate (regarding duration of the visit) is on a case-by-case basis. Whenever possible, it is desirable to complete endodontic treatment for vital teeth in one visit for several reasons, including less posttreatment pain. [15][24][41][44]

Nonvital Cases

Although consensus exists that teeth with nonvital pulp and apical periodontitis are more complex cases with greater resistance to endodontic treatment (i.e., reduced success rate), agreement is lacking concerning the appropriateness of single-visit endodontics for treating these cases. Some have postulated that the intervisit use of an antimicrobial dressing is essential in eradicating infection completely from the root canal system. [51][52] In contrast, other researchers have found no statistically significant difference in success when using the single-visit or multivisit approach to the nonvital tooth with apical periodontitis. [20][42][57] The final answer is yet to be determined.

Research Review

Agreement is lacking concerning long-term success rates associated with single-visit and multivisit procedures. Sjogren and associates [51] investigated the influence of infection at the time of root filling on the outcome of endodontic treatment of teeth with apical periodontitis. Periapical healing was observed for 5 years. They concluded that “Complete periapical healing occurred in 94% of cases that yielded a negative culture. When the samples were positive before root filling, the success rate of treatment was just 68%—a statistically significant difference.” They concluded that the objective of eliminating bacteria from the root canal system “cannot be reliably achieved in a one-visit treatment because it is not possible to eradicate all infection from the root canal without the support of an interappointment antimicrobial dressing.” The findings of Friedman, [20] Weiger et al, [57] and Peters and Wesselink [42] contrast with those of Sjogren et al. [51] Those studies found no statistically significant differences in healing observed between teeth treated in one visit and two visits with the inclusion of calcium hydroxide as an intravisit medication. [42][57] This is a complicated issue since the inability to detect differences between groups might also be due to sample size, duration of follow-up times, treatment methods, and so on.

A recent study concerning the outcome of initial treatment noted the complexity of treating apical periodontitis. The author commented that “…treatment of this disease cannot be improved merely by changing treatment techniques. Because apical periodontitis results from interactions between microorganisms, their environment and the host immune system, only use of effective modifiers of any of these three factors might significantly improve the outcome of treatment.” [20]

Scheduling Considerations

If a vital case must be treated using a multivisit approach, it is the author’s opinion that the clinician should allow 5 to 7 days between canal instrumentation and obturation for the periradicular tissue to recover. When a vital case is to be treated in a single visit (usually the preferred treatment plan), adequate time must be scheduled so the clinician can complete the procedure without stress. It is wise to schedule patients who require mandibular block anesthesia to arrive 15 to 20 minutes before their treatment visit. This avoids the frustration of “losing treatment time” while the anesthetic agent becomes fully effective.

Subsequent appointments for treating nonvital cases should be scheduled with approximately 1 week between visits in order to maximize the antimicrobial effect of the intracanal dressing when calcium hydroxide
Acute (painful) nonvital cases must be seen every 24 to 48 hours in order to monitor the patient’s progress and bring the acute symptoms under control. Further cleaning and shaping are important components of the treatment as the clinician seeks to eliminate persistent microbes in the canal system. Long delays between visits contribute to the development of resistant microbial strains and should be avoided.
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Chapter 5  - Preparation for Treatment

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Before nonsurgical root canal treatment can begin, a number of issues related to treatment considerations along with clinician and patient needs must be addressed. These include proper infection control and occupational safety procedures for the entire health care team and treatment environment; appropriate communication with the patient, including case presentation and informed consent; premedication, if necessary, followed by effective administration of local anesthesia; a quality radiographic or digital-image survey; and thorough isolation of the treatment site.

PREPARATION OF THE OPERATORY

Infection Control

Because all dental health care personnel (DHCP), including those not directly involved in patient care, are at risk for exposure to a host of infectious organisms (e.g., influenza; upper respiratory disease; tuberculosis (TB); herpes; hepatitis B, C, D; acquired immunodeficiency syndrome (AIDS)), effective infection control procedures must be used to minimize the risk of cross contamination in the work environment. These infection control procedures must not only protect patients and the dental team from contracting infections during dental procedures, but also reduce the number of microorganisms in the immediate dental environment to the lowest level possible.

As the AIDS epidemic continues to expand, it has been established that the potential for occupational transmission of human immunodeficiency virus (HIV) and other fluid-borne pathogens can be minimized by enforcing infection control policies specifically designed to reduce exposure to blood and other infected body fluids. Because HIV has been shown to be fragile and easily destroyed by heat or chemical disinfectants, the highly resistant nature of the hepatitis B virus, along with its high blood titer, makes it a good model to evaluate infection control practices in order to prevent transmission of a large number of other pathogens via blood or saliva. Because all infected patients are not readily identifiable through the routine medical history and many are asymptomatic, the American Dental Association (ADA) recommends that each patient be considered potentially infectious; this means that the same strict infection control policies or universal precautions apply to all patients. In addition, the Occupational Safety and Health Administration (OSHA) of the U.S. Department of Labor, in conjunction with both the ADA and the Centers for Disease Control and Prevention (CDC), has issued detailed guidelines on hazard and safety control in the dental setting. In 1992, laws specifically regulating exposure to blood-borne disease became effective through OSHA’s Occupational Exposure to Bloodborne Pathogens Standard. Primarily designed to protect any employee who could be “reasonably anticipated” to have contact with blood or any other potentially infectious materials, the standard encompasses a combination of engineering and work practice controls, as well as recommendations for the use of equipment and protective clothing, training, signs and labels, and hepatitis B vaccinations. It also authorizes OSHA to conduct inspections and impose financial penalties for failure to comply with specific regulations.

In 1993 the ADA, CDC, and OSHA recommended or mandated specific infection control guidelines for dental practice. In 2003, the CDC updated these guidelines to help further reduce the potential for disease transmission from patient to DHCP, from DHCP to patient, and from patient to patient. The document now emphasizes the use of standard precautions rather than universal precautions for the prevention of exposure to and transmission of not only blood-borne pathogens but also other pathogens encountered in oral health settings.

The major recommendations including updates are as follows:

1. The ADA and CDC recommend that all DHCP with potential occupational exposure to blood or other potentially infectious material be vaccinated against hepatitis B. The OSHA standard requires that employers make the hepatitis B vaccine available to occupationally exposed employees, at the employer’s expense, within 10 working days of assignment to tasks that may result in exposure. An employee who refuses the vaccine must sign a declination form that uses specific language approved by OSHA. In addition, postexposure follow-up and evaluation must be made available to all employees who have been exposed.
employees who have had an exposure incident. In addition, all DHCP must be educated about tuberculosis; baseline tuberculin skin tests (TST) must be done for all DHCP who might have contact with persons suspected or confirmed to have active TB. [14]

2. A thorough patient medical history, which includes specific questions about hepatitis, AIDS, current illnesses, unintentional weight loss, lymphadenopathy, and oral soft-tissue lesions, must be taken and updated at subsequent appointments. All patients should be screened for latex allergies, and they should be referred if an allergy is suspected. [14]

3. Dental personnel must wear protective attire and use proper barrier techniques. The standard requires the employer to ensure that employees use personal protective equipment (PPE) and that such protection is provided at no cost to the employee.

a. Disposable latex or vinyl gloves must be worn when contact with body fluids or mucous membranes is anticipated or when touching potentially contaminated surfaces; they may not be washed for reuse. OSHA requires that gloves be replaced after each patient contact, when torn, or when punctured. If their integrity is not compromised, sturdy, unlined utility gloves for cleaning instruments and surfaces may be decontaminated for reuse. Polyethylene gloves may be worn over treatment gloves to prevent contamination of objects, such as drawers, light handles, or charts.

b. Hands, wrists, and lower forearms must be washed with either a nonantimicrobial soap or antimicrobial soap and water when hands are visibly soiled, after bare-handed touching of inanimate objects likely to be contaminated, before and after treating each patient, before donning gloves, and immediately after removing gloves. [14] An antimicrobial surgical hand scrub should be used for surgical procedures before donning sterile gloves. The standard requires that any body area that has contact with a potentially infectious material, including saliva, must be washed immediately after contact. It is strongly recommended that hand lotions that do not affect glove integrity be used to prevent dryness associated with handwashing. [14] Sinks should have electronic, elbow-, foot-, or knee-action faucet controls for asepsis and ease of function. Employers must provide washing facilities (including an eye wash) that are readily accessible to employees.

c. Masks and protective eyewear with solid side shields or chin-length face shields are required when splashes or sprays of potentially infectious materials are anticipated and during all instrument and environmental cleanup activities. When a face mask is removed, it should be handled by the elastic or cloth strings, not by the mask itself. It is further suggested that the patient wear protective eyewear.

d. Protective clothing, either reusable or disposable, must be worn when clothing or skin is likely to be exposed to body fluids, and it should be changed when visibly soiled or penetrated by fluids. OSHA’s requirements for protective clothing (i.e., gowns, aprons, lab coats, clinic jackets) are difficult to interpret, because the “type and characteristics [thereof] will depend upon the task and degree of exposure anticipated.” The ADA and CDC recommend long-sleeved uniforms. However, according to OSHA, long sleeves are required only if significant splashing of blood or body fluids to the arms or forearms is expected. Thus endodontic surgery would likely warrant long-sleeved garments. OSHA requires that the protective garments not be worn outside the work area. The standard prohibits employees from taking contaminated laundry home to be washed; it must be washed at the office or by an outside laundry service. Contaminated laundry must be placed in an impervious laundry bag that is colored red and labeled “BIOHAZARD.” Although OSHA does not regulate nonprotective clothing (e.g., scrubs), such clothing should be handled like protective clothing once fluids have penetrated it.

e. Patients’ clothing should be protected from splatter and caustic materials, such as sodium hypochlorite, with waist-length plastic coverings overlaid with disposable patient bibs.

f. High-volume evacuation greatly reduces the number of bacteria in dental aerosols and should be employed when using the high-speed handpiece, water spray, or ultrasonics.

g. Use of the dental dam as a protective barrier is mandatory for nonsurgical root canal treatment, and failure to use this barrier is considered to be below standard care. [15 [16] [18] [19]

4. OSHA regulates only contaminated sharps. Contaminated disposable sharps (e.g., syringes, needles, scalpels) and contaminated reusable sharps (e.g., endodontic files) must be placed into separate, leak-proof, closable, puncture-resistant containers. These containers should be colored red or labeled “BIOHAZARD,” and they should be marked with the biohazard symbol. The standard states that before decontamination (i.e., sterilization), contaminated reusable sharps must not be stored or processed in a way that requires employees to use their hands to reach into the containers to retrieve the instruments. The OSHA ruling allows picking up sharp instruments by hand only after
they are decontaminated.  

a. The clinician should take the following steps when handling contaminated endodontic files:

With tweezers, place used files in glass beaker containing a nonphenolic disinfectant and detergent holding solution. At the end of the day, discard solution and rinse with tap water. Add ultrasonic cleaning solution, and place beaker in ultrasonic bath until thoroughly clean (i.e., 5 to 15 minutes). Discard ultrasonic solution, and rinse with tap water. Pour contents of beaker onto clean towel, and use tweezers to place clean files into metal box for sterilization. Files with any visible debris should be separately sterilized. Once sterilized, these files can be picked up by hand and debrided using 2 × 2 inch sponges. Once cleaned, files should be returned to metal box for sterilization. (As indicated in Chapter 9, all files should be regarded as disposable.)

b. Generally the standard prohibits bending or recapping of anesthesia needles. However, during endodontic treatment, reinjection of the same patient is often necessary, so recapping is essential. Recapping with a one-handed scoop method and using a mechanical device are the only permissible techniques; needles must not be recapped by using both hands or directing the needle point toward any part of the body. Shearing or breaking of contaminated needles should never be permitted.

5. Countertops and operatory surfaces, such as light handles, radiograph unit heads, chair switches, and any other surface likely to become contaminated with potentially infectious materials, can be either covered or disinfected. Protective coverings (e.g., clear plastic wrap, special plastic sleeves, aluminum foil) can be used. These coverings should be changed between patients and when they become contaminated. OSHA mandates, however, that work surfaces be decontaminated or recovered or both at the end of each work shift and immediately after overt contamination. The coverings should be removed by gloved personnel, discarded, and then replaced with clean coverings after gloves are removed. Alternatively, countertops and operatory surfaces can be wiped with absorbent toweling to remove extraneous organic material and then sprayed with an Environmental Protection Agency (EPA)–registered and ADA-accepted tuberculocidal disinfectant (e.g., 1:10 dilution of sodium hypochlorite, iodophor, synthetic phenol). With the advent of endodontic microscopy, appropriate barriers should be placed on the handles and controls of the microscope, or the entire unit can be draped to prevent cross contamination. If the system becomes contaminated, disinfection should be performed according to the microscope manufacturer’s guidelines.

6. Contaminated radiographic film packets must be handled in a way that prevents cross contamination. Contamination of the film (when it is removed from the packet) and subsequent contamination of the processing equipment can be prevented either by properly handling the film as it is removed from the contaminated packet or by preventing the contamination of the packet during use. After exposure, “overgloves” should be placed over contaminated gloves to prevent cross contamination of processing equipment or darkroom surfaces. For darkroom procedures, films should be carefully manipulated out of their holders and dropped onto a disinfected surface or into a clean cup without being touched. Once the film has been removed, gloves should be removed and discarded; the film can then be processed. All contaminated film envelopes must be accumulated (after film removal) in a strategically positioned impervious bag and disposed of properly. For daylight loaders, exposed film packets should be placed into a paper cup; gloves should be discarded and hands washed. Next, a new pair of gloves should be donned, and the paper cup with films and an empty cup should be placed into the chamber. Using gloved hands, the chamber should be entered and packets should be carefully opened, allowing the film to drop onto a clean surface in the chamber. Empty film packets should then be placed into an empty cup and gloves removed and discarded in the cup; films can then be processed. Plastic envelopes, such as the ClinAsept Barriers (Eastman Kodak, Rochester, NY), have simplified the handling of contaminated, exposed films by protecting films from contact with saliva and blood during exposure. Once a film is exposed, the barrier envelope is easily opened and the film can be dropped into a paper cup or onto a clean area before processing. The barrier-protected film, however, should be wiped with an EPA-approved disinfectant as an added precaution against contamination during opening. For digital radiography sensors, U.S. Food and Drug Administration (FDA)–cleared barriers should be used.

7. In conjunction with the previously mentioned guidelines for infection control, a mouth rinse of 0.12% chlorhexidine gluconate, such as Peridex (Procter & Gamble, Cincinnati), is suggested before treatment. This rinse will minimize the number of microbes in the mouth and, consequently, in any splatter or aerosols generated during treatment. It should be noted, however, that such mouth rinses have not proved to reduce the incidence of clinical infections.

8. After treatment, all instruments and burs must be cleaned and sterilized by sterilizers monitored with biologic indicators. Cassettes, packs, or trays should be rewrapped in original wrap, and individually
packaged instruments should be placed in a covered container. Air and water syringes must be flushed, cleaned, and sterilized. Antiretraction valves (i.e., one-way flow check valves) should be installed to prevent fluid aspiration and to reduce the risk of transfer of potentially infective material. Heavy-duty rubber gloves must be worn during clean-up. The ADA and CDC recommend that all dental handpieces and “prophy” angles be heat sterilized between patients. Before sterilization, all handpieces should be wiped with an EPA-registered disinfectant. In addition, high-speed handpieces should be run for a minimum of 30 seconds to discharge water and air, with spray directed into a high-volume evacuation system. Dental unit water lines should be periodically flushed with water or a 1:10 dilution of 5.25% sodium hypochlorite (NaOCl) to reduce biofilm formation. All regulated infectious waste must be immediately disposed of in containers that meet specific criteria. Disposal must be in accordance with applicable federal, state, and local regulations.

In 1994 the CDC issued its position statement on the prevention of transmission of TB in dental settings. The CDC also stated that emergency care for a patient with TB should only be provided in facilities with appropriate respirators, negative-pressure treatment areas, and other respiratory engineering controls. Compliance with OSHA regulations and with evolving infection control policies of the ADA and CDC will help provide a safer workplace for the entire dental treatment team.

In 1997 the infection control decision-making process was transferred to the U.S. government through OSHA. The goal of OSHA is to establish a routine and practical program of enforcing infection control standards (based on published CDC guidelines) to ensure the health and safety of all members of the dental health team. According to OSHA, clinicians must classify personnel and tasks in the dental practice according to levels of risk of exposure and must establish “standard operating procedures” to protect the patient and staff from infection transmission. OSHA requires the clinician to provide infection control training for all employees and to maintain records of such training; all hazardous substances that employees are exposed to on the job must be properly labeled; and a written hazard communications program with manufacturers’ material safety data sheets (MSDSs) is needed for all hazardous substances. With the enactment of OSHA’s Bloodborne Pathogens Standard in 1992, employers must make exposure determinations and develop an exposure control plan. As mentioned previously, the rule encompasses a number of critical areas (e.g., universal precautions, engineering and work practice controls, employee training, specific record keeping) designed to protect employees from exposure to blood-borne pathogens, particularly the HIV and the hepatitis B virus. Although the OSHA standard was written principally to protect employees, it does not encompass all the infection control practices recommended by the ADA and CDC to protect clinicians and patients.

**Health Insurance Portability and Accountability Act**

The Health Insurance Portability and Accountability Act (HIPAA) was passed into law on August 21, 1996; the original purpose of this law was to make health care insurance “portable” so that an individual’s insurance could be passed from one employer to another employer. Because of additions to help fight fraud and abuse, ensure the security of medical records, protect the privacy of a patient’s confidential health information, and a worthwhile goal to replace paper transactions with electronic transactions, the HIPAA standard has become one of the most widespread and complicated regulations ever passed. On April 14, 2003, HIPAA launched a whole new era of medical/dental care since it is now the responsibility of the dentist-employer to make sure employees conduct themselves in a manner that supports the provisions of the standard. Two of the rules under HIPAA that affect clinicians are the Transactions Rule and the Privacy Rule. For the purposes of this chapter, only the Privacy Rule will be discussed (see Chapter 11 for other information on HIPAA).

The Privacy Rule controls what is called protected health information (PHI). PHI is individually identifiable health information that is held or released by a practice regardless of how it is communicated (oral, paper, or electronic). The entire Privacy Rule was created to ensure that a patient’s PHI is not used or disclosed to those individuals or parties who do not need to know such information. In general, the Privacy Rule requires dental practices to take reasonable steps to limit use of disclosure of PHI to the minimum necessary to achieve an intended purpose. This rule does not apply to uses or disclosures made to the patient, another provider (for treatment purposes), or governmental authorities.

The clinician must employ or appoint a privacy officer to help bring the office into compliance. The privacy officer oversees all ongoing activities related to maintaining the privacy of PHI consistent with state law. It is the officer’s duty to report to the dentist-employer the status of the office’s compliance efforts and to...
develop appropriate documents such as patient request forms, acknowledgement forms, and patient authorization forms. When such documents are ready for disposal, it is the privacy officer’s responsibility to see that documents containing PHI are shredded or deidentified. The Notice of Privacy Practices is a kind of “reverse” informed consent for the patient. Any dentist who has a direct-treatment relationship with an individual has to provide that individual with a Notice of Privacy Practices. Further, the dental practice must provide a copy of the current notice to anyone who asks for it (whether a patient or not). The notice must explain how PHI may be used or disclosed by the practice, the patient’s privacy rights as to PHI, and the practice’s obligations as to PHI. The final Privacy Rule only requires the dentist who has a direct-treatment relationship with a patient to make a “good faith” effort to obtain a patient’s written “acknowledgement” that he or she has received the Notice of Privacy Practices. The patient cannot be “made” to sign such a statement. In addition, the patient can file a complaint against the practice for alleged violations of privacy policies. Thus, under HIPAA, the patient has the following rights: the right to receive a copy of the practice’s Notice of Privacy Practices, the right to request a restriction on uses and disclosures, the right to request receipt of confidential communications by alternative means or at alternative locations, the right to request access to inspect and copy the dental record, the right to request an amendment to the dental record, and the right to request an accounting of disclosures. With the exception of the first right, these rights are all followed by the phrase “to request.” The practice does not have to grant all requests; as with any law, there are exceptions to the rules. However, if the clinician agrees to a request, any violation of the request is a violation of the privacy regulations.

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PATIENT PREPARATION

Treatment Planning

Aside from emergencies that require immediate attention, endodontic treatment usually occurs early in the total treatment plan for the patient. Therefore any asymptomatic but irreversible pulpal and periradicular problems are managed before they become symptomatic and more difficult to handle. The most important rationale for the high priority of endodontics is to ensure that a sound, healthy foundation exists before further treatment is attempted. A stable root system within sound periradicular and periodontal tissues is paramount to the placement of any definitive restorations.

Regardless of the specifics of the case, the clinician is responsible for explaining the nature of the treatment and informing the patient of any risks, the prognosis, and other pertinent facts. Because of bad publicity and hearsay, root canal treatment is reputed to be a horrifying experience. Consequently, some patients may be reluctant, anxious, or even fearful of undergoing root canal treatment. Thus it is imperative that the clinician educate the patient before treatment (i.e., “informing before performing”) to allay concerns and minimize misconceptions.

Good clinician and patient relationships are built on effective communication. Sufficient evidence suggests that clinicians who establish warm, caring relationships with their patients through effective case presentation are perceived more favorably. These clinicians also have a more positive impact on the patient’s anxiety, knowledge, and compliance than those who maintain impersonal, noncommunicative relationships. Most patients experience increased anxiety while in the dental chair. However, a simple but informative case presentation that answers all questions reduces patient anxiety and solidifies the patient’s trust in the clinician.

Case Presentation

The ADA and the American Association of Endodontists (AAE) publish brochures (e.g., Endodontics: Your Guide to Endodontic Treatment) to help patients understand root canal treatment. Valuable educational aids of this nature should be made available to the patient either before or immediately after case presentation. This supportive information addresses the most frequently asked questions concerning endodontic treatment. The following section reviews these questions. Accompanying each question is an example of an explanation that patients should be able to understand. In addition, the clinician will find it useful to have a set of illustrations or drawings to help explain the procedure. The AAE offers specialized case presentation forms with carbonless copies for record keeping and patient use.

What Is Endodontic (Root Canal) Treatment?

Endodontics is the specialty in dentistry concerned with the prevention, diagnosis, and treatment of diseases or injuries to the dental pulp. The pulp, which some people call “the nerve,” is the soft tissue inside the tooth that contains the nerves and blood vessels and is responsible for tooth development. Root canal treatment is a safe and effective means of saving teeth that otherwise would be lost.

What Causes the Pulp to Die or Become Diseased?

When a pulp is injured or diseased and unable to repair itself, it becomes inflamed and eventually dies. The most frequent causes of pulp death are extensive decay, deep fillings, trauma (e.g., severe blow to a tooth), cracks in teeth, and periodontal or gum disease. When a pulp is exposed to bacteria from decay or saliva that has leaked into the pulp system, infection can occur inside the tooth and, if left untreated, can cause infection to build up at the tip of the root, forming an abscess. Eventually the bone supporting the tooth will be destroyed, and pain and swelling will often accompany the infection. Without endodontic treatment, the tooth will eventually have to be removed.
What Are the Symptoms of a Diseased Pulp?

Symptoms may range from momentary to prolonged, mild to severe pain on exposure to hot or cold or on chewing or biting. In some cases the condition may produce no symptoms at all. The patient should be informed that the radiographic examination may not demonstrate abnormal conditions of the tooth. The clinician should also make it clear that sometimes in the absence of pain, radiographic evidence of pulpal or periradicular disease or both may be present.

What Is the Success Rate of Root Canal Therapy?

Endodontics is one of the few procedures in dentistry that has a predictable prognosis if treatment is performed properly. Studies indicate that root canal treatment is usually 90% to 95% successful. Those in the failure group may still be amenable to re-treatment or surgical treatment to save the tooth, although no treatment’s success can be guaranteed. In addition, patients must understand that the prognosis may vary depending on the specifics of each case and that, without good oral hygiene and a sound restoration after endodontics, there may be an increased chance for failure. The need for periodic follow-up must be addressed to assess the long-term status of the tooth and periradicular tissues.

Will the Endodontically Treated Tooth Discolor After Treatment?

If the treatment is done correctly, discoloration seldom occurs. Bleaching with heat or chemicals can be used to treat discolored teeth. Some endodontically treated teeth appear discolored because they have been restored with tooth-colored fillings that have become stained or with amalgam restorations that leach silver ions. In these instances the fillings may be replaced, but often the placement of crowns or veneers is indicated.

What Are the Alternatives to Root Canal Treatment?

The only alternative is to extract the tooth, which often leads to shifting and crowding of surrounding teeth and subsequent loss of chewing efficiency. The patient should understand that often, extraction is the easy way out and, depending on the case, may prove to be more costly for the patient in the long run. The patient always reserves the right to do nothing about the problem, provided the clinician has explained the associated risks of this decision.

Will the Tooth Need a Crown or Cap After the Treatment?

If there is no previously existing crown, the need for a crown or cap depends on the amount of sound tooth structure remaining after endodontic treatment. In addition, the need for a crown or cap depends on the type of tooth and the amount of chewing force to which the tooth will be subjected. Loss of tooth structure significantly weakens the tooth and renders it more susceptible to fracture; as a result, it may be necessary to protect what is left with a restoration, such as a crown. Significant loss of tooth structure with a concomitant loss of retentive areas for coronal buildups may necessitate the placement of a metallic, resin, or ceramic post in a canal to retain the buildup material (Fig. 5-1, I and J) (for further information on these issues, see Chapter 2).
What Does Root Canal Treatment Involve?

Treatment may require one to three appointments, depending on the diagnosis, the number of roots, and the complexity of the case. During these appointments the clinician removes the injured or diseased pulp tissue. The root canals are cleaned, enlarged, and sealed to prevent recontamination of the root canal system. The following steps (see Fig. 5-1) describe the technical aspects of the treatment (illustrations, diagrams, radiographs, and digital images should be used as aids to the presentation):

1. Local anesthesia is usually administered.
2. The tooth is isolated with a rubber dam to prevent contamination from saliva and to protect the patient. This procedure is followed at each subsequent visit.
3. An opening is made through the top of the tooth to gain entrance to the root canal system.
4. The pulp tissue is painlessly removed with special instruments called files.
5. Periodic radiographs or digital images must be taken to ensure that these instruments correspond to the exact length of the root so that the entire tissue can be removed. Electronic apex locators can be used as adjuncts to help determine or verify lengths.
6. The root canal is cleaned, enlarged, and shaped so that it can be filled or sealed properly at the final appointment.

Figure 5-1 Series of radiographs and illustrations demonstrating root canal treatment and restoration of a maxillary canine. A and B, Maxillary canine with periradicular lesion of endodontic origin. C and D, Endodontic file corresponding to length of canal; isolation with rubber dam throughout procedure. E and F, Endodontic filling material placed after cleaning and shaping of canal. G and H, Canal system filled and post space made. I and J, One-year follow-up shows completed restoration and healed periradicular bone.
Some additional points should be conveyed to the patient after treatment. The patient should not be given the impression that there will be no pain after the treatment. In most cases, the mild discomfort the patient may experience is transitory and can usually be treated with an over-the-counter antiinflammatory or analgesic agent, such as aspirin or an ibuprofen-containing compound. In fact, prophylactic administration of these drugs before the patient leaves the office will help reduce postoperative discomfort by achieving therapeutic blood levels of analgesic before the local anesthesia wears off (see Chapter 18). In certain cases simply handing the patient a written prescription for a stronger analgesic, “just in case,” conveys a feeling of empathy and caring toward the patient and strengthens the doctor-patient relationship.

If the dentist wishes to refer the patient to an endodontist for treatment, skillful words of encouragement and explanation will convey the caring and concern behind this recommendation. Many patients already feel comfortable with their dentists and are fearful of seeing someone new. In addition, they may not understand why a general dentist chooses not to do the root canal treatment. The referring dentist can help by carefully explaining the complex nature of the case and why it would be in the patient’s best interests to visit the endodontist, who is specially trained to handle complex cases.

Informed Consent

Much controversy surrounds the legal aspects of informed consent. The current thinking in the courts is that for consent to be valid, it must be freely given; that all terms must be presented in language that the patient understands; and that the consent must be “informed.” For consent to be informed, the following conditions must be included in the presentation to the patient:

- The procedure and prognosis must be described. (This includes prognosis in the absence of treatment.)
- Alternatives to the recommended treatment must be presented, along with their respective prognoses.
- Foreseeable risks and material risks must be described.
- Patients must have the opportunity to have questions answered.

It is probably in the best interests of the dentist/patient relationship to have the patient sign a valid informed consent form. With the continuous rise in dental litigation, it is important to realize that “no amount of documentation is too much and no amount of detail is too little.” (For further information on this subject, see Chapter 11.)

Radiation Safety

A critical portion of the endodontic case presentation and informed consent is educating the patient about the requirement for radiographs as part of the treatment. The dentist must communicate to the patient that the benefits of radiographs far outweigh the risks of receiving small doses of ionizing radiation, as long as techniques and necessary precautions are properly executed. Although levels of radiation in endodontic radiography range from only 1/100 to 1/1000 of the levels needed to sustain injury, it is still best to keep ionizing radiation to a minimum for the protection of both the patient and the dental delivery team.

Two simple analogies can be used to help the patient understand the small risk associated with dental radiographs. A patient would have to receive 25 complete full mouth series (i.e., 450 exposures) within a very short time to significantly increase the risk of skin cancer. One full mouth survey (i.e., 20 Ektaspeed E – speed films with rectangular collimation) has been found to deliver less than one half of the amount of radiation of a single chest film and less than 1% of the amount of a barium study of the intestines. Nevertheless, the principles of ALARA (as low as reasonably achievable), which are techniques used to reduce radiation exposure, should be followed as closely as possible to minimize the amount of radiation that both patient and treatment team receive. ALARA also implies the possibility that no matter how small the radiation dose, there still may be some deleterious effects.

Principles of ALARA

7. Sometimes medications are placed in the opening to prevent infection between appointments.
8. A temporary filling is placed in the crown opening between appointments.
9. At the final appointment the canal is sealed to safeguard it from further contamination.
10. Permanent restoration of the tooth is accomplished after completion of the root canal treatment.
In endodontic radiography, fast (i.e., sensitive) speed film, either Ultraspeed (U) or E, should be selected. Although E-speed film allows for a reduction of approximately 50% of the radiation exposure required for D speed, findings in observer preference studies have been mixed as to the quality, clarity, and diagnostic capability of E film compared with D film. Processing of the E-speed film is also more sensitive.

Specialized radiographic systems (using direct or indirect digital intraoral radiography) involve the digitization of ionizing radiation and use considerably smaller amounts of radiation to produce an image that is available immediately after exposure (see “Digital Radiographic Techniques” later in the chapter).

Meticulous radiographic technique helps reduce the number of retakes and obviates further exposure. Film-holding devices (discussed later in the chapter) along with correct film and tube head positioning are essential for maintaining film stability and producing radiographs of diagnostic quality.

Dental units should be operated using at least 70 kVp. The lower the kilovoltage, the higher the patient’s skin dose. Optimally, 90 kVp should be used. Units operating at 70 kVp or higher must have a filtration equivalent of 2.5 mm of aluminum to remove the extraneous low-energy x-rays before the patient absorbs them.

Collimation also reduces exposure level. Collimation, essentially, is the restriction of the x-ray beam size by means of a lead diaphragm so that the beam does not exceed 2.75 inches (7 cm) at the patient’s skin surface. Open-ended, circular, or rectangular lead-lined cylinders, known as position-indicating devices (PIDs), help direct the beam to the target. However, the universal rectangular cylinder also collimates the x-ray beam by decreasing beam size even more, reducing the area of skin surface exposed to x-radiation and reducing radiation burden by approximately 50% (Fig. 5–2). These PIDs, or cones, should be at least 12 to 16 inches long, because the shorter (i.e., 8-inch) cones that provide shorter source-to-film distances permit more divergence of the beam and more exposure to the patient. Pointed cones, illegal in some states, should not be used because of the increased amount of scatter radiation they produce.

For “declared” pregnant workers, the Nuclear Regulatory Commission limits the radiation dose to the fetus to 0.5 mSv during the gestation period. It is important to note that the MPD is specified as occupational exposure and should not be confused with exposure that patients receive as a result of radiographic procedures. Although no state-recommended maximum patient exposures exist, anyone who administers ionizing radiation is responsible for consulting the respective state’s bureau of radiation control to obtain information on current laws. Nonetheless, every effort should be made to keep the radiation dose to all individuals as low as possible and to avoid any unnecessary radiation exposure.
Premedication with Antibiotics

Prophylactic coverage with antibiotics or antiinfectives is indicated for patients who are susceptible to systemic disease after bacteremia. Although it has been documented that the incidence of bacteremia associated with nonsurgical root canal treatment is essentially negligible as long as endodontic instruments are confined to the root system, the American Heart Association (AHA) recommends prophylactic antibiotic coverage for patients who have prostheses, shunts, or certain diseases. The use of prophylactic antibiotics in these patients prevents blood-borne microorganisms from lodging on shunts and prostheses or from multiplying within a depressed system.

With respect to premedication for dental patients with total joint replacements, there has been considerable controversy as to whether such patients require routine prophylaxis. In 1997 the ADA and AAOS (American Academy of Orthopedic Surgeons) drafted an advisory statement on antimicrobial premedication for dental patients with total joint replacements. The joint organizations recognized that there was no agreed-on scientific evidence to support the contention that antibiotic prophylaxis is necessary to prevent metastatic infection in patients with total joint prostheses. They also agreed that the analogy between late prosthetic joint infections and infective endocarditis was invalid, because the anatomy, blood supply, types of microorganisms involved, and mechanisms of infection all differ. The ADA and AAOS concluded that antibiotic prophylaxis is not indicated for dental patients with pins, plates, and screws, nor is it routinely indicated for most dental patients with total joint replacements.

However, because limited evidence exists that some dental procedures are high-risk procedures (e.g., extractions, intraligamentary local anesthesia, endodontic surgery, endodontic instrumentation “beyond the apex”) and that some medically compromised patients with total joint replacements (e.g., insulin-dependent diabetes; inflammatory arthropathies, such as rheumatoid arthritis; immunosuppression; hemophilia; previous prosthetic joint infections) may be at higher risk for hematogenous infections, an antibiotic regimen should be considered. Prophylaxis should also be recommended during the first 2 years after joint replacement. The antibiotic regimen is cefazolin, cephradine, or amoxicillin (2 g PO, 1 hour before procedure). For those allergic to penicillin or cephalosporin, the recommended antibiotic is clindamycin (600 mg PO, 1 hour before procedure). It is recommended that patients who are not allergic to penicillin but who are unable to take oral medications should receive cefazolin (1 g) or ampicillin (2 g), IM or IV, 1 hour before the dental procedure. For patients allergic to penicillin and unable to take oral medications, the recommendation is clindamycin (600 mg IM or IV, 1 hour before the dental procedure). Similar to the AHA guidelines, follow-up doses are no longer recommended. The advisory statement only represents recommended guidelines and is not intended as a standard of care, because it is impossible to make recommendations for all clinical situations in which late infection might occur in total joint prostheses. Practitioners must exercise their own clinical judgment in determining whether to premedicate a patient.

Patients with certain cardiac conditions are candidates for antibiotic coverage to prevent subacute bacterial endocarditis (SBE). In 1997 the AHA revised its recommendations for the prevention of bacterial endocarditis that may be the result of an invasive procedure. The major modifications include the recognition and emphasis that most cases of endocarditis are not the result of an invasive procedure; that predisposing cardiac conditions are stratified into high-, moderate-, and negligible-risk categories based on the potential outcome should endocarditis develop; and that modification of the drugs and dosages is necessary for prophylaxis.

On the basis of the new guidelines, prophylaxis is recommended for individuals in high-risk and moderate-risk categories. Individuals at high risk are those who have prosthetic heart valves, previous history of endocarditis, complex cyanotic congenital heart disease, and surgically constructed systemic pulmonary shunts. Those conditions in the moderate-risk category include most other congenital cardiac malformations, rheumatic heart disease, hypertrophic cardiomyopathy, and mitral valve prolapse with valvular regurgitation or thickened leaflets or both. Conditions in the negligible-risk category (i.e., no greater risk than the general population) and for which prophylaxis is not recommended include previous coronary artery bypass graft surgery, mitral valve prolapse without valvular regurgitation, previous rheumatic fever without valvular dysfunction, and cardiac pacemakers (both intravascular and epicardial).

The AHA has developed a standard prophylactic antibiotic regimen for patients at risk and a set of alternative regimens for those unable to take oral medications, for those who are allergic to the standard antibiotics, and for those who are not candidates for the standard regimen. The recommended standard prophylactic regimen for all dental, oral, and upper respiratory tract procedures is currently amoxicillin. This is because amoxicillin is better absorbed by the gastrointestinal tract and provides higher and more sustained serum levels than penicillin.
The major modification in the new regimen is that the postoperative dose has been eliminated; the rationale for this is that amoxicillin has a sufficiently high plasma level for an adequate time to prevent endocarditis. Erythromycin has also been eliminated as a recommended drug in the penicillin-allergic patient because of the high incidence of gastrointestinal upset and the variability of the pharmokinetics of the various erythromycin preparations. The official AHA recommendations for prophylactic antibiotic regimens do not specify all clinical situations for which patients may be at risk. Thus it is the responsibility of the clinician to exercise judgment or consult the patient’s physician before giving treatment. (The current AHA guidelines for prophylactic antibiotic coverage are listed in Chapters 4 and 15.)

**Antianxiety Regimens**

Because patients often have been misinformed about root canal treatment, some may understandably experience increased anxiety about undergoing the procedure. Fortunately, however, the vast majority of patients are able to tolerate their anxiety, control their behavior, and allow treatment to proceed with few problems. Appropriate behavioral approaches can be used to manage most anxious dental patients. Retrospective studies concerning dental anxiety have clearly demonstrated that explaining each procedure before beginning root canal treatment can effectively reduce a patient’s anxiety. The clinician can also reduce patient anxiety by giving specific information during treatment, by advising the patient about possible minor discomfort, and by explaining how that discomfort can be controlled. Verbal support, reassurance, and personal warmth also help to ease patient anxiety during root canal treatment. Many of these measures can be taken during the case presentation.

Although the clinician’s hope and desire may not cure a patient’s fear of root canal treatment, each clinician should realize that all anxious patients are not alike; therefore each patient should be managed individually. If behavioral solutions are not feasible or effective in a particular case, pharmacologic approaches to managing patient anxiety may be exercised. Selection of such pharmacotherapeutic techniques must involve a careful assessment of the relative risks and benefits of the alternative approaches. All pharmacologic treatment regimens include the need for good local anesthetic technique. For the management of mild to moderate anxiety states, these regimens range from nitrous oxide plus oxygen sedation to oral sedation to intravenous or conscious sedation. (For further information on these issues, see Chapter 18.)

**Pain Control with Preoperative Administration of NSAIDs**

During root canal cleaning and shaping, extrusion of small amounts of pulp tissue remnants and dentin filings is likely to occur. Often this extrusion results in additional inflammation and some postoperative discomfort. Prophylactic administration of a nonsteroidal antiinflammatory drug (NSAID), such as 200 to 400 mg of ibuprofen 30 to 60 minutes before the procedure, has been shown to reduce or prevent postoperative dental pain. (See Chapter 18 for further information.)

**Pain Control with Local Anesthesia**

It is paramount to obtain a high level of pain control when performing root canal treatment; in no other specialty is this task as challenging or as demanding. The clinician must strive for a “painless” local anesthetic injection technique, with relatively rapid onset of analgesia (see Chapter 19).
PREPARATION OF RADIOGRAPHS

Radiographs are essential to all phases of endodontic therapy. They inform the diagnosis and the various treatment phases and help evaluate the success or failure of treatment. Because root canal treatment relies on accurate radiographs, it is necessary to master radiographic techniques to achieve films of maximum diagnostic quality. Such mastery minimizes retaking of films and avoids additional exposure of patients. Expertise in radiographic interpretation is essential for recognizing deviations from the norm and for understanding the limitations associated with endodontic radiography.

Functions, Requirements, and Limitations of the Radiograph in Endodontics

The primary radiograph used in endodontics is the periapical radiograph. In diagnosis this film is used to identify abnormal conditions in the pulp and periradicular tissues. It is also used to determine the number of roots and canals, location of canals, and root curvatures. Because the radiograph is a two-dimensional image (a major limitation), it is often advantageous to take additional radiographs at different horizontal or vertical angulations when treating multicanal and multitrooted teeth. Taking additional radiographs is also helpful when treating teeth with severe root curvature. These supplemental radiographs enhance visualization and evaluation of the three-dimensional structure of the tooth.

Technically, for endodontic purposes, a radiograph should depict the tooth in the center of the films. Consistent film placement in this manner will minimize interpretation errors, because the center of the films contains the least amount of distortion. In addition, at least 3 mm of bone must be visible beyond the apex of the tooth. Failure to capture this bony area may result in misdiagnosis, improper interpretation of the apical extent of a root, or incorrect determination of file lengths for canal cleaning and shaping. Finally, the image on the film must be as anatomically correct as possible. Image shape distortion caused by elongation or foreshortening may lead to interpretive errors during diagnosis and treatment.

The bite-wing radiograph may be useful as a supplemental film. This film normally has less image distortion because of its parallel placement, and it provides critical information on the anatomic crown of the tooth. This information includes the anatomic extent of the pulp chamber, the existence of pulp stones or calcifications, recurrent decay, the depth of existing restorations, and any evidence of previous pulp therapy. The bite-wing also indicates the relationship of remaining tooth structure relative to the crestal height of bone. Thus it can aid in determining the restorability of the tooth.

In addition to their diagnostic value, high-quality radiographs are mandatory during the treatment phase. Technique is even more critical, however, because working radiographs must be exposed while the rubber dam system is in place. Visibility is reduced, and the bows of the clamp often restrict precise film positioning. During treatment, periradicular radiographs are used to determine canal working lengths; the location of superimposed objects, canals, and anatomic landmarks (by altering cone angulations); biomechanical instrumentation; and master cone adaptation (see Fig. 5–1, C to F). After completion of the root canal procedure, a radiograph should be exposed to determine the quality of the root canal filling or obturation. Follow-up radiographs exposed at similar angulations enhance assessment of the success or failure of treatment (see Fig. 5–1, I and J).

The astute clinician can perceive that precise radiographic interpretation is undoubtedly one of the most valuable sources of information for endodontic diagnosis and treatment, but the radiograph is only an adjunctive tool and can be misleading. Information gleaned from proper inspection of the radiograph is not always absolute and must always be integrated with information gathered from a thorough medical and dental history, clinical examination, and various pulp-testing procedures (see Chapter 1).

Use of the radiograph depends on an understanding of its limitations and its advantages. The advantages are obvious: the radiograph allows a privileged look inside the jaw. The information it furnishes is essential and cannot be obtained from any other source, and its value is not diminished by a critical appraisal of its limitations.

One major limitation of radiographs is their inability to detect bone destruction or pathosis when it is limited to
the cancellous bone. Studies have proved that radiolucencies usually do not appear unless there is external or internal erosion of the cortical plate. This factor must be considered in evaluating teeth that become symptomatic but show no radiographic changes. In most cases, root structure anatomically approaches cortical bone and, if the plate is especially thin, radiolucent lesions may be visible before there is significant destruction of the cortical plate. Nevertheless, inflammation and resorption affecting the cortical plates must still be sufficiently extensive before a lesion can be seen on a radiograph.

**Principles of Endodontic Radiography**

**Film Placement and Cone Angulation**

For endodontic purposes, the paralleling technique produces the most accurate periradicular radiograph. Also known as the long-cone or right-angle technique, it produces improved images. The film is placed parallel to the long axis of the teeth, and the central beam is directed at right angles to the film and aligned through the root apex (Fig. 5–3, A and B). To achieve this parallel orientation it is often necessary to position the film away from the tooth, toward the middle of the oral cavity, especially when the rubber dam clamp is in position. The long-cone (i.e., 16 to 20 inches) aiming device is used in the paralleling technique to increase the focal spot-to-object distance. This has the effect of directing only the most central and parallel rays of the beam to the film and teeth, reducing size distortion. This technique permits a more accurate reproduction of the tooth’s dimensions, thus enhancing a determination of the tooth’s length and relationship to surrounding anatomic structures. In addition, the paralleling technique reduces the possibility of superimposing the zygomatic processes over the apices of maxillary molars, which often occurs with more angulated films, such as those produced by means of the bisecting-angle technique (see Fig. 5–3, C and D). If properly used, the paralleling technique will provide the clinician with films with the least distortion, minimal superimposition, and utmost clarity.

![Figure 5-3](http://home.mdconsult.com.eproxy1.lib.hku.hk/das/book/body/0/1357/3...2007-1-19)

Variations in size and shape of the oral structures (e.g., shallow palatal vault, tori, or extremely long roots) or...
gagging by the patient can make true parallel placement of the film impossible. To compensate for difficult placement, the film can be positioned so that it diverges as much as 20 degrees from the long axis of the tooth, with minimal longitudinal distortion. With maxillary molars, any increase in vertical angulation increases the chances of superimposing the zygomatic process over the buccal roots. A vertical angle of not more than 15 degrees should usually project the zygomatic process superiorly and away from the molar roots. To help achieve this, a modified paralleling technique that increases vertical angulation by 10 to 20 degrees can be used. Although this orientation introduces a small degree of foreshortening, it increases periradicular definition in this troublesome maxillary posterior region. The Dunvale Snapex System (Dunvale Corporation, Gilberts, IL), a film holder and aiming device originally designed for the bisecting-angle technique, has been altered for the modified paralleling technique. In conjunction with this technique, a distal angulated radiograph (i.e., a 10- to 20-degree horizontal shift of the cone from the distal, with the beam directed toward the mesial) tends to project buccal roots and the zygomatic process to the mesial, thus enhancing anatomic clarity.

The bisecting-angle technique is not preferred for endodontic radiography. However, when a modified paralleling technique cannot be used, there may be no choice because of difficult anatomic configurations or patient management problems. The basis of this technique is to place the film directly against the teeth without deforming the film (see Fig. 5–3, C and D). The structure of the teeth, however, is such that with the film in this position, an obvious angle exists between the plane of the film and the long axis of the teeth. This causes distortion, because the tooth is not parallel to the film. If the x-ray beam is directed at a right angle to the film, the image on the film will be shorter than the actual tooth (i.e., foreshortened). If the beam is directed perpendicularly to the long axis of the teeth, the image will be much longer than the tooth (i.e., elongated). Thus, by directing the central beam perpendicular to an imaginary line that bisects the angle between tooth and film, the length of the tooth’s image on the film should be the same as the actual length of the tooth.

Although the projected length of the tooth is correct, the image will show distortion because the film and object are not parallel and the x-ray beam is not directed at right angles to both. This distortion increases along the image toward its apical extent. The technique produces additional error potential, because the clinician must imagine the line bisecting the angle (an angle that, in itself, is difficult to assess). In addition to producing more frequent superimposition of the zygomatic arch over apices of maxillary molars, the bisecting-angle technique causes greater image distortion than the paralleling technique and makes it difficult for the operator to reproduce radiographs at similar angulations to assess healing after root canal treatment (see Fig. 5–3, C and D).

**Film Holders and Aiming Devices**

Film holders and aiming devices are required for the paralleling technique because they reduce geometric distortion caused by misorientation of the film, central beam, and tooth. They also minimize cone cutting, improve diagnostic quality, and allow similarly angulated radiographs to be taken during treatment and at recall. By eliminating the patient’s finger from the x-ray field and thus the potential for displacing the film, these devices help to minimize retakes and make it easier for the patient and clinician to properly position the film.

A number of commercial devices are available that position the film parallel and at various distances from the teeth, but one of the most versatile film-holding devices is the hemostat. The clinician positions a hemostat-held film, and the handle is used to align the cone vertically and horizontally. The patient then holds the hemostat in the same position, and the cone is positioned at a 90-degree angle to the film (Fig. 5–4, A). When taking working radiographs, a radiolucent, plastic, rubber dam frame, such as an Ostby or Young frame, should be used and not removed. To position the hemostat or other film-holding device, a corner of the rubber dam is released for visibility and to allow the subsequent placement of the device-held film (Fig. 5–4, B). The Stabe disposable film holder (Dentsply Rinn Corporation, Elgin, IL) (Fig. 5–5) is another film-holding device that is ideal for taking preoperative and postoperative films.
Besides the Dunvale Snapex System mentioned earlier, the major commercial film-holding and aiming devices include the XCP (extension cone paralleling) instruments, the Endo Ray II endodontic film holder, the Uni-Bite film holder, the Snap-H-Ray film holder, the Snapex System film holder with aiming device, and the Crawford Film Holder System (Figs. 5–6, 5–7, 5–8, 5–9, 5–10).

**Figure 5-4**  A. With the paralleling technique, the tube head is positioned at a 90-degree angle to the film. The hemostat aids in film placement and in cone alignment. Note that the hemostat is resting on the mandibular anterior teeth so that the film is parallel with the long axis of the maxillary central incisors. B. Releasing a corner of the rubber dam aids in hemostat placement so that the film can be properly aligned.  (A Courtesy Dr. Eddy Tidwell. B Courtesy Dr. Michelle Speier.)

**Figure 5-5** Examples of XCP® Film Holding Devices. Left to right, XCP Bite-Block, Stabe Bite-Block, EZ-Prop mouth prop, bite-wing loops, and adhesive bite-wing tabs.  (Courtesy Dentsply Rinn, Elgin, IL.)

**Figure 5-6** XCP instruments hold the radiograph film packets and aid in cone alignment. Cone cutting is prevented, and consistent angulation can be achieved.  (Courtesy Dentsply Rinn, Elgin, IL.)
Variations in the use of the XCP system, for example, can prevent displacement of the rubber dam clamp and increase periradicular coverage during endodontic procedures. The film is placed off center in the bite block, and the cone is placed off center with respect to the aiming ring. This allows for placement of the bite block adjacent to the rubber dam clamp without altering the parallel relation of the cone to the film. A customized hemostat (with rubber bite block attached) can also be made to assist film placement during the taking of working radiographs. Other specialized film holders, such as the EndoRay and the Crawford Film Holder System, have been designed to help the dentist secure parallel working films with the rubber dam clamp in
place. Generally these holders all have an x-ray beam-guiding device for proper beam/film relationship and a modified bite block and film holder for proper positioning over or around the rubber dam clamp (Fig. 5-10).

Exposure and Film Qualities

The intricacies of proper kilovoltage, milliamperage, and time selection serve as examples of how the diagnostic quality of a film may be altered by changes in the film’s density and contrast. Density is the degree of darkening of the film, whereas contrast is the difference between densities. The amount of darkening depends on the quantity and quality of radiation delivered to the film, the subject thickness, and the developing or processing conditions. Milliamperage controls the electron flow from cathode to anode; the greater the electron flow per unit of time, the greater will be the quantity of radiation produced. Proper density is primarily a function of milliamperage and time. Kilovoltage also affects film density by controlling the quality and penetrability of the rays. Higher kilovoltage settings produce shorter wavelengths that are more penetrating than the longer wavelengths produced at lower settings. The ability to control the penetrability of the rays by alterations in kilovoltage affects the amount of radiation reaching the film and the degree of darkening or density. Altering exposure time or milliamperage or both for each respective unit can control variations in density.

Contrast is defined as the difference between shades of gray or the difference between densities. Most variation observed in endodontic radiography is because of subject contrast, which depends on the thickness and density of the subject and the kilovoltage used. Thus kilovoltage is really the only exposure parameter under the clinician’s control that directly affects subject contrast. Exposure time and milliamperage only control the number of x-rays; therefore they mainly influence the density of the film image. A radiographic film may exhibit a long scale, or low, contrast (i.e., more shades of gray or more useful densities); high-kilovoltage techniques (e.g., 90 kVp) produce this long scale of contrast as a result of the increased penetrating power of the rays. This results in images with many more shades of gray and less distinct differences. Films exposed at low kilovoltage settings (e.g., 60 kVp) exhibit short-scale, or high, contrast, with sharp differences between a few shades of gray, black, and white. Although they are perhaps more difficult to read, films exposed at higher kilovoltage settings (e.g., 90 kVp) make it possible to discriminate between images, often enhancing diagnostic quality; films exposed at a lower kilovoltage (e.g., 70 kVp) have better clarity and contrast between radiopaque and radiolucent structures, such as endodontic instruments near the root apex. Nevertheless, the optimal kilovoltage and exposure time should be individualized for each radiograph unit and exposure requirement.

Processing

Proper darkroom organization, film handling, and adherence to the time and temperature method of film processing play important roles in producing films of high quality. For the sake of expediency in the production of working films in endodontics, rapid processing methods are used to produce relatively good films in less than 1 to 2 minutes. Although the contrast in using rapid-processing chemicals is lower than that achieved using conventional techniques, the radiographs have sufficient diagnostic quality to be used for treatment films and are obtained in less time and with less patient discomfort. Rapid-processing solutions are available commercially, but they tend to vary in shelf life, in tank life, and in the production of films of permanent quality.

Figure 5-11 Chairside darkroom allows rapid processing of endodontic working films. (Courtesy Dentsply Rinn, Elgin, IL.)

To maintain the radiographic image for documentation, it is recommended that after an image has been
evaluated it be returned to the fixer for 10 minutes more and then washed for 20 minutes and dried. An alternative is to reprocess the film by means of the conventional technique. Double film packets can also be used for working films: one can be processed rapidly and the other conventionally. Regardless of what method is used for working films, a controlled time and temperature method should be used for the diagnostic qualities desired in pretreatment, posttreatment, and recall radiographs. All radiographs taken during the course of endodontic treatment should be preserved as a part of the patient’s permanent record.

**Radiographic Interpretation in Endodontics**

**Examination and Differential Interpretation**

Radiographic interpretation is not strictly the identification of a problem and the establishment of a diagnosis. The dentist must read the film carefully, with an eye toward diagnosis and treatment. Frequently overlooked are the small areas of resorption, invaginated enamel, separated files, minute fracture lines, extra canals or roots, curved and calcified canals, and, in turn, the potential problems they may create during treatment (Fig. 5–12). If a thorough radiographic examination is conducted, problems during treatment, additional time, and extra expense can be avoided or at least anticipated. As mentioned earlier, additional exposures at various angulations may be necessary to gain a better insight into the three-dimensional structure of a tooth.
Many anatomic structures and osteolytic lesions can be mistaken for periradicular pathoses. Among the more commonly misinterpreted anatomic structures are the mental foramen and the incisive foramen. These radiolucencies can be differentiated from pathologic conditions by exposures at different angulations and by pulp-testing procedures. Radiolucencies not associated with the root apex will move or be projected away from the apex by varying the angulation. Radiolucent areas resulting from sparse trabeculation can also simulate radiolucent lesions. In such cases these areas must be differentiated from the lamina dura and periodontal ligament space.

A commonly misinterpreted osteolytic lesion is periapical cemental dysplasia or cementoma (Fig. 5–13). The use of pulp-testing procedures and follow-up radiographic examinations will prevent the mistake of diagnosing this as a periradicular pathosis. The development of this lesion can be followed radiographically from its early, more radiolucent stage through its mature or more radiopaque stage.

**Figure 5-12** A. Maxillary left central incisor with history of trauma and thin walls in the apical one third of the tooth. Once an apical barrier is formed, pressures exerted during obturation could cause fracture. B. Maxillary right first premolar with three separate roots (arrows). C. Maxillary right central with history of trauma. Apical resorption and calcification of the canal system complicate treatment. D. Dilacerated root system on maxillary left canine. E. Maxillary left first molar with calcification of the chamber and root canal system. F. Endodontically treated mandibular second molar with apical root resorption (star on mesial root) and external root resorption (star on distal root); separated file in mesial root (arrow). G. Retrieved file. H. Completed retreatment. I. Angled radiograph showing evidence of another root (apical arrows) in an endodontically treated maxillary first premolar; coronal arrow indicates sealer in unprepared canal. J. Completed root canal treatment of two separate canals. K. Bifurcation (arrows) of the root canal system in a mandibular second premolar. (H, J, and K Courtesy Dr. Francisco A. Banchs.)
Other anatomic radioluencies that must be differentiated from periradicular pathoses are the maxillary sinus, nutrient canals, nasal fossa, and lateral or submandibular fossa. Many systemic conditions can mimic or affect the radiographic appearance of the alveolar process. A discussion of these conditions is beyond the scope of this chapter, but the reader is encouraged to read further in any oral pathology textbook.

Lamina Dura: a Question of Integrity

One key challenge in endodontic radiographic interpretation is understanding the integrity, or lack of integrity, of the lamina dura, especially in its relationship to the health of the pulp. Anatomically, the lamina dura is a layer of compact bone (i.e., cribriform plate or alveolar bone proper) that lines the tooth socket. Noxious products emanating from the root canal system can effect a change in this structure that is visible radiographically. X-ray beams passing tangentially through the socket must pass through many times the width of the adjacent alveolus, and they are attenuated by this greater thickness of bone, producing the characteristic “white line.” If, for example, the beam is directed more obliquely so that it is not as attenuated, the lamina dura appears more diffuse, or it may not be discernible at all. Therefore the presence or absence and integrity of the lamina dura are determined largely by the shape and position of the root and, in turn, by its bony crypt, in relation to the x-ray beam. This explanation is consistent with the radiographic and clinical findings of teeth with normal pulps and no distinct lamina dura.

Changes in the integrity of the periodontal ligament space, the lamina dura, and the surrounding periradicular bone certainly have diagnostic value, especially when recent radiographs are compared with previous ones. However, the significance of such changes must be tempered by a thorough understanding of the features that give rise to these images.

Buccal-Object Rule (Cone Shift)

In endodontic therapy it is imperative that the clinician know the spatial or buccolingual relation of an object within the tooth or alveolus. The technique used to identify the spatial relation of an object is called the cone or tube shift technique. Other names for this procedure are the buccal-object rule, Clark’s rule, and the SLOB (same lingual, opposite buccal) rule.[30][48][55][62] Proper application of the technique allows the dentist to locate additional canals or roots, to distinguish between objects that have been superimposed, and to distinguish between various types of resorption. It also helps the clinician to determine the buccolingual position of fractures and perforative defects, to locate foreign bodies, and to locate anatomic landmarks in relation to the root apex, such as the mandibular canal.[60]

The buccal-object rule relates to the manner in which the relative position of radiographic images of two separate objects changes when the projection angle at which the images were made is changed. The principle states that the object closest to the buccal surface appears to move in the direction opposite the movement of the cone or tube head, when compared with a second film. Objects closest to the lingual surface appear to move (on a film) in the same direction that the cone moved; thus the “same lingual, opposite buccal” rule. Fig. 5 - 14 shows three simulated radiographs of a buccal object (yellow circle) and a lingual object (red triangle) exposed at different horizontal angles. The position of the objects on each radiograph is compared with the reference structure (i.e., the mesial root apex of the mandibular first molar). The first radiograph (see Fig. 5 - 14, A and B) shows superimposition of the two objects; in this case the tube head...
was positioned for a straight-on view. In the second radiograph (see Fig. 5–14, C and D), the tube head shifted mesially, and the beam was directed at the reference object from a more mesial angulation. In this case the lingual object (red triangle) moved mesially with respect to the reference object, and the buccal object (yellow circle) moved distally with respect to the reference object. In the third radiograph (see Fig. 5–14, E and F), the tube head shifted distally and the beam was directed at the reference object from a more distal angulation; here the triangle moved distally with respect to the mesial root of the mandibular first molar, and the circle moved mesially. These radiographic relations confirm that the lingual object (red triangle) moves in the same direction with respect to reference structures as the radiograph tube and that the buccal object (yellow circle) moves in the opposite direction of the radiograph tube. Thus, according to the rule, the object farthest (i.e., most buccal) from the film moves farthest on the film with respect to a change in horizontal angulation of the radiograph cone. In an endodontically treated mandibular molar with four canals (Fig. 5–15), a straight-on view results in superimposition of the root-filled canals on the radiograph. If the cone is angled from mesial to distal, the mesiolingual and distolingual canals will move mesially and the mesiobuccal and distobuccal canals will move distally on the radiograph, when compared with the straight-on view.

**Figure 5-14** Objects may be localized with respect to reference structures by using the buccal-object rule (i.e., tube-shift technique). A and B, A straight-on view will cause superimposition of the buccal object (yellow circle) with the lingual object (red triangle). C and D, Using the tube-shift technique, the lingual object (red triangle) will appear more mesial with respect to the mesial root of the mandibular first molar, and the buccal object (yellow circle) will appear more distal on a second view projected from the mesial. E and F, The object (red triangle) on the lingual surface will appear more distal with respect to the mesial root of the mandibular first molar, and the object (yellow circle) on the buccal surface will appear more mesial on a view projected from the distal aspect.
The examples cited previously involve application of the buccal-object rule, using changes in horizontal angulation. The clinician should be aware that this rule also applies to changes in vertical angulation (Fig. 5-16). To locate the position of the mandibular canal relative to mandibular molar root apices, radiographs must be taken at different vertical angulations. If the canal moves with or in the same direction as the cone head, the canal is lingual to the root apices; if the mandibular canal moves opposite the direction of the cone head, the canal is buccal to the root apices. The clinician should recognize the wide range of applicability of the buccal-object rule in determining the buccolingual relationship of structures not visible in a two-dimensional image.

**Figure 5-15** Comparison of straight-on and mesial-angled views of an endodontically treated mandibular molar with four canals. A to C, Straight-on view of the mandibular molar shows superimposition of the root canal fillings. D to F, Mesiodistal angulation produces separation of the canals. The mesiolingual (ML) and distolingual (DL) root-filled canals move mesially (i.e., toward the cone), and the mesiobuccal (MB) and distobuccal (DB) root-filled canals move distally (i.e., away from the cone) on the radiograph.

**Figure 5-16** Examples of the buccal-object rule using shifts in vertical and horizontal angulations. A, Bite-wing radiograph (straight-on view with minimal horizontal and vertical angulation) depicts amalgam particle superimposed over the mesial root of the mandibular first molar. To determine the buccolingual location of the object, the tube-shift technique (buccal-object rule) must be applied. B, The
Digital Radiographic Techniques

The replacement of traditional radiographic film with digital sensors offers many advantages to radiography. The evolution of computer technology for radiography has allowed for nearly instantaneous image acquisition, image enhancement, storage, retrieval, and even transmission of images to remote sites in a digital format. The major advantages of using digital radiography in endodontics are that radiographic images are obtained immediately and radiation exposure is reduced from 50% to 90% compared with conventional film-based radiography. The primary disadvantages of digital imaging systems are their high initial cost and potential for reduction in image quality when compared with conventional radiography.

Digital imaging systems require an electronic sensor or detector, an analog-to-digital converter, a computer, and a monitor or printer for image display. (See Chapter 26 for a further discussion of digital imaging systems and how they function.)

Digitization of ionizing radiation first became a reality in the late 1980s with the development of the original RadioVisioGraphy (RGV) system by Dr. Francis Mouyen. This system has evolved into the RVGui (Trex Trophy, Danbury, CT). Other available systems include Dexis Digital X-Ray (Provision Dental Systems, Redwood City, CA) and Computed Dental Radiography (CDR) (Schick Technologies, Long Island City, NY) (Fig. 5-17, A and C). The FDA has approved all these systems.

Figure 5-17. Digital imaging systems. A, Dexis Digital X-Ray System. B, Special shape of Dexis sensor. C, Schick desktop digital system with wireless sensor. D, Clinical placement of wireless sensor. E, Schick wired sensor covered by plastic sheath for infection...
Direct digital systems have three components: (1) the “radio” component, (2) the “visio” component, and (3) the “graphy” component. The “radio” component consists of a high-resolution sensor with an active area that is similar in size to conventional film. However, length, width, and thickness vary slightly depending on the respective system (see Fig. 5–17, B and E). The sensor is protected from x-ray degradation by a fiberoptic shield, and it can be disinfected. Specially designed multiple types of sensor holders are available; for infection control, disposable plastic sheaths are used to cover the sensor when it is in use (see Fig. 5–17, E). Wireless CDR sensors have recently become available through Schick Technologies, Inc. This technology provides cable-free sensors to allow enhanced mobility at chairside (see Fig. 5–17, C and D). CDR Wireless is the first wireless direct digital radiography system. Wireless sensors provide greater mobility at chairside while reportedly providing the same level of image quality acquired with conventional CDR systems. Sensors instantly transmit images directly from the mouth. The image is automatically transmitted to the computer via radio waves. Images do not need to be processed as with traditional film and storage phosphor plates. Chemical processing as with traditional film is not needed. Also, sensors do not need to be downloaded, erased, or reset between shots.

The second component of a direct digital system, the “visio” portion, consists of a video monitor and display-processing unit (see Fig. 5–17, A and C). As the image is transmitted to the processing unit, it is digitized and stored by the computer. The unit magnifies the image for immediate display on the video monitor; it also can produce colored images and display multiple images simultaneously, including a full mouth series on one screen. Because the image is digitized, further manipulation of the image is possible; this includes enhancement, contrast stretching, and reversing. A zoom feature is also available to enlarge a portion of the image up to full-screen size.

The third component of a direct digital system is the “graphy,” a high-resolution video printer that provides a hard copy of the screen image, using the same video signal. In addition, a digital intraoral camera can be integrated with most systems. Indirect digital imaging or cordless systems, such as Digora (Soredex-Finndent, Conroe, TX) and DenOptix Digital Imaging System (Dentsply/Gendex, York, PA), involve the use of a reusable filmlike plate without wires. The image to be scanned by a laser (to digitize it before viewing on the computer) is recorded on this plate. Although indirect digital imaging still incorporates reduced radiation exposure and image manipulation, it usually takes slightly longer before the image can be viewed.

The advantages of both direct and indirect digital radiography seem numerous, but the primary ones include the elimination of standard radiograph film and processing chemicals, a significant reduction in exposure time (i.e., 80% to 90% reduction, when compared with D-speed film), and rapid image display. Virtually all systems can be linked with electronic record systems so that patient data can be stored, accessed, and transmitted easily. An exposure time in the range of hundredths of a second is all that is needed to generate an image. One study showed that digital radiographic resolution was slightly lower than that produced with silver halide film emulsions, but the radiographic information may be increased with the electronic image treatment capabilities of the system. These systems appear to be very promising for endodontics and for general dentistry.

Digital subtraction radiography is a sensitive method for detecting changes in radiographic density over time. In endodontics, digital subtraction radiography may be especially useful for evaluating osseous healing after treatment and as an aid in diagnosis. By definition, subtraction radiography requires that two images have nearly identical image geometry; specialized positioning devices and bite registrations aid in matching the images. The subtracted image is a composite of the images, representing their variations in density. By subtracting all anatomic structures that have not changed between radiographic examinations, changes in diagnostic information become easier to interpret. Any change is displayed on the resultant image against a neutral, gray background. Recently, advances in computer technology have incorporated built-in algorithms to correct for variations in exposure and projection geometry. These advances have also enabled colorization of density changes so that hard tissue gain is represented by one color and hard tissue loss is represented by another color.

**Orascopy and Endoscopy**

Orascopy (Fig. 5–18, A), or endoscopy, is a new method for enhanced visualization in endodontics using a flexible, fiberoptic endoscope. These fiberoptic probes are available in various diameters; the probes provide a large depth of field, and refocusing is not needed after the initial focus. Once the probe is applied, the
clinician views the conventional or surgical site from the magnified image displayed on the monitor. Endoscopic endodontics allows the clinician to have a nonfixed field of vision, and probes can be manipulated at various angles and distances from an object without loss of focus or image clarity. With orascopy, finite fracture lines, accessory canals, missed canals and isthmuses, and apical tissues can be viewed (see Fig. 5–18, B to E). Evolving technology will likely enhance the precision and accuracy of the fiberoptic probes.

**Figure 5-18**  A, Orascope instruments include various diameter probes. B, Endoscopic view of lateral canal at resected root end. C, Endoscopic view of resected root end after removal of lateral canal. D, Endoscopic view of ultrasonic preparation of isthmus and lingual canal at resected root end. E, Endoscopic view of Stropko syringe at prepared root end. *(Courtesy Dr. Barnet B. Shulman.)*
PREPARATION FOR ACCESS: TOOTH ISOLATION

Principles and Rationale

The use of the rubber dam is mandatory in root canal treatment. Developed in the nineteenth century by S.C. Barnum, the rubber dam has evolved from a system that was designed to isolate teeth for placement of gold foil to one of sophistication for the ultimate protection of both patient and clinician. The advantages and absolute necessity of the rubber dam must always take precedence over convenience and expediency (a rationale often cited by clinicians who condemn its use). When properly placed, the rubber dam facilitates treatment by isolating the tooth from obstacles (e.g., saliva, tongue) that can disrupt any procedure. Proper rubber dam placement can be done quickly and will enhance the entire procedure.

The rubber dam is used in endodontics because it ensures the following:

1. Patient is protected from aspiration or from the swallowing of instruments, tooth debris, medicaments, and irrigating solutions.
2. Clinician is protected from litigation because of patient aspiration or swallowing of an endodontic file.
3. A surgically clean operating field is isolated from saliva, hemorrhage, and other tissue fluids. The dam reduces the risk of cross contamination of the root canal system, and it provides an excellent barrier to the potential spread of infectious agents. It is a required component of any infection control program.
4. Soft tissues are retracted and protected.
5. Visibility is improved. The rubber dam provides a dry field and reduces mirror fogging.
6. Efficiency is increased. The rubber dam minimizes patient conversation during treatment and the need for frequent rinsing.

The dentist should be aware that in some situations, especially in teeth with crowns, access into the pulp system may be difficult without first orienting root structure to the adjacent teeth and periodontal tissues. Radiographically, the coronal pulp system is often obscured by the restoration, and, as a result, the dentist may misdirect the bur during access. In these cases it may be necessary to locate the canal system before placing the dam. In doing so the dentist can visualize root topography, making it easier to orient the bur toward the long axis of the roots and prevent perforation. Once the root canal system is located, however, the rubber dam should be immediately placed.

* References: [1][2][3][4][5][6][7][8][9][10][11][12][13]

Armamentarium

The mainstay of the rubber dam system is the dam itself. These autoclavable sheets of thin, flat latex come in various thicknesses (e.g., thin, medium, heavy, extra-heavy, special heavy) and in two different sizes (5 × 5 inches and 6 × 6 inches). For endodontic purposes, the medium thickness is probably best because it tends to tear less easily, retracts soft tissues better than the thin type, and is easier to place than the heavier types. However, a thinner gauge may be desirable to decrease tension if retainer placement is questionable or if the retainer is resting on a band. The dam is also manufactured in various colors, ranging from light yellow to blue to green to gray. The darker-colored dams may afford better visual contrast, thus reducing eye strain. However, the lighter-colored dams, because of their translucency, have the advantage of naturally illuminating the operating field and allowing easier film placement underneath the dam. Depending on individual preference and specific conditions associated with a tooth, the clinician may find it necessary to vary the color and thickness of the rubber dam used. Glare and eyestrain can be reduced and contrast enhanced by routinely placing the dull side of the dam toward the operator.

For patients with latex allergies, a nonlatex rubber dam is available from Coltene/Whaledent, Inc. (Fig. 5–19). This powder-free, synthetic dam comes in one size (6 × 6 inches) and in one thickness (medium gauge). It has a shelf life of 3 years but only one third the tensile strength of a latex dam. Other companies provide nitrile rubber dams.
Another component of the rubber dam system is the rubber dam frame, which is designed to retract and stabilize the dam. Both metal and plastic frames are available, but plastic frames are recommended for endodontic procedures. They appear radiolucent, do not mask key areas on working films, and do not have to be removed before film placement. The Young’s rubber dam frame (plastic type), the Star Visi frame, and the Nygaard-Ostby (N-O) frame are examples of radiolucent frames used in endodontics (Fig. 5–20). New to endodontics is a specially designed foldable plastic frame (Fig. 5–21), with a hinge to facilitate film or sensor placement without disengaging the entire frame. The disposable Insti-Dam (Fig. 5–22) and Handidam (Aseptico, Woodinville, WA) rubber dam system also provide a radiolucent plastic frame. The Quickdam (Ivoclar/Vivadent, Amherst, NY) is another disposable single-isolation device with a flexible outer ring, eliminating the need for an additional frame. Although metal frames (see Fig. 5–20) can be used, their radiopacity tends to block out the radiograph. If removed, this may result in destabilization of the dam and salivary contamination of the canal system, negating the disinfected environment that was previously attained.

Figure 5-19  Nonlatex dental dam is ideal for patients with known latex allergies. (Courtesy Coltene/Whaledent, Inc., Cuyahoga Falls, OH.)

Figure 5-20  Plastic radiolucent and metal rubber dam frames. Top left, Young’s frame. Top center, Nygaard-Ostby (N-O) frame.
Rubber dam clamps or retainers anchor the dam to the tooth requiring treatment or, in cases of multiple-tooth isolation, to the most posterior tooth. They also aid in soft-tissue retraction. These clamps are made of stainless steel, and each consists of a bow and two jaws. Regardless of the type of jaw configuration, the prongs of the jaws should engage at least four points on the tooth. This four-point clamp-to-tooth relationship stabilizes the retainer and prevents any rocking, which in itself can be injurious to both hard and soft tissues.

Clamps are available from a variety of manufacturers and are specifically designed for all classes of teeth with a variety of anatomic configurations (Fig. 5-23). For most uncomplicated endodontic isolations, the clinician’s basic armamentarium should consist of winged clamps, a butterfly-type clamp for anterior teeth, a universal premolar clamp, a mandibular molar clamp, and a maxillary molar clamp. The wings, which are extensions of the jaws, not only provide for additional soft-tissue retraction but also facilitate placement of the rubber dam, frame, and retainer as a single unit (see “Methods of Rubber Dam Placement”).

Figure 5-21  Foldable plastic rubber dam frame (Plast-Frame) with hinge to allow for easy film/sensor placement. (Courtesy Hager Worldwide, Odessa, FL.)

Figure 5-22  Insti-Dam is a disposable dam system available in both latex and nonlatex. A, Bendable flexible frame allows for easy placement. B, Use of Insti-Dam during endodontic treatment. (Courtesy Zirc Company, Buffalo, MN.)
Other retainers are designed for specific clinical situations in which clamp placement may be difficult. For example, when minimal coronal tooth structure remains, a clamp with apically inclined jaws may be used to engage tooth structure at or below the level of the free gingival margin. Retainers with serrated jaws, known as tiger clamps, also may increase stabilization of broken-down teeth. Another type of retainer, the S-G (Silker-Glickman) clamp, should also be included in the dentist’s armamentarium (Fig. 5-24). Its anterior extension allows for retraction of a dam around a severely broken-down tooth, and the clamp itself is placed on a tooth proximal to the one being treated.

The remaining components of the rubber dam system include the rubber dam punch and the rubber dam forceps. The punch has a series of holes on a rotating disk from which the clinician can select according to the size of the tooth or teeth to be isolated. The forceps holds and carries the retainer during placement and removal.

**Methods of Rubber Dam Placement**

As mentioned earlier, an expedient method of dam placement is to position the bow of the clamp through the hole in the dam and place the rubber over the wings of the clamp (a winged clamp is required) (Fig. 5-24). The forceps stretch the clamp to maintain the position of the clamp in the dam, and the dam is attached to the plastic frame, allowing for the placement of the dam, clamp, and frame in one motion (Fig. 5-25). Once the clamp is secured on the tooth, the dam is teased under the wings of the clamp with a plastic instrument.
Another method is to place the clamp, usually wingless, on the tooth and then stretch the dam over the clamped tooth (Fig. 5-26).\[28\][60] This method offers the advantage of enabling the clinician to see exactly where the jaws of the clamp engage the tooth, thus avoiding possible impingement on the gingival tissues. Gentle finger pressure on the buccal and lingual apron of the clamp before the dam is placed can be used to test how securely the clamp fits. Variations of this method include placing the clamp and dam first, followed by the frame, or placing the rubber dam first, followed by the clamp and then the frame.\[60\]

A third method, the split-dam technique, may be used to isolate anterior teeth without using a rubber dam clamp. Not only is this technique useful when there is insufficient crown structure, as in the case of horizontal fractures, but also it prevents the possibility of the jaws of the clamp engaging the tooth, thus avoiding possible impingement on the gingival tissues. Studies\[37\][45][45] on the effects of retainers on porcelain-fused-to-metal restorations and tooth structure itself have demonstrated that there can be significant damage to cervical porcelain, as well as to dentin and cementum, even when the clamp is properly stabilized. Thus for teeth with porcelain restorations, ligation with dental floss is recommended as an alternate method to retract the dam and tissues, or the adjacent tooth can be clamped.

In the split-dam method (Fig. 5-27), two overlapping holes are punched in the dam. A cotton roll is placed under the lip in the mucobuccal fold over the tooth to be treated. The rubber dam is stretched over the tooth to

Figure 5-25 A. Rubber dam, clamp, and frame. B. Dam, clamp, and frame carried to mouth as one unit and placed over the tooth. C. Clamp in place with four-point contact and rubber tucked under the wings.

Figure 5-26 A. After the clamp is placed, the dam is attached to the frame and gently stretched over the clamped tooth with the index finger of each hand. B. Clamp is tested for a secure fit with gentle finger pressure (alternately) on the buccal and lingual aspects of the clamp apron.
be treated and over one adjacent tooth on each side. The edge of the dam is carefully teased through the contacts on the distal sides of the two adjacent teeth. Dental floss helps carry the dam down around the gingiva. The tension produced by the stretched dam, aided by the rubber dam frame, secures the dam in place. The tight fit and the cotton roll help produce a relatively dry field. If the dam has a tendency to slip, a premolar clamp may be used on a tooth distal to the three isolated teeth or even on an adjacent tooth (see Fig. 5–27, A). The clamp is placed over the rubber dam, which then acts as a cushion against the jaws of the clamp.

Figure 5–27 Split-dam technique. A, Premolar clamp on maxillary central incisor along with ligation on the maxillary canine prevents dam slippage and aids in dam retraction during endodontic treatment on broken-down maxillary lateral incisor. B, Split dam used during post removal and retreatment of a maxillary central incisor. (A Courtesy Dr. James L. Gutmann. B Courtesy Dr. Francisco A. Banchs.)

Aids in Rubber Dam Placement

Punching and Positioning of Holes

The rubber dam may be divided into four equal quadrants, and the proper place for the hole is estimated according to which tooth is undergoing treatment. The more distal the tooth, the closer to the center of the dam the hole is placed. This method becomes easier as the clinician gains experience. The hole must be punched cleanly, without tags or tears. If the dam is torn, it may leak or permit continued tearing when stretched over the clamp and tooth.

Orientation of the Dam and Bunching

The rubber dam must be attached to the frame with enough tension to retract soft tissues and prevent bunching, without tearing the dam or displacing the clamp. The rubber dam should completely cover the patient’s mouth without infringing on the patient’s nose or eyes. To prevent bunching of the dam in the occlusal embrasure, only the edge of the interseptal portion of the dam is teased between the teeth. Dental floss is then used to carry the dam through the contacts. These contacts should always be tested with dental floss before the dam is placed. A plastic instrument is used to invert the edge of the dam around the tooth to provide a seal.

Problem Solving in Tooth Isolation

Leakage

The best way to prevent seepage through the rubber dam is meticulous placement of the entire system. Proper selection and placement of the clamp; sharply punched, correctly positioned holes; use of a dam of adequate thickness; and inversion of the dam around the tooth all help reduce leakage through the dam and into the root canal system.[36][44][60] Nevertheless, there may be clinical situations in which small tears, holes, or continuous minor leaks may occur. These often can be patched or blocked with Cavit, OraSeal Caulking, rubber base adhesive,[9] “liquid” rubber dam, or periodontal packing. If leakage continues, the dam should be replaced with a new one.

Because salivary secretions can seep through even a well-placed rubber dam, persons who salivate
excessively may require premedication to reduce saliva flow to a manageable level. Failure to control salivation may result in salivary contamination of the canal system and pooling of saliva beneath the dam, as well as drooling and possible choking. Such occurrences can disrupt treatment and should be prevented. Excessive saliva flow can be reduced with an anticholinergic drug, such as atropine sulfate, propantheline bromide (Pro-Banthine), methantheline (Banthine), or glycopyrrolate (Robinul). Therapeutic doses of atropine sulfate for adults range from 0.3 to 1 mg PO, 1 to 2 hours before the procedure. The synthetic anticholinergic drug propantheline bromide reportedly has fewer side effects than methantheline. The usual adult dose of propantheline bromide for an adult is 7.5 to 15 mg, taken orally 30 to 45 minutes before the appointment. Because anticholinergics can cause undesirable autonomic effects, especially through various drug interactions, they should be used only in specific cases and only as a last resort.

Unusual Tooth Shapes or Positions That Cause Inadequate Clamp Placement

Some teeth do not conform to the variety of clamps available. These include partially erupted teeth, teeth prepared for crowns, and teeth fractured or broken down to the extent that their margins are subgingival. To handle these cases, rubber dam retainers may be customized by modifying the jaws to adapt to a particular tooth (Fig. 5–28). In partially erupted teeth or cone-shaped teeth, such as those prepared for full coverage, one technique is to place spots of self-curing resin on the cervical surface of the tooth. These resin beads act as a scaffold for the retainer during treatment. Another method is to place small acid-etched composite lips on the teeth; these resin lips serve as artificial undercuts and remain on the teeth between appointments. When the root canal treatment is complete, the resin beads are easily removed. In multiple-treatment cases involving misshapen teeth, a customized acrylic retainer can be used in conjunction with a dam to isolate the operating field.

![Figure 5-28](http://home.mdconsult.com.eprxy1.lib.hku.hk/das/book/body/0/1357/3...)

Loss of Tooth Structure

If insufficient tooth structure prevents the placement of a clamp, the clinician must first determine whether the tooth is periodontally sound and restorable. Meticulous and thorough treatment planning often can prevent
embarrassing situations for both the doctor and patient. One example is the case in which the endodontic
treatment is completed before restorability is determined; it is then discovered that the tooth cannot be
restored.

Once a tooth is deemed restorable but the margin of sound tooth structure is subgingival, a number of
methods should be considered. As mentioned earlier, less invasive methods, such as using a clamp with
prongs inclined apically or using an S-G clamp, should be attempted first (see Fig. 5-24). If neither of these
techniques effectively isolates the tooth, the clinician may consider the clamping of the attached gingiva and
alveolar process. In this situation it is imperative that profound soft-tissue anesthesia exists before clamp
placement. Although the procedure may cause some minor postoperative discomfort, the periodontal tissues
recover quickly with minimal postoperative care.

Restorative Procedures

If none of the techniques mentioned previously are desirable, a variety of restorative methods may be
considered to build up the tooth so that a retainer can be placed properly. A preformed copper band,
a temporary crown, or an orthodontic band (Figs. 5-29 and 5-30) may be cemented over the remaining
natural crown. This band or crown not only enables the clamp to be retained successfully but also serves as a
seal for the retention of intracanal medicaments and the temporary filling between appointments. These
temporary bands or crowns have several disadvantages. One of their main problems is their inability to
provide a superior seal. Another concern is that particles of these soft metals or cement can block canal
systems during access opening and instrumentation. Third, these temporary crowns and bands, if they
become displaced or are not properly contoured, can cause periodontal inflammation.

![Figure 5-29](http://home.mdconsult.com.eproxy1.lib.hku.hk/das/book/body/0/1357/3...)

A, Preoperative radiograph of mandibular premolar region depicts limited supracrestal tooth structure. B, Bony
exostoses and minimal tooth structure make it a difficult case for tooth isolation. C, Fitted orthodontic bands on mandibular premolars.
D, Orthodontic bands cemented in place with IRM (i.e., reinforced zinc oxide–eugenol cement). E, Effective isolation with rubber dam clamp placed on distal tooth. (Courtesy Dr. Robert Roda.)
Occasionally so little tooth structure remains that even band or crown placement is not possible. In these cases it becomes necessary to replace the missing tooth structure to facilitate placement of the rubber dam clamp and prevent leakage into the pulp cavity during the course of treatment. Replacement of missing tooth structure can be accomplished by means of pin-retained amalgam buildups; composites; glass ionomer cements, such as Ketac-Silver, Fuji II (Fig. 5-31), or Photac-Fil; or dentin-bonding systems, such as Scotchbond 2, Tenure Bond, Gluma, Optibond, PermaQuik, or C&B Metabond. Although these newer dentin-bonding systems form a very strong immediate bond and are generally simple to use, any restorative method for building up a broken-down tooth is time consuming, can impede endodontic procedures, and may duplicate restorative treatment. Many restorations that have been hollowed out by access cavities are weakened and require redoing.

Figure 5-30  A, Broken-down maxillary molar after removal of restoration, post, and caries. B, Fitted orthodontic band; cotton in access opening to protect orifices. C, IRM loaded into band before cementation. D, Completed temporary restoration before rubber dam placement. (Courtesy Dr. Robert Roda.)
Canal Projection

Canal projection is a technique that facilitates preendodontic buildup of broken-down coronal and radicular structure while preserving individualized access to the canal. Although any of a number of syringeable materials (glass ionomer cements, temporary cements, permanent cements, etc.) and even “packable” composites may be used to project the canals, bonded injectable autopolymerizing composites have proven to be the most versatile and reliable buildup material for this technique (Fig. 5-32). The advantages of the technique are numerous:

1. Isolation. When deep coronal-radicular defects prevent clamp retention, a tooth is often considered to be endodontically untreated. Canal projection essentially replaces missing structures to facilitate clamp retention, rendering many structurally debilitated teeth endodontically treatable.

2. Seal of chamber floor. The accessory canals that exit the chamber floor into the furcation are well documented and can conduct inflammatory agents from the deteriorating pulpal system into the furcation. In addition, when caries or exploratory procedures lead to a paper-thin chamber floor, the risk of contaminants extending into the furcal apparatus increases significantly. Often such complicated cases require multiple visits, and the interappointment interval with customary temporary coronal seal provides opportunities for serious furcation degradation, particularly if a patient does not return in a timely fashion for completion of treatment. Sealing the chamber floor early in treatment greatly reduces this risk. As an initial step in the endodontic process, canal projection using bonded composite achieves this early objective.

3. Elongation of canals. The canal projection process elongates the “hydraulic chamber” of each canal from the access cavity floor to the occlusal surface, offering advantages during the hydraulic condensation of obturation materials. Essentially all currently accepted warm vertical compaction techniques (conventional warm vertical compaction, warm sectional compaction, continuous wave compaction) rely on the rheology that takes place between the chamber floor and the primary exit of the canal. These methods focus their hydraulic effects on the apical region while only incidentally addressing those accessory and lateral canals that exit from the more coronal aspects of the system. In contrast, when the canal is projected, the hydraulic chamber is elongated as much as 5 to 10 mm such that the rheology occurs not just between the chamber floor and the primary canal exit but also between the occlusal surface and the primary exit. This allows for additional warm vertical compaction “strokes,” additional warm “sections” of gutta-percha, or additional milliseconds spent in the continuous wave of compaction. Regardless of which hydraulic condensation method is used, canal projection provides greater opportunity to address coronally positioned exits.

Figure 5-31 A. Broken-down mandibular molar after crown and caries removal; preexisting pin will aid retention of restorative material. B. Isolation with wedged Automatrix. C. Completed temporary restoration using glass ionomer cement (Fuji II). D. Access through completed restoration after rubber dam placement. (Courtesy Dr. Robert Roda.)
4. Overlay of perforation repair. Early repair of perforation defects can have a significant effect on success of perforation treatment. As such, performing perforation repair before completion of endodontic therapy is often preferable. The delicate nature of these types of repairs, however, leaves them vulnerable to reaggravation during subsequent cleaning, shaping, and obturation procedures. It can be most disheartening to perform a complicated perforation repair procedure only to see it herniate into adjacent periodontal ligament and bone under obturation hydraulics. Delaying the repair until endodontic therapy is completed may put the tooth at risk if the treatment cannot be completed in a single visit. In addition, performing endodontic therapy in the presence of an unrepaired perforation may needlessly expose the perforation site to irritating solvents and irrigants and to accidental penetration by instruments. In many cases, perforation repair with mineral trioxide aggregate (MTA) can be performed before completion of endodontic therapy.[27 After confirmation that the MTA has set, canal projection offers a means of fortifying the repair by overlaying it with a bonded resin or glass ionomer before proceeding with endodontic therapy.

5. Prevention of perforation. In those circumstances that lead to a paper-thin chamber floor, the risk of inadvertent perforation with a file, explorer, or bur can be reduced or eliminated by placing a preendodontic buildup via canal projection.

6. Recontour of irregularities on chamber floor and walls. Irregularities on the access cavity floor and walls can lead to complications during treatment. Misdirected access cavities, divots in walls, misdirected post preparations and ledges, and so on can be “corrected” by essentially reconstructing the walls and floor around “internal matrix barriers” via canal projection.

7. Reduced potential for crack initiation or propagation. On posterior teeth in particular, the period between initiation of endodontic therapy and placement of a restoration that provides cuspal protection can introduce the risk of coronal-radicular fracture—the longer the time period, the greater the risk. Bonded coronal buildup has been shown to reduce this risk.[23 Bonded canal projection performed at the first endodontic treatment visit imparts a measure of protection against the development of a fracture from the time treatment is initiated until the tooth is permanently restored. In teeth that present with incipient fractures, early placement of a bonded buildup can reduce the likelihood of propagation of these fractures as well.

8. Prevention of ingrowth of tissues. When coronal or radicular defects extend to axial walls at or beyond the gingival level, tissue ingrowth leads to contamination during endodontic therapy and subsequent restorative procedures. Preendodontic buildup, as with canal projection, eliminates this complexity.

9. Individualization of canals. In multicanal teeth, as the projectors pass through the buildup material to the occlusal surface, they can be oriented such that they are slightly separated from each other before the buildup material polymerizes. This can simplify management of canals that lie in close proximity to each other on the chamber floor. It also provides for individualization of the canals so that specific solvents, irrigants, medicaments, lubricants, and other agents can be placed into specific canals.

10. Elimination of “blind exploration” on the chamber floor and improvement of mechanics related to handpiece-driven files. Once all canals have been located, straight-line access created, and the canals projected to the occlusal surface of the buildup, the resultant projected orifices will lie clearly visible on the surface of the projection buildup, no longer obscured by prominent marginal ridges and other visual obstructions. This also creates a significant advantage for entry of handpiece-driven files—particularly nickel-titanium files—into mesial canals of molars. By virtue of their increased long-axis dimension, the tips of handpiece-driven files can be difficult to introduce into mesial canals, and nickel-titanium files are even more difficult because they will not retain a bend. When the canals are projected onto the occlusal surface of the preendodontic buildup, however, it becomes a simple matter to place the file tip within the rim of the projected canal on the occlusal surface, and then by merely advancing the file, it is driven smoothly into the canal.
Periodontal Procedures

As a result of excessive crown destruction or incomplete eruption, the presence of gingival tissue may preclude the use of a clamp without severe gingival impingement. Various techniques of gingivectomy (Fig. 9–33) or electrosurgery have been suggested for cases in which the remaining tooth structure still lies above the crestal bone. With an inadequate zone of attached gingiva, osseous defects, or a poor anatomic form, an apically positioned flap with a reverse bevel incision is the technique of choice to “lengthen” the crown. [43][44]
Electrosurgery and the conventional gingivectomy are crown-lengthening procedures for teeth that have sufficient attached gingiva and no infrabony involvement. The electrosurgery method offers the advantage of leaving a virtually bloodless site for immediate rubber dam placement. Electrosurgery units have become highly sophisticated and are capable of providing both cutting and coagulating currents that, when used properly, will not cause cellular coagulation. The wide variety of sizes and shapes of surgical electrodes enables the clinician to reach areas inaccessible to the scalpel. Further, electrosurgery facilitates the removal of unwanted tissue in such a manner as to re-create normal gingival architecture. This feature, combined with controlled hemostasis, makes the instrument extremely useful in the preparation of some teeth for placement of the rubber dam clamp.

The main drawback of electrosurgery is the potential for damage to the adjacent tissues; if the electrode contacts bone, significant destruction of bone can occur. As a result this technique is not recommended when the distance between the crestal level of bone and the remaining tooth structure is minimal. Compared with electrosurgery, conventional gingivectomy presents the major problem of hemorrhage after the procedure; this forces delay of endodontic treatment until tissues have healed.

The apically positioned flap is a crown-lengthening technique for teeth with inadequate attached gingiva, infrabony pockets, or remaining tooth structure below the level of crestal bone. With this technique as well, endodontic treatment should be delayed until sufficient healing has occurred.

Figure 5-33  A. Gingival hypertrophy on mandibular molar and erupting premolar of young patient; mandibular molar requires root canal treatment. B. Rubber dam clamp impinging on gingival tissues; tissue removed with scalpel. C. Automatrix placed immediately after tissue removal; bleeding was minimal. D. Placement of IRM temporary restoration after pulpectomy. E. Postoperative facial view immediately after gingivectomy; note homeostasis. F. Six-week postoperative occlusal view exhibits fully exposed mandibular molar and recently erupted premolar. (Courtesy Dr. Robert Roda.)
Orthodontic Procedures

The most common indication for orthodontic extrusion is a fracture of the anterior tooth margin below the crestal bone. The clinician should be aware that, because bone and soft-tissue attachments follow the tooth during extrusion, crown-lengthening procedures after extrusion are often necessary to achieve the desired clinical crown length and restore the biologic and aesthetic tissue relationships. Ultimately, the purpose of orthodontic extrusion is to erupt the tooth to provide 2 to 3 mm of root length above crestal bone level.
SUMMARY

Success in endodontic therapy is predicated on a host of factors, many of which are controllable before the clinician ever initiates treatment. Proper and thorough preparation of both patient and tooth for endodontic treatment should lay the groundwork for a relatively trouble-free experience that will increase the chances for the ultimate success of the entire treatment.
Chapter 6  – Armamentarium and Sterilization

Paul D. Eleazer

Preparation for endodontic treatment requires a somewhat different approach compared with many other types of dental therapy. Endodontic treatment breaks through the body’s primary protective barrier, the integumentary system. Teeth are a specialized part of this system that also includes skin and mucous membranes; collectively, the integumentary system serves to protect humans from invasion by microbes, among other functions. This barrier is breached when caries, trauma, or other insults provide entry into the pulp space of a tooth. Sterile instruments and proper technique are needed to avoid contamination by microorganisms or noxious chemicals during endodontic therapy.

The well-prepared clinician realizes that a postoperative infection could be caused by a break in sterile technique. The astute clinician realizes that time spent preoperatively in the organization and sterilization of instruments and supplies will lead to fewer postoperative patient problems and result in a more efficient practice.

In addition to the need for impeccable sterility, endodontics differs from many other aspects of dentistry. Access and visibility are severely limited by the nature of the irregular and branching canal spaces within the roots. Individual variation means that clinicians cannot know exactly what condition is present throughout the entire root canal system (see Chapter 7 for more details). Enhanced lighting and magnification have resolved visual access problems to some extent (Figs. 6–1, 6–2, 6–3, 6–4). Nevertheless, limitations remain and there continues to be a need for special instruments and techniques.

Figure 6-1  Surgical telescopes (loupes).  (Courtesy Orascoptic Research, Madison, WI.)

Figure 6-2  Light for loupes.  (Courtesy High Q Systems, Scottsdale, AZ.)
SELECTION OF THE ARMAMENTARIUM

Preparation for treatment begins with selection of the armamentarium for routine endodontic patient care. Instruments used for every patient should be assembled and sterilized before use. Box 6-1 lists a typical armamentarium that can be customized for the individual practitioner (Figs. 6-5, 6-6, 6-7).

Box 6-1

<table>
<thead>
<tr>
<th>Armamentarium for Routine Endodontic Patient Care</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mirror</td>
</tr>
<tr>
<td>Periodontal probe and standard dental explorer</td>
</tr>
<tr>
<td>Anesthetic syringe</td>
</tr>
<tr>
<td>Rubber dam instruments</td>
</tr>
</tbody>
</table>
Rubber dam punch  
Rubber dam clamp holder  
Rubber dam frame  

High-speed handpiece and burs  
Low-speed handpiece and burs  
Long shank excavator (31L)  
Canal irrigating syringe(s), with container(s) for solution(s)  
Mixing spatula and mixing surface  
Obturation instruments  
Plastic instrument for temporary filling

**Figure 6-5** IMS instrument cassette. *(Courtesy Hu-Friedy Company, Chicago.)*

**Figure 6-6** Cassette wrapped in porous autoclave paper in preparation for sterilization. *(Courtesy Hu-Friedy Company, Chicago.)*
Root canal instruments of appropriate length and type, including files, reamers, broaches, or specialized burs, may be sterilized separately because variables (e.g., tooth length, canal size, clinical diagnosis) may affect this part of the armamentarium. Additional items that are needed occasionally (e.g., chlorhexidine, intraosseous injection kit) should be in sterile containers and readily available to the dental assistant (Figs. 6–8 and 6–9). This approach provides a basic endodontic setup tray with optional items sterilized and ready for use in individual cases. The overarching philosophical approach is to develop a standard setup for all patients and to have readily available specialized kits for specific procedures or clinical situations.
Figure 6-9  Micro-Apical Placement device for insertion of MTA filling.  (Courtesy Roydent Dental Products.)
PREOPERATIVE STERILIZATION AND DISINFECTION

The next phase after selection of the armamentarium is developing a preoperative sterilization plan. Sterile is defined as the absence of life forms. Disinfection means killing most life forms, especially pathogens. As commonly used, the term disinfection does not include killing spores. Manufacturers’ claims for disinfectants are based on performance against Mycobacterium, which is the genus that includes the species that causes tuberculosis (TB). For assessing virucidal efficacy, the astute clinician should be aware that agents that kill the hardy hepatitis B virus will likely be effective at destroying all viruses.

The Centers for Disease Control and Prevention (CDC) released new guidelines for sterilization in 2003, and these are available on the Internet (http://www.cdc.gov/mmwr/preview/mmwrhtml/rr5217a1.htm). Box 6–2 lists the elements of a typical sterilization plan. These guidelines clarify the need for staff training programs to ensure that sterilization procedures are effective. Specific items include weekly monitoring of the effectiveness of the process with biologic monitors. In such systems, packets of spores are placed in the sterilizer for one cycle. The spores are then placed in growth medium to ensure that all have been killed. Overpacking the sterilizer is a common reason for inadequate sterilization because steam cannot penetrate well. Thus assessment of the effectiveness of the sterilization plan is an essential feature of preoperative planning (Fig. 6–10).

Box 6-2

<table>
<thead>
<tr>
<th>Elements of a Sterilization Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Transporting contaminated items from the operatory</td>
</tr>
<tr>
<td>a. Items must be stored in a container to prevent perforation</td>
</tr>
<tr>
<td>2. Instrument processing area</td>
</tr>
<tr>
<td>a. Instruments must be sorted, cleaned (e.g., removal of all visible debris by scrubbing, ultrasonic cleaner), and rinsed with water in an area separate from sterilization</td>
</tr>
<tr>
<td>b. Instruments should be inspected, assembled into trays, and wrapped for sterilization in packages containing sterilization indicator</td>
</tr>
<tr>
<td>c. Instrument packages should be sterilized using approved methods</td>
</tr>
<tr>
<td>d. Instruments should be stored for event-related use</td>
</tr>
<tr>
<td>3. Environmental infection control</td>
</tr>
<tr>
<td>a. Clinical contact surfaces (barrier protection, spray disinfectants)</td>
</tr>
<tr>
<td>b. Dental unit water lines</td>
</tr>
<tr>
<td>c. Housekeeping surfaces</td>
</tr>
<tr>
<td>4. Nonregulated and regulated medical waste</td>
</tr>
<tr>
<td>5. Monitoring plan</td>
</tr>
<tr>
<td>6. Training plan</td>
</tr>
</tbody>
</table>

Modified from CDC Guidelines for Infection Control in Dental Health-Care Settings 2003. Available at http://www.cdc.gov/mmwr/preview.
Monitoring of the sterilizer by watching the gauges or relying on printouts of temperature, pressure, and time helps to ensure patient safety, but weekly biologic monitoring guards against sensor failure. Heat-sensitive indicators, such as special tapes that change color when exposed to sterilizer temperatures, are also ineffective to ensure proper sterilization because these heat-sensing indicators merely show that the desired temperature has been reached, not that enough time has passed for proper killing. Accordingly, they are best used to simply record that the package was autoclaved; they should not be inferred to indicate sterility.

Further guidelines about sterilizers include drying of instruments before removing from the sterilizer. Wet wraps may tear easily or allow microbes to reach the sterile contents. In addition, cooling avoids thermal injury to personnel. Some of the new sterilizers work faster because they vacuum air from the chamber before sterilization; these models also cool faster because of a second vacuum cycle after sterilization.

Another guideline reinforces the previous policy that the pathway from the sterilizer to the point of use should not cross the path of contaminated instruments as they are brought from the treatment area, cleaned, and packaged for resterilization. Thus separate areas are required for cleaning/sorting/packaging and for sterilization and cool down.

Approved methods of sterilization include pressurized steam (autoclaving), pressurized heated chemicals, dry heat, and cold chemicals (Figs. 6–11, 6–12, 6–13). Cold chemicals are not favored because the time cycle is difficult to monitor; they are recommended only for those items that cannot be heat sterilized. Room temperature chemical sterilants are not time efficient enough to be popular in dentistry. Cold sterilants generally require extended soak times. Their proper use necessitates rinsing in sterile water to remove traces of disinfectant and handling with sterile tongs or sterile gloves to place them in a sterile storage container following treatment. Cold sterilants are poisonous and can be harmful to patients, even in small amounts.
Autoclaving is the typical method of sterilization for most health care facilities. The usual cycle is 30 minutes at 250°F (121°C) at 15 psi. Flash sterilization at higher temperatures of 273°F (134°C) for 10 minutes and 30 psi is also approved. The Statim brand autoclave uses the higher temperatures to reduce cycle time.

Chemiclave uses a solution of 72% ethanol and 0.23% formaldehyde in place of water in its “autoclave.” This avoids the instrument corrosion typical of steam autoclaves. They use 270°F (132°C) at 20 psi for 20 minutes, including drying time. Arguably a longer cycle time may be needed to meet guidelines for safety margins.[17] Ventilation or filtration is required to handle formaldehyde fumes. Chemiclave chemicals can dissolve into liquids, so liquids should be steam autoclaved.

Dry heat sterilizers, either still air in an oven or forced air, also avoid corrosion of instruments. After preheating the instruments to sterilizing temperature, still air models provide sterility in 1 hour at 375°F (191°C). The Cox sterilizer uses forced hot air of the same temperature and sterilizes in 6 minutes. Wrapped packs increase the time needed for processing. Hot air sterilizers may require special wraps.
In-operatory sterilizers were once popular among clinicians for decontaminating instruments during treatment. Such sterilizers achieved 450°F (218°C), and typical cycles were a few seconds for metal instruments. Glass beads or salt were used to transfer dry heat to endodontic canal instruments. These sterilizers are no longer approved for use because of the possibility that practitioners relied on them for sterilization between patients. One study found that they were ineffective at killing spores on cotton and paper products. Endodontic instruments used for recapitulation in a canal as it is progressively decontaminated may be disinfected chemically.

Following patient treatment, barriers should be removed and surfaces disinfected (Fig. 6-14). Aerosols generated by dental care can land anywhere, so all surfaces that may be touched during treatment of the next patient should be disinfected. Special attention should be given to instrument holders and hoses. Door and drawer pulls should be included in the disinfection routine or covered with barriers. Pens, pencils, and even patient charts should be considered contaminated.

Disinfection of the treatment room includes wiping all surfaces to be used with an appropriate disinfectant. Governmental agencies catalog such disinfectants as low-level and intermediate-level disinfectants, and Table 6-1 lists examples. High-level disinfectants are cold sterilizers. Low-level disinfectants are for surfaces that are not contaminated by blood. In dentistry, blood contamination is likely, so intermediate-level disinfectants seem appropriate. Many low-level disinfectants are the same chemicals found in higher-level disinfectants. Stronger concentrations often allow a given chemical to be classed higher.

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>SPECTRUM</th>
<th>USE</th>
<th>EXAMPLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low level</td>
<td>Bacteria except mycobacteria and spores</td>
<td>Surfaces without blood</td>
<td>Quaternary ammoniums, some phenolics, some iodofors</td>
</tr>
<tr>
<td></td>
<td>Some fungi and some viruses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate level</td>
<td>Mycobacteria, not spores</td>
<td>Surfaces with blood</td>
<td>Quaternary ammoniums with alcohol, chlorines, phenolics, iodofors</td>
</tr>
<tr>
<td></td>
<td>Most fungi and most viruses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High level</td>
<td>All microbes except spores</td>
<td>Immersion</td>
<td>Glutaraldehyde, strong peroxides, o-phthaldehyde</td>
</tr>
</tbody>
</table>

Note that high-level disinfectants are used as room temperature sterilizing solutions with extended contact times.

Following disinfection of the treatment surfaces, dental assistants should wash their hands and reglove before proceeding with barrier placement and opening of sterile packs. Fresh barriers should be placed on light handles, dental unit switches, chair controls, and so on. X-ray generators and microscopes can be effectively isolated by using large plastic bags, such as dental chair covers or laundry bags. Other items for barrier consideration include electric pulp testers and other thermal pulp testers. Recycled anesthetic cartridges used
for ice testing should be autoclaved before adding water and freezing.

Some people express concern that resistance to disinfectants may occur, as has happened with antibiotics. This is not likely because disinfectants (in appropriate concentration) kill rapidly, so bacteria are not able to adapt to them.

The current report of the CDC indicates that sterile packs will remain sterile if they remain dry in closed cabinets and if the sterile wrapping remains intact. This philosophy means that routine resterilization is not needed. Resterilization is indicated if the wrap has been exposed to fluids that may wick into the sterile side of the package or if an instrument has broken through the wrap. Packages should be dated for identification in case the biologic monitor shows incomplete spore kill.

An additional concern is microbes in dental water lines. Chlorination or other municipal disinfection has brought a substantial improvement in public health in the last century. However, these steps do not ensure sterile water. Just as dental plaque bacteria colonize on teeth and cause problems, plastic water lines within the dental unit are a haven for bacteria to colonize. The sticky, dental plaque-like water-line biofilm grows unhindered by the slow water movement in dental water lines. Bacteria from patients can travel upstream into dental water lines. The relatively small numbers of bacteria allowable in municipal water supplies flourish within the dental unit, even in independent water bottles. It is now known that biofilms establish themselves in these systems quickly. One approach to cleaning independent dental water lines is weekly use of strong chemicals, although staff compliance is a potential problem. Another approach is continuous use of low-concentration chemicals. Flushing water lines will not eliminate the biofilm, yet a 20- to 30-second flush between patients remains recommended to avoid microbes from one patient being transmitted to the next. Regular culturing of dental unit water lines remains the only method to ensure that a system meets the CDC and EPA no more than minimum standard of 500 colony-forming units (CFU) per milliliter of water.

![Figure 6-15](http://home.mdconsult.com.eproxy1.lib.hku.hk/das/book/body/0/1357/3...?2007-1-19

**Figure 6-15** Independent water source. Water is pressurized by compressed air. *(Courtesy DentalEZ, Bay Minette, AL.)*
The American Dental Association goal is less than 200 CFU/mL, and the European Union strives for less than 100 CFU/mL.

One can readily see that organization and quality control monitoring are essential to avoid contamination of the endodontic operating field. Organization should be a key item in assembling the armamentarium, sterilization of instruments before treatment, and preparation of the operating area with disinfectants and barriers. Attention to every detail is needed to avoid microbial contamination.
**TREATMENT**

Collection of a proper medical history is mandatory for proper treatment planning. Many examples illustrate the need for thorough consideration of medical aspects unique to each patient. For example, recent mutations of the tubercle bacillus, *Mycobacterium tuberculosis*, now endow it with resistance to multiple antibiotics. Infectious microscopic droplets hang in the air for hours after dental treatment, and this is a particular concern when treating TB patients. These droplets pose a serious risk for staff and other patients. For public health reasons, patients with active TB must be treated in a special negative-air pressure room. Treatment room air must be vented outside through high-efficiency filters that are then properly treated. The use of preoperative oral irrigants containing chlorhexidine gluconate has been recommended for reduction of microflora in aerosols.[11]

Patients with heart defects may also need special treatment.[8] Oral bacteria that escape from the oral cavity or from an endodontic infection can cause serious complications or even initiate disease in healthy hearts.

Clothing worn by office personnel is a concern for staff safety. The purpose of protective fabric is to avoid contamination of skin and street clothes. Regulations mandate coverage of forearms. The garment should be changed if visibly soiled or wet by potentially infectious matter. *The protective clothing should not be worn outside the office.* Laundering at home is a potential source of contamination of family members and is not allowed.

Eye protection and masks should be donned before washing and gloving. Glasses and masks protect thin mucous membranes from possible contamination. Documentation of virus transmission via the conjunctiva of the eye has resulted in the recommendation for protection of these membranes.[23] Risk of human immunodeficiency virus (HIV) transfer to a health care worker exposed by mucous membrane is estimated to be about 0.1%.[14] Eyeglasses should have side shields.

Microscope controls should be covered with a barrier, such as a large plastic bag used for laundry or a dental chair cover. The plastic can be torn and stretched over the objective lens. The eyepieces should be adjusted for use with glasses. Those who wear magnifying loupes should not adjust them during treatment unless followed by regloving. An assistant not involved with treatment may do so, or a barrier that can be immediately discarded may be used to adjust glasses or replace wet masks.

Masks commonly available for use in dentistry protect the wearer only partially. Small droplets containing bacteria can pass through most clinical masks. Wet masks are even less efficient and should be changed immediately. Masks that do not seal around the face fail to give maximal protection. The ideal mask has not yet been developed.

Dental treatment produces large amounts of potentially contaminated droplets during treatment. Rubber dam use reduces the aerosol, but infected pulp tissue can serve as a source for aerosol-borne biocontaminants. Most droplets from dental treatment quickly drop out of the air because of their relatively large size, but small particles can remain suspended in the air for long periods. Microbes are carried in these small droplets deep into lungs where they cause infection. Airborne transmission definitely accounts for spread of legionnaires’ disease, TB, severe acute respiratory syndrome (SARS), and influenza. Other diseases may spread by droplets. Use of a preprocedural mouth rinse reduces the aerosol along with proper high-velocity evacuation common in large-bore dental evacuators.[13][18]

Sterile gloves should be worn for surgical procedures. Exam-type gloves may harbor microbes from the point of manufacture or from contamination at the point of use. Hand lotions may degrade the rubber of gloves and should not be used until treatment has concluded for the day. Sharp jewelry and artificial nails can penetrate the gloves, even if such penetrations are too small to be seen; thus they should not be worn with gloves. The glove material weakens during use, especially when using hand files. Gloves should be changed between patients and more often if harshly used. Interruption of treatment to answer the telephone or to develop a radiograph presents an opportune time for fresh gloves.

Evaluation of sterile technique often discloses contamination early in the treatment process. Procedures such
as diagnosis or application of the rubber dam contaminate gloves. Gloves should be considered only a barrier for staff protection. Patient protection comes from careful attention to sterile technique, including not allowing nonsterile gloves to touch anything that will go into the root canal.

Because of the lack of total protection with gloves, it is recommended that a disinfectant hand wash be used. Chlorhexidine has a property called substantivity, meaning that it bonds to skin and maintains antibacterial action longer than other surgical scrubs. Alcohol-based hand rubs have recently become popular for hospital workers. Presently available waterless techniques appear less effective than a surgical soap and water method.[6]

Reducing bacteria within the oral cavity before treatment should be of concern to every practitioner for every procedure. Degerming the oral cavity with an appropriate mouthwash before treatment has been recommended by Bender[1] as a means of reducing bacteremia.[10]

Sterile technique should be used. Commonly the application of the rubber dam will contaminate gloves, and one approach is to change gloves after dam application. Another possibility is to have the assistant place the rubber dam and then reglove.

Sharps should be handled with caution. Needles should be recapped using one hand to avoid possible injury to the hand holding the needle cover. Needles are available that recap automatically. Scalpel blades should be placed and removed from the handle using a hemostat or needle holder, with consideration to where hands are positioned, to avoid an injury in case something slips.

Disinfection of the canal continues to be a heavily researched topic. Currently the only agent that dissolves pulp tissue is sodium hypochlorite. This explains its continued popularity among clinicians. Studies have demonstrated that 7 minutes of tissue contact time with sodium hypochlorite dissolved 75% of a tissue plug in vitro.[3][12][16] Dilute concentrations of sodium hypochlorite are less effective for dissolving remaining tissue, so the full-strength concentration is popular. However, it should be remembered that even dilute solutions can cause untoward reactions if injected periapically or exposed onto oral tissues. Another clinical use for sodium hypochlorite is for disinfection of gutta-percha cones. A 1-minute exposure to 1% or a 5-minute exposure to 0.5% has been shown to be an effective gutta-percha disinfectant[2].

Small instruments such as canal files may be dropped into a chairside container of disinfectant when no longer needed. This approach will provide some protection to staff members if they are accidentally stuck by an instrument in the cleaning and repackaging process. Such an approach will not positively ensure protection from infectious agents but will certainly reduce risk. Some practitioners have adopted the approach of using files as disposable instruments. Files require sterilization before treatment except those few sterilized by the manufacturer.[22] Following single use, files can be discarded in the chairside sharps container. This philosophy of single use has the added advantage of reducing the possibility of fracture of instruments caused by repeated use (see also Chapters 8 and 9).

An often overlooked clinical problem is decontamination of radiographs. The use of digital radiography has improved patient protection with single-use sleeves covering the digital sensor. Proper technique dictates placing the barrier over the digital sensor when other barriers are placed before treatment commences. The barrier should completely cover the holder or a sterilized holder or disposable holder used for each patient.

Conventional radiographic films or gloves worn from the treatment area into the developing area can contaminate this area. Staff should be required to disinfect conventional films and deglove before leaving the treatment room. Hand washing and regloving should occur before treatment continues.

Reusable instruments should be taken to a dedicated area for removal of gross debris by scrubbing or preferably by ultrasonic bath. The ultrasonic bath should be a germicide to minimize infection spread to office workers. The ultrasonic bath cover should be used to reduce aerosols.

If time is not available to clean instruments immediately, they should be placed in a disinfectant bath to prevent drying of foreign material on the instruments because dried material is more difficult to remove.

If scrubbing is the only feasible means of cleaning, heavy puncture-resistant gloves should be worn and brushes should be long handled to minimize risk of percutaneous injury. After the ultrasonic bath the instruments should be rinsed in tap water and wrapped for sterilization. Many offices favor cassette systems to lessen the risk of a stick injury. Staff should be advised of the risk of a sharp instrument protruding through an opening in a cassette, even one that is wrapped.
As instruments move along a path from dirty to clean and then sterile, the path should not cross itself in order to avoid cross contamination.
GENERAL CONSIDERATIONS FOR THE OFFICE

Government guidelines spell out requirements for staff education.[11] Staff meetings are strongly recommended because of the many advantages of well-educated personnel in the dental office. Proof of staff meetings should be kept in a log. Box 6–3 includes items for consideration.

Box 6-3

**Written Records for Consideration by Dental Practitioners**

1. Manufacturer safety data sheets (MSDSs)
2. Posting of Department of Labor policies, e.g., workers’ compensation; may vary by state
3. Written infection control plan, including the following:
   a. Infection control coordinator (perhaps the clinician)
   b. Annual record of employee training, with record of immediate training for new hires and those changing to jobs with patient contact
   c. Written plan for postexposure actions following potential infection transmission. Records of worker injury will necessitate a record that will remain in employee’s confidential record. The written plan should prearrange for the following:
      (1) Reporting criteria and procedures, to include date, time, and details of injury, and infectious status of patient (perhaps on a previously prepared reporting form)
      (2) Evaluation by a physician (establish a relationship with a physician before injury occurs)
      (3) Counseling (establish a relationship with a counselor before injury occurs)
      (4) Treatment (probably with the physician listed in [2])
      (5) Medical follow-up (probably with the physician listed in [2])
4. Vaccinations, with log of appropriate updates (boosters)
5. Log of skin test for tuberculosis, especially for baseline for new hires
6. Log of sterilizer monitoring
   a. Log of pressure, temperature, and time of each load
   b. Weekly log of results of biologic monitor for each sterilizer
7. Log of hand-washing education and critique of employees’ performance on a regular basis
8. Log of education about barrier placement need and technique and critique of employees’ performance on a regular basis
9. Log of sharps hygiene education and critique of employees’ performance on a regular basis
10. Log of annual review of exposure plan
11. Log of results of dental water monitoring
12. Log of medical and other waste education and critique of employees’ performance on a regular basis
13. Log of patients who make unscheduled return visits for possible infection control breach
14. Plan for health care workers infected with various agents, including possible restriction of patient contact and conditions for return to full duty (e.g., workers with hepatitis A are restricted from
Vaccinations for all employees working in the treatment room must include the hepatitis B series of three injections. Other vaccinations are recommended as a means of preventing disease. Such expense is minimal considering lost time and possible sequelae to valuable workers. Box 6-4 includes 2004 vaccination recommendations of the CDC.[11]

It is now evident that antibody levels to hepatitis B wane over time. CDC findings suggest that 60% of those vaccinated will have no detectable antibodies after 12 years.[3] Hepatitis B is a serious threat to unprotected individuals. The risk of clinical hepatitis B to an unvaccinated health care worker stuck with a needle from a patient positive for both hepatitis B surface antigen and hepatitis B e antigen is 22% to 31%.[4]

Janitors and those who dispose of dental office wastes must be protected from harm. They should be protected from sharps such as canal instruments that are misplaced in an area they will clean. Janitors need education in use of personal protective equipment, such as heavy gloves and appropriate disinfectants.

Dental offices do not generate large volumes of medical wastes.[20] Dental offices are estimated to generate only 1% to 2% of their waste as medical waste. The majority of waste is not subject to regulation. Used gloves, masks, and protective garb and barriers are not regulated waste.

Sharps are part of regulated medical waste. Sharps include needles, scalpel blades, endodontic instruments, and other items capable of breaking the skin. Used anesthetic cartridges are classified as sharps because they could break and cause an injury if placed in regular waste. Sharps should be discarded at the point of use in a rigid container with a biohazard label. After sealing this puncture-resistant container with a tamper-proof seal, the container can be discarded in normal fashion.

Regulated medical waste includes items soaked in blood or saliva, such as 2 × 2 inch gauze or cotton rolls. This type of medical waste must be sealed in a leak-resistant biohazard bag that does not contain sharps. This type of waste could be placed in a sharps container. State regulations should be consulted before discarding biohazard bags in regular waste.

Liquid medical wastes, such as contents of a vacuum system separator, can be disposed of in a sanitary sewer, although care should be taken to avoid splatter when pouring into a toilet or sink. Normal protective gear including office garb, eyeglasses, and mask is needed for pouring liquid medical waste into a drain.

Some municipalities mandate mercury separators (endodontic offices may be exempt). These separators remove the heavy metal before it enters the city waste system and help the local government comply with regulations regarding mercury in solid waste and effluent from sewage treatment.

Nitrous oxide scavengers remove some of the gas exhaled by patients. These devices reduce but do not eliminate the gas from the office. Scavengers are connected to the central dental vacuum system and require a high flow rate. The vacuum system exhaust should be piped outside rather than into the mechanical room.
where it may reenter the office air, because nitrous oxide interferes with deoxyribonucleic acid (DNA) synthesis. Further, nitrous oxide increases the rate of congenital abnormalities in children of both males and females exposed to the gas in the dental office environment. [7]
FUTURE CONSIDERATIONS

Patient concerns will likely surface as more knowledge about existing pathogens becomes apparent and new pathogens arise. Practitioners should be ready to modify their practices and procedures to allay fears. Increased use of disposable products is likely. Many clinicians are already using new canal files for each patient.

A potential threat on the horizon is prions (PREE-onz). Prions are glycoproteins found on cell surfaces. Modified versions of normal prions cause various slow-moving, often fatal diseases of the nervous system. Prions are extremely difficult to sterilize and have an affinity for stainless steel. They can be killed with certain caustic chemical treatment, such as sodium hydroxide. Current CDC recommendations for autoclaving call for double pressure at 132°F (56°C) for 4.5 hours.

Currently no vaccination exists against hepatitis C. Fortunately the rate of disease for health care workers is low. The estimates of disease from a needle stick range up to 7%.[21]

Other hazards may also arise. Clinicians must keep abreast of research findings and changes of guidelines from regulatory agencies. New inventions will help clinicians deal with the current threats both as immunizations and as innovations to make the workplace safer for staff and for patients.

Dental air may contain spores. Although this has not been found to be problematic at present, it presents a possible concern for the future.
References


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Chapter 7  – Tooth Morphology and Access Cavity Preparation

Frank J. Vertucci  James E. Haddix  Leandro R. Britto

This chapter is divided into eight major sections: (1) components of the root canal system; (2) root canal anatomy; (3) anatomy of the apical root; (4) objectives and guidelines for access cavity preparation; (5) mechanical phases of access cavity preparation; (6) challenging access preparations; (7) errors in access cavity preparation; and (8) morphology and access cavity preparations for individual teeth.

The hard tissue encompassing the dental pulp can take a variety of configurations and shapes. A thorough knowledge of tooth morphology, careful interpretation of angled radiographs, and adequate access to and exploration of the tooth’s interior are prerequisites for treatment. Magnification and illumination are indispensable aids. This chapter describes and illustrates tooth morphology and explains the techniques crucial to achieving unobstructed direct access to the root canal and apical foramina. Only after correct completion of this phase of therapy can the clinician perform thorough shaping and cleaning and three-dimensional (3-D) obturation. The optimal endodontic result is difficult to achieve if the access is not properly prepared. The clinician must have an understanding of the complexity of the root canal system to understand the principles and problems of shaping and cleaning, to determine the apical limits and dimensions of preparations, and to perform microsurgical procedures successfully.

Practitioners must have a knowledge of the internal anatomic relationships of teeth and must be able to visualize these relationships before undertaking endodontic therapy. Careful evaluation of two or more periapical radiographs, exposed at different horizontal angulations of the x-ray cone, is mandatory. These radiographs provide important information about root canal morphology. The clinician must keep in mind that the inclination of the x-ray tube significantly influences the ability to detect root canal systems present in premolar teeth. For example, if the horizontal angle is varied by 20 or 40 degrees, the number of root canals seen in the maxillary first and second premolars and the mandibular first premolars coincide with the number of canals actually present. In the mandibular second premolar, only the 40-degree horizontal angle correctly identifies the root canal morphology. The critical importance of a careful reading of each radiograph before and during root canal therapy is well recognized. As shown in a case report of five canals in a mandibular first molar, the radiographic appearance significantly aided recognition of the complex canal morphology. This study concluded that “any attempt to develop techniques that require fewer radiographs runs the risk of missing information which may be significant for the success of therapy.”

However, radiographs may not always determine the correct morphology, particularly when only a buccolingual view is taken. In one study, 790 extracted mandibular incisors and premolars were radiographed to assess the incidence of canal bifurcation in a root. When the fast break guideline was used (i.e., disappearance or narrowing of a canal implies that it divides), the result was failure to diagnose one third of these divisions from a single radiographic view. Evaluation of the root canal system is most accurate when the clinician uses information from several radiographic views together with a thorough clinical exploration of the interior and exterior of the tooth.

Figure 7-1  Periapical radiographs can reveal clues to root canal morphology. Abrupt disappearance of the large canal in the mandibular premolars usually signifies a canal bifurcation.
The main objectives of root canal therapy are thorough shaping and cleaning of all pulp spaces and complete obturation of these spaces with an inert filling material. The presence of an untreated canal may be a reason for failure. A canal may go untreated because the clinician fails to detect it. It is extremely important that clinicians use all the armamentaria at their disposal to locate and treat the entire root canal system. The complexity of the spaces that must be accessed, shaped, cleaned, and filled is remarkable. However, even under the most difficult circumstances, current root canal techniques have an exceptionally high rate of success.

Diagnostic measures are important aids in the location of root canal orifices. These measures include obtaining multiple pretreatment radiographs, examining the pulp chamber floor with a sharp explorer, troughing grooves with ultrasonic tips, staining the chamber floor with 1% methylene blue dye, performing the sodium hypochlorite “champagne bubble” test (Fig. 7-2), and visualizing canal bleeding points. Sequential application of 17% aqueous ethylenediamine tetra-acetic acid (EDTA) and 95% ethanol (using the Stropko irrigator fitted with a 27-gauge notched irrigating needle) has been recommended for effective cleaning and drying of the pulp chamber floor before visual inspection of the canal system.[146]

An important aid for locating root canals is the dental operating microscope (DOM), which was introduced into endodontics to provide enhanced lighting and visibility (Fig. 7-3). The DOM enhances the clinician’s ability to remove dentin with great precision, thereby minimizing procedural errors. Numerous studies have shown that it also significantly improves the practitioner’s ability to locate and negotiate canals. For example, the number of second mesiobuccal (MB-2) canals identified in maxillary molars increased from 51% with the naked eye to 82% with the microscope.[4] In another study, 41.3% of MB-2 canals were identified when magnifying loupes were used, and 93.7% were identified when the DOM was used.[131] Other clinicians have noted that use of the DOM improves the detection of MB-2 canals to more than 90% in maxillary first molars and 60% in maxillary second molars.[75][146] All these studies demonstrate that magnification and illumination are essential components of root canal therapy. In contrast, one group of investigators determined that dental loupes and the DOM were equally effective for locating MB-2 canals in maxillary molars.[18] Other investigators determined that the DOM did not significantly enhance the ability to locate canals but did improve the ability to negotiate them.[62] Nevertheless, most clinicians would agree that the DOM makes canals easier to locate by magnifying and illuminating the grooves in the pulpal floor and by distinguishing the color differences of the dentin of the floor and walls.[67]
The entire space in the dentin where the pulp is housed is called the root canal system (Fig. 7–4). The outline of this system corresponds to the external contour of the tooth. However, factors such as physiologic aging, pathosis, and occlusion all modify its dimensions through the production of secondary and tertiary dentin and cementum. The root canal system is divided into two portions: the pulp chamber, located in the anatomic crown of the tooth, and the pulp or root canal(s), found in the anatomic root. Other features are the pulp horns; accessor, lateral, and furcation canals; canal orifices; apical deltas; and apical foramina. A root canal begins as a funnel-shaped canal orifice, generally at or apical to the cervical line, and ends at the apical foramen, which opens onto the root surface at or 3 mm from the center of the root apex. Nearly all root canals are curved, particularly in a faciolingual direction. These curvatures may pose problems during shaping and cleaning procedures because they are not evident on a standard facial radiograph. Angled views are necessary to determine their presence, direction, and severity. A curvature may be a gradual curve of the entire canal or a sharp curvature near the apex. Double S-shaped canal curvatures also can occur. In most cases the number of root canals corresponds to the number of roots; however, an oval root may have more than one canal.

Accessory canals are minute canals that extend in a horizontal, vertical, or lateral direction from the pulp to the periodontium. In 73.5% of cases they are found in the apical third of the root, in 11.4% in the middle third, and in 15.1% in the cervical third. These canals contain connective tissue and vessels but do not supply the pulp with collateral circulation. They are formed by the entrapment of periodontal vessels in Hertwig’s epithelial root sheath during calcification. Pathologically they are significant because they serve as avenues for the passage of irritants, primarily from the pulp to the periodontium.

Accessory canals may also occur in the bifurcation or trifurcation of multirooted teeth. Vertucci and Williams called these furcation canals (Fig. 7–5). Furcation canals form as a result of the entrapment of periodontal vessels during the fusion of the diaphragm, which becomes the pulp chamber floor. In mandibular molars these canals occur in three distinct patterns (Fig. 7–6). Tables 7–1 and 7–2 present the incidence of furcation canals for each tooth.
Figure 7-5  Mandibular first molar showing a furcation canal (FC, arrows). RC, Root canal; PC, pulp chamber floor; F, furcation.

Figure 7-6  Accessory canals occur in three distinct patterns in the mandibular first molars. A, In 13% a single furcation canal extends from the pulp chamber to the intraradicular region. B, In 23% a lateral canal extends from the coronal third of a major root canal to the furcation region (80% extend from the distal root canal). C, About 10% have both lateral and furcation canals.

Table 7-1  -- Morphology of the Maxillary Permanent Teeth[^1]

<table>
<thead>
<tr>
<th>TOOTH</th>
<th>ROOT</th>
<th>NUMBER OF TEETH</th>
<th>CANALS WITH LATERAL CANALS</th>
<th>POSITION OF LATERAL CANALS</th>
<th>TRANSVERSE ANASTOMOSIS BETWEEN CANALS</th>
<th>POSITIVE CERVICAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CERVICAL</td>
<td>MIDDLE</td>
<td>APICAL</td>
</tr>
<tr>
<td>Central</td>
<td>-</td>
<td>100</td>
<td>24</td>
<td>1</td>
<td>6</td>
<td>93</td>
</tr>
<tr>
<td>Lateral</td>
<td>-</td>
<td>100</td>
<td>26</td>
<td>1</td>
<td>8</td>
<td>91</td>
</tr>
<tr>
<td>Canine</td>
<td>-</td>
<td>100</td>
<td>30</td>
<td>0</td>
<td>10</td>
<td>90</td>
</tr>
<tr>
<td>First premolar</td>
<td>-</td>
<td>400</td>
<td>49.5</td>
<td>4.7</td>
<td>10.3</td>
<td>74</td>
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<tr>
<td>Second premolar</td>
<td>-</td>
<td>200</td>
<td>59.5</td>
<td>4</td>
<td>16.2</td>
<td>78.2</td>
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<tr>
<td>First molar</td>
<td>MB</td>
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<td>51</td>
<td>10.7</td>
<td>13.1</td>
<td>58.2</td>
</tr>
<tr>
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<td>DB</td>
<td>100</td>
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<td>12.3</td>
<td>59.6</td>
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<tr>
<td></td>
<td>P</td>
<td>100</td>
<td>48</td>
<td>9.4</td>
<td>11.3</td>
<td>61.3</td>
</tr>
</tbody>
</table>

[^1]: Adapted from [source].
According to the findings of scanning electron microscopy, the diameter of furcation openings in mandibular molars varies from 4 to 720 µm. The number of furcation canals ranges from none to more than 20 per specimen. Foramina on both the pulp chamber floor and the furcation surface were found in 36% of maxillary first molars, 12% of maxillary second molars, 32% of mandibular first molars, and 24% of mandibular second molars (Fig. 7–7). Mandibular teeth have a higher incidence of foramina involving both the pulp chamber floor and the furcation surface (56%) than do maxillary teeth (48%). No relationship was found between the incidence of accessory foramina and the occurrence of pulp chamber calcification or the distance from the chamber floor to the furcation. Radiographs failed to demonstrate the presence of furcation and lateral canals in the coronal portion of these roots. In one study, the pulp chamber floor of 200 permanent molars in a Turkish population was stained with 0.5% basic fuschian dye. Patent furcation canals were detected in 24% of maxillary and mandibular first molars, 20% of mandibular second molars, and 16% of maxillary second molars. These canals may be the cause of primary endodontic lesions in the furcations of multirooted teeth (Fig. 7–8).
Figure 7-7  A, Electron photomicrograph of the pulp chamber floor of a mandibular first molar. Multiple accessory foramina can be seen, ranging from 20 to 140 µm (×20). B, Electron photomicrograph of the furcation surface of a mandibular first molar. Multiple accessory foramina can be seen on the furcation surface (×30) (D, distal canal; M, mesial canals).

Figure 7-8  A, Preoperative radiograph of a mandibular first molar showing furcation and periradicular radiolucencies. B, One year follow-up radiograph showing significant healing. (Courtesy Dr. Raed S. Kasem, Clearwater, FL.)

* References [18][13][15][17][19][16]

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ROOT CANAL ANATOMY

Together with diagnosis and treatment planning, a knowledge of common root canal morphology and its frequent variations is a basic requirement for endodontic success. The significance of canal anatomy has been underscored by studies demonstrating that variations incanal geometry before shaping and cleaning had a greater effect on the changes that occurred during preparation than the instrumentation techniques.[114][115][116]

From the early work of Hess and Zurcher[60] to the most recent studies[21][55][68][134] demonstrating the anatomic complexities of the root canal system, it has long been established that a root with a tapering canal and a single foremen is the exception rather than the rule. Investigators have shown multiple foramina, additional canals, fins, deltas, intercanal connections, loops, C-shaped canals, and furcation and lateral canals in most teeth.[106][117][139][156] Consequently, in treating each tooth the clinician must assume that complex anatomy occurs often enough to be considered normal. The first premolar in Fig. 7 – 9, A is a good example of complex anatomy. The extra root is not obvious in a normal radiograph (Fig. 7 – 9, B). Fig. 7 – 10 shows a cross section of a similar tooth. This tooth has a fine, ribbon-shaped canal system instead of two distinct canals. Both these teeth present challenges for shaping, cleaning, and obturation.

Figure 7-9 A, Mandibular first premolar with three separate roots trifurcating at midroot. B, Radiograph of three views. Small canals diverging from the main canal create a configuration that is very difficult to prepare and obturate biomechanically.

Figure 7-10 Root section of a premolar showing a ribbon-shaped canal system.
The clinician must be familiar with the various pathways root canals take to the apex. The pulp canal system is complex, and canals may branch, divide, and rejoin. Weine categorized the root canal systems in any root into four basic types. Vertucci et al., using cleared teeth in which the root canal systems had been stained with hematoxylin dye, found a much more complex canal system; they identified eight pulp space configurations, which briefly can be described as follows (Fig. 7-11):

**Type I:** A single canal extends from the pulp chamber to the apex (1).
**Type II:** Two separate canals leave the pulp chamber and join short of the apex to form one canal (2-1).
**Type III:** One canal leaves the pulp chamber and divides into two in the root; the two then merge to exit as one canal (1-2-1).
**Type IV:** Two separate, distinct canals extend from the pulp chamber to the apex (2).
**Type V:** One canal leaves the pulp chamber and divides short of the apex into two separate, distinct canals with separate apical foramina (1-2).
**Type VI:** Two separate canals leave the pulp chamber, merge in the body of the root, and redivide short of the apex to exit as two distinct canals (2-1-2).
**Type VII:** One canal leaves the pulp chamber, divides and then rejoins in the body of the root, and finally redivides into two distinct canals short of the apex (1-2-1-2).
**Type VIII:** Three separate, distinct canals extend from the pulp chamber to the apex (3).

<table>
<thead>
<tr>
<th>TEETH</th>
<th>NUMBER OF TEETH</th>
<th>TYPE I 1 CANAL</th>
<th>TYPE II 2-1 CANALS</th>
<th>TYPE III 1-2-1 CANALS</th>
<th>TOTAL WITH ONE CANAL AT APEX</th>
<th>TYPE IV 2 CANALS</th>
<th>TYPE V 1-2 CANALS</th>
<th>TYPE VI 1-2-1 CANALS</th>
<th>TYPE VII 1-2-1-2 CANALS</th>
<th>TOTAL WITH TWO CANALS</th>
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<td>100</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>0</td>
<td>0</td>
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<td>0</td>
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</tbody>
</table>

**Figure 7-11** Diagrammatic representation of Vertucci’s canal configurations.

The percentages of human permanent teeth with these canal configurations are presented in Tables 7-3 and 7-4. The anatomic variations present in these teeth are listed in Tables 7-1 and 7-2. The only tooth that showed all eight possible configurations was the maxillary second premolar.
Other studies using more than 1000 teeth have described similar morphologic results. Another study involving Turkish patients used more than 1000 teeth and described similar morphologic results with the exceptions that one canal was found in 23% of maxillary laterals, 55% of mesiobuccal roots of maxillary second molars, and 30% of distal roots of mandibular second molars. The differences are most likely the result of variations of populations in the two studies. Another group studied 100 mandibular anterior teeth and described similar morphologic results.

<table>
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<tr>
<th>TEETH</th>
<th>NUMBER OF TEETH</th>
<th>TYPE I</th>
<th>TYPE II</th>
<th>TYPE III</th>
<th>TOTAL WITH ONE CANAL AT APEX</th>
<th>TYPE IV</th>
<th>TYPE V</th>
<th>TYPE VI</th>
<th>TYPE VII</th>
<th>TOT. WITH TWO CANAL AT APEX</th>
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<td>5</td>
<td>22</td>
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<td>3</td>
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<td>Mandibular canine</td>
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<td>14</td>
<td>2</td>
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<td>0</td>
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<tr>
<td>Mandibular first premolar</td>
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<td>4</td>
<td>74</td>
<td>1.5</td>
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<td>25</td>
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<tr>
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<td>97.5</td>
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<td>28</td>
<td>0</td>
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<td>43</td>
<td>8</td>
<td>10</td>
<td>0</td>
<td>59</td>
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<td>Distal</td>
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<td>15</td>
<td>0</td>
<td>85</td>
<td>5</td>
<td>8</td>
<td>2</td>
<td>0</td>
<td>15</td>
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<tr>
<td>Mandibular second molar</td>
<td></td>
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<td>Mesial</td>
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<td>38</td>
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<td>26</td>
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<td>1</td>
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found two new root canal types. In one configuration, two separate canals extended from the pulp chamber to midroot, where the lingual canal divided into two; all three canals joined in the apical third of the root and exited as one canal (Fig. 7–12, left). In the other configuration, one canal left the pulp chamber, divided into two in the middle third of the root, then rejoined to form one canal, which again split and exited as three separate canals with separate foramina (Fig. 7–12, right). Another set of variants was first observed in the mandibular molars of Burmese study subjects; this study revealed seven additional canal configurations (Fig. 7–13). These include three canals joining into one or two canals; two canals separating into three canals; two canals joining, redividing into two, and terminating as one canal; four canals joining into two; four canals extending from orifice to apex; and five canals joining into four at the apex. Another study evaluated gender-specific root canal configurations in 2800 teeth in a Turkish population. Of these specimens 99% were identical to those in the Vertucci classification. The remaining 1% (36 teeth) represented 14 additional canal morphologies, which occurred twice as often in mandibular teeth. These authors concluded that gender plays a role in determining canal morphology and that both gender and ethnic origin should be considered in the preoperative evaluation for root canal therapy.

Figure 7-12 Diagrammatic representation of Kartal and Yanikoglu’s canal configurations.
In addition to in vitro studies, a large number of case reports published over the past two decades have described a variety of complex canal configurations. Some of these reports are listed in Tables 7–8, 7–9, 7–10, 7–11, 7–12, 7–13, 7–14, 7–15, 7–16, 7–17, 7–18, 7–19, 7–20, 7–21, 7–22, 7–23, 7–24, 7–25, 7–26, 7–27. Some authors have been critical of case studies reporting “freak” cases thought to be rare.[172] However, reports of complex anatomy from both in vitro and in vivo investigations seem to be increasing. This emphasizes the adage that it is easier to recognize an anatomic feature if one is already prepared to see it.

Table 7-8 -- Studies of Apical Canal Configurations for the Maxillary Central Incisor

<table>
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<tr>
<th>AUTHORS</th>
<th>ONE CANAL (%)</th>
<th>TWO CANALS (%)</th>
<th>FOUR CANALS (%)</th>
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<tr>
<td>Vertucci[156]</td>
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<td></td>
</tr>
<tr>
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<tr>
<td>Caliskan et al[21]</td>
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</tr>
<tr>
<td>Kasahara et al[39]</td>
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<tr>
<td>Mangani and Ruddle[88]</td>
<td></td>
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<tr>
<td>Todd[153]</td>
<td></td>
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<td></td>
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<tr>
<td>Genovese and Marsico[49]</td>
<td>-</td>
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<td>Sinai and Lustbader[137]</td>
<td>-</td>
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<td>Von der Vyver and Traub[162]</td>
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Table 7-9 -- Studies of Apical Canal Configurations for the Maxillary Lateral Incisor

Figure 7-13 Diagrammatic representation of Gulabivala and coworkers’ supplemental canal configurations.
### Table 7-10 -- Studies of Apical Canal Configurations for the Maxillary Canine

<table>
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<th>AUTHORS</th>
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<th>TWO CANALS (%)</th>
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<tr>
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<td>Pineda and Kuttler [117]</td>
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<td>95.1</td>
<td>4.9</td>
<td>-</td>
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<tr>
<td>Pecora and Santanar [108]</td>
<td>-</td>
<td>Case report</td>
<td>-</td>
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<tr>
<td>Thompson et al [151]</td>
<td>Case report (2:1)[*]</td>
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<td>-</td>
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<tr>
<td>Fabra-Campos [42]</td>
<td>-</td>
<td>Case report</td>
<td>-</td>
</tr>
<tr>
<td>Christie et al [26]</td>
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<tr>
<td>Collins [28]</td>
<td>-</td>
<td>Case report</td>
<td>-</td>
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</table>

* Two canals joined to become one before reaching the apex.

### Table 7-11 -- Studies of Apical Canal Configurations for the Maxillary First Premolar

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<th>AUTHORS</th>
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<th>THREE CANALS (TWO BUCCAL, ONE PALATAL) (%)</th>
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<td>Vertucci [156]</td>
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<td>69</td>
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<td>50.1</td>
<td>49.4</td>
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<td>Caliskan et al [21]</td>
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<td>90.2</td>
<td>-</td>
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<td>Carns and Skidmore [24]</td>
<td>22</td>
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<td>Walker [164]</td>
<td>36</td>
<td>64</td>
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<td>9.7</td>
<td>88.6</td>
<td>1.7</td>
</tr>
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<td>17.1</td>
<td>80.4</td>
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<tr>
<td>Soares and Leonardo [142]</td>
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<td>-</td>
<td>Case report</td>
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</table>

### Table 7-12 -- Studies of Apical Canal Configurations for the Maxillary Second Premolar

<table>
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</thead>
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<td>18.2</td>
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<td>-</td>
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<td>Barkhordar and Sapone [7]</td>
<td>-</td>
<td>-</td>
<td>Case report</td>
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<tr>
<td>Low [82]</td>
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### Table 7-13 -- Studies of Apical Canal Configurations for the Palatal Root of the Maxillary First Molar

<table>
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<tr>
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<tr>
<td>Vertucci[156]</td>
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<td>Caliskan et al[21]</td>
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<td>Acosta Vigouraux and Trugeda Bosaans[1]</td>
<td>100</td>
<td></td>
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</tr>
<tr>
<td>Thomas et al[150]</td>
<td>99.1 (0.9)[†]</td>
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<td>Pecora et al[112]</td>
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<td>Wasti et al[170]</td>
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<tr>
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</table>

* Percentage of cases in which one canal divided to form two.
† Percentage of cases or case report in which two canals joined to form one.

### Table 7-14 -- Studies of Apical Canal Configurations for the Distobuccal Root of the Maxillary First Molar

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<td>Maggiore et al[82]</td>
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</tr>
<tr>
<td>Cecic et al[25]</td>
<td>Case report</td>
<td></td>
</tr>
<tr>
<td>Baratto-Filho et al[8]</td>
<td>Case report</td>
<td></td>
</tr>
<tr>
<td>Wong[183]</td>
<td>Case report</td>
<td></td>
</tr>
</tbody>
</table>

* Percentage of cases in which two canals joined to form one.
### Table 7-15 -- Studies of Apical Canal Configurations for the Mesiobuccal Root of the Maxillary First Molar

<table>
<thead>
<tr>
<th>AUTHORS</th>
<th>ONE CANAL (%)</th>
<th>TWO CANALS (%)</th>
<th>THREE CANALS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertucci[156]</td>
<td>82 (17)</td>
<td>18</td>
<td>-</td>
</tr>
<tr>
<td>Pineda and Kuttler[117]</td>
<td>51.5 (12.2)</td>
<td>48.5 (12.8)</td>
<td>-</td>
</tr>
<tr>
<td>Caliskan et al[21]</td>
<td>75.4 (41)</td>
<td>24.6 (1.6)</td>
<td>-</td>
</tr>
<tr>
<td>Acousta Vigouraux and Trugeda Bosaans[1]</td>
<td>28.4</td>
<td>69.3</td>
<td>2.3</td>
</tr>
<tr>
<td>Seidberg et al[122]</td>
<td>75 (37)</td>
<td>25</td>
<td>-</td>
</tr>
<tr>
<td>Weine et al[177]</td>
<td>86 (37.5)</td>
<td>14</td>
<td>-</td>
</tr>
<tr>
<td>Stropko[146]</td>
<td>45.1 (38.1)</td>
<td>54.9</td>
<td>-</td>
</tr>
<tr>
<td>Fogel et al[45]</td>
<td>68.3 (39.4)</td>
<td>31.7</td>
<td>-</td>
</tr>
<tr>
<td>Pomeranz and Fishelberg[119]</td>
<td>52 (21)</td>
<td>48</td>
<td>-</td>
</tr>
<tr>
<td>Kulild and Peters[85]</td>
<td>41 (38.6)</td>
<td>59 (2.4)</td>
<td>-</td>
</tr>
<tr>
<td>Thomas et al[150]</td>
<td>73.6 (27.3)</td>
<td>26.4 (12)</td>
<td>-</td>
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<tr>
<td>Neaveth et al[109]</td>
<td>37.7 (16.7)</td>
<td>61.9 (1.8)</td>
<td>0.4</td>
</tr>
<tr>
<td>Weine et al[178]</td>
<td>66.2 (24.2)</td>
<td>33.8 (3.4)</td>
<td>-</td>
</tr>
<tr>
<td>Gilles and Reader[50]</td>
<td>61.9 (52.4)</td>
<td>38.1 (4.8)</td>
<td>-</td>
</tr>
<tr>
<td>Pecora et al[112]</td>
<td>92.5 (17.5)</td>
<td>7.5</td>
<td>-</td>
</tr>
<tr>
<td>Hartwell and Bellizzi[67]</td>
<td>81.4</td>
<td>18.6</td>
<td>-</td>
</tr>
<tr>
<td>Weller and Hartwell[179]</td>
<td>61</td>
<td>39</td>
<td>-</td>
</tr>
<tr>
<td>Wasti et al[179]</td>
<td>56.6 (23.3)</td>
<td>43.4 (13.3)</td>
<td>-</td>
</tr>
<tr>
<td>al Shalabi et al[2]</td>
<td>36.4 (15.9)</td>
<td>62.6 (6.1)</td>
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</tr>
<tr>
<td>Bond et al[19]</td>
<td>-</td>
<td>Case report</td>
<td>-</td>
</tr>
<tr>
<td>Beatty[10]</td>
<td>-</td>
<td>-</td>
<td>Case report</td>
</tr>
<tr>
<td>Maggiore et al[82]</td>
<td>-</td>
<td>Case report</td>
<td>-</td>
</tr>
<tr>
<td>Cecic et al[25]</td>
<td>-</td>
<td>Case report</td>
<td>-</td>
</tr>
<tr>
<td>Baratto-Filho et al[8]</td>
<td>Case report</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wong[183]</td>
<td>Case report</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* Number in parenthesis is the percentage of cases in which two canals joined to form one.
† Number in parenthesis is the percentage of cases in which one canal divided to form two.

### Table 7-16 -- Studies of Apical Canal Configurations for the Mesiobuccal Root of the Maxillary Second Molar

<table>
<thead>
<tr>
<th>AUTHORS</th>
<th>ONE CANAL (%)</th>
<th>TWO CANALS (%)</th>
<th>THREE CANALS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertucci[156]</td>
<td>88 (17)</td>
<td>12</td>
<td>-</td>
</tr>
<tr>
<td>Pineda and Kuttler[117]</td>
<td>72.8 (8.2)</td>
<td>27.2 (14.4)</td>
<td>-</td>
</tr>
<tr>
<td>Caliskan et al[21]</td>
<td>68.7 (23.6)</td>
<td>27.1 (4.2)</td>
<td>4.2</td>
</tr>
<tr>
<td>Pecora et al[112]</td>
<td>80 (22)</td>
<td>20</td>
<td>-</td>
</tr>
<tr>
<td>Gilles and Reader[50]</td>
<td>62 (32.4)</td>
<td>38 (2.7)</td>
<td>-</td>
</tr>
<tr>
<td>Stropko[146]</td>
<td>78 (45.6)</td>
<td>22</td>
<td>-</td>
</tr>
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<td>Eskoz and Weine[40]</td>
<td>80.6 (20.9)</td>
<td>19.4 (3)</td>
<td>-</td>
</tr>
<tr>
<td>Pomeranz and Fishelberg[119]</td>
<td>75.9 (13.8)</td>
<td>24.1</td>
<td>-</td>
</tr>
<tr>
<td>AUTHORS</td>
<td>ONE CANAL (%)</td>
<td>TWO CANALS (%)</td>
<td></td>
</tr>
<tr>
<td>-----------------------------</td>
<td>---------------</td>
<td>----------------</td>
<td></td>
</tr>
<tr>
<td>Nosonowitz and Brenner[105]</td>
<td>94.4 (25.5)</td>
<td>5.6</td>
<td></td>
</tr>
<tr>
<td>Shalabi et al[2]</td>
<td>50 (5.6)</td>
<td>50 (16.7)</td>
<td></td>
</tr>
<tr>
<td>Benenati[14]</td>
<td>Case report</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fahid and Taintor[43]</td>
<td>Case report</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Number in parenthesis is the percentage of cases in which two canals joined into one.
† Number in parenthesis is the percentage of cases in which one canal divided to form two.

### Table 7-18 -- Studies of Apical Canal Configurations for the Palatal Root of the Maxillary Second Molar

<table>
<thead>
<tr>
<th>AUTHORS</th>
<th>ONE CANAL (%)</th>
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<tbody>
<tr>
<td>Vertucci[156]</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Pineda and Kuttler[117]</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Caliskan et al[21]</td>
<td>97.9</td>
<td>2.1[†]</td>
</tr>
<tr>
<td>Pecora et al[112]</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Shalabi et al[2]</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Benenati[14]</td>
<td>Case report</td>
<td></td>
</tr>
<tr>
<td>Fahid and Taintor[43]</td>
<td>-</td>
<td>Case report</td>
</tr>
</tbody>
</table>

* Percentage of cases in which one canal divided to form two.

### Table 7-19 -- Studies of Apical Canal Configurations for the Maxillary Third Molar

<table>
<thead>
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<th>AUTHORS</th>
<th>NUMBER OF ROOTS</th>
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<td></td>
<td>Number of Canals (%)</td>
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<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Sidow et al[135]</td>
<td>1 (2.7</td>
</tr>
<tr>
<td></td>
<td>2 (4.7%[†])</td>
</tr>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Pineda and Kuttler[117]</td>
<td>Mesiobuccal</td>
</tr>
<tr>
<td>Pecora et al[112]</td>
<td>Mesiobuccal</td>
</tr>
</tbody>
</table>

* Percentage of cases in which two canals joined to form one.

### Table 7-20 -- Studies of Apical Canal Configurations for the Mandibular Incisors

<table>
<thead>
<tr>
<th>AUTHORS</th>
<th>TOOTH</th>
<th>ONE CANAL (%)[†]</th>
<th>TWO CANALS (%)</th>
<th>THREE CANALS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertucci[156]</td>
<td>Central</td>
<td>97 (5)</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Pineda and Kuttler[117]</td>
<td>Central</td>
<td>97.9 (2)</td>
<td>2</td>
<td>-</td>
</tr>
</tbody>
</table>
Table 7-21 -- Studies of Apical Canal Configurations for the Mandibular Canine

<table>
<thead>
<tr>
<th>AUTHORS</th>
<th>ONE CANAL (%)</th>
<th>TWO CANALS (%)</th>
<th>THREE CANALS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertucci[156]</td>
<td>94 (14)</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>Pineda and Kuttler[117]</td>
<td>95 (13.5)</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>Caliskan et al[21]</td>
<td>98 (3.9)</td>
<td>2†</td>
<td>-</td>
</tr>
<tr>
<td>Pecora et al[111]</td>
<td>97.1 (4.9)</td>
<td>2.9</td>
<td>-</td>
</tr>
<tr>
<td>D’Arcangelo et al[93]</td>
<td>-</td>
<td>Case report</td>
<td>-</td>
</tr>
<tr>
<td>Orguneser and Kartal[107]</td>
<td>-</td>
<td>Case report (3 2) ‡</td>
<td>-</td>
</tr>
<tr>
<td>Heling et al[59]</td>
<td>-</td>
<td>-</td>
<td>Case report</td>
</tr>
</tbody>
</table>

* Number in parenthesis is the percentage of cases in which two canals joined to form one.
† Percentage of cases in which one canal divided to form two.
‡ Three canals reconfigured to form two.

Table 7-22 -- Studies of Apical Canal Configurations for the Mandibular First Premolar

<table>
<thead>
<tr>
<th>AUTHORS</th>
<th>ONE CANAL (%)</th>
<th>TWO CANALS (%)</th>
<th>THREE CANALS (%)</th>
<th>FOUR CANALS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertucci[156]</td>
<td>74</td>
<td>25.5 (24)</td>
<td>0.5</td>
<td>-</td>
</tr>
<tr>
<td>Pineda and Kuttler[117]</td>
<td>74.2</td>
<td>24.9 (23.4)</td>
<td>0.9</td>
<td>-</td>
</tr>
<tr>
<td>Caliskan et al[21]</td>
<td>75.5 (7.6†)</td>
<td>18.8 (9.4)</td>
<td>5.7</td>
<td>-</td>
</tr>
<tr>
<td>Zillich and Dowson[192]</td>
<td>80.7</td>
<td>18.9</td>
<td>0.4</td>
<td>-</td>
</tr>
<tr>
<td>Baisden et al[5]</td>
<td>76</td>
<td>(24)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Yoshioka et al[190]</td>
<td>80.6</td>
<td>15.1 ‡</td>
<td>4.3</td>
<td>-</td>
</tr>
<tr>
<td>Trope et al[154]</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>← Black patients</td>
<td>67.2</td>
<td>-</td>
<td>32.8</td>
<td>-</td>
</tr>
<tr>
<td>← White patients</td>
<td>86.3</td>
<td>-</td>
<td>13.7</td>
<td>-</td>
</tr>
</tbody>
</table>

* Number in parenthesis is the percentage of cases in which one canal divided to form two.
† Percentage of cases in which two canals joined to form one.
‡ Percentage of cases in which one canal divided into two, then rejoined to form one (Vertucci type VI).
### Table 7-24 -- Studies of Apical Canal Configurations for the Mesial Root of the Mandibular First Molar

<table>
<thead>
<tr>
<th>AUTHORS</th>
<th>ONE CANAL (%)</th>
<th>TWO CANALS (%)</th>
<th>THREE CANALS (%)</th>
<th>FOUR CANALS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertucci[156]</td>
<td>97.5</td>
<td>2.5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pineda and Kuttler[117]</td>
<td>98.8</td>
<td>1.2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Caliskan et al[21]</td>
<td>93.6</td>
<td>6.4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Kerekes and Tronstad[71]</td>
<td>85</td>
<td>15</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Okumura[108]</td>
<td>98.2</td>
<td>1.8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Zillich and Dowson[192]</td>
<td>88.4 (1[†])</td>
<td>11.2</td>
<td>0.4</td>
<td>-</td>
</tr>
<tr>
<td>Trope et al[154]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>†Black patients</td>
<td>92.2</td>
<td>7.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>‡White patients</td>
<td>97.2</td>
<td>2.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Holtzman[61]</td>
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<td>-</td>
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<td>Case report</td>
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<tr>
<td>El Deeb[39]</td>
<td>-</td>
<td>-</td>
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<td>Case report</td>
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<tr>
<td>Rödig and Hülsmann[128]</td>
<td>-</td>
<td>-</td>
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<td>Case report</td>
</tr>
<tr>
<td>Bram and Fleisher[17]</td>
<td>-</td>
<td>-</td>
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<td>Case report</td>
</tr>
<tr>
<td>Rhodes[122]</td>
<td>-</td>
<td>-</td>
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<td>Case report</td>
</tr>
<tr>
<td>Macri and Zmener[84]</td>
<td>-</td>
<td>-</td>
<td></td>
<td>Case report (5 4)</td>
</tr>
</tbody>
</table>

* * Percentage of cases in which one canal divided to form two.
† Percentage of cases in which two canals joined to form one.
‡ Five canals reconfigured to form four.
### Table 7-25 -- Studies of Apical Canal Configurations for the Distal Root of the Mandibular First Molar

<table>
<thead>
<tr>
<th>AUTHORS</th>
<th>ONE CANAL (%)</th>
<th>TWO CANALS (%)</th>
<th>THREE CANALS (%)</th>
<th>OTHER (%)</th>
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</thead>
<tbody>
<tr>
<td>Vertucci[156]</td>
<td>85 (15)</td>
<td>15 (8)</td>
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<td>-</td>
</tr>
<tr>
<td>Pineda and Kuttler[117]</td>
<td>85.7 (12.7)</td>
<td>14.3 (8.6)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Caliskan et al[21]</td>
<td>81.4 (33)</td>
<td>16.9 (7)</td>
<td>1.7</td>
<td>-</td>
</tr>
<tr>
<td>Zaatar et al[193]</td>
<td>83.7 (8)</td>
<td>16.3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sperber and Moreau[143]</td>
<td>78</td>
<td>(22)</td>
<td>0.2</td>
<td>-</td>
</tr>
<tr>
<td>Gulabivala et al[55]</td>
<td>83.3 (4)</td>
<td>16 (3)</td>
<td>0.7</td>
<td>-</td>
</tr>
<tr>
<td>Wasti et al[170]</td>
<td>56.7 (27)</td>
<td>43.3 (20)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Skidmore and Bjorndal[139]</td>
<td>88.8 (18)</td>
<td>11.2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ricucci[123]</td>
<td>Case report</td>
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<td>-</td>
<td>-</td>
</tr>
<tr>
<td>DeGrood and Cunningham[93]</td>
<td>-</td>
<td>Case report (3</td>
<td>2)</td>
<td>-</td>
</tr>
<tr>
<td>Martinez-Berná and Badanelli[84]</td>
<td>Case report (3</td>
<td>1)</td>
<td>Case report (3</td>
<td>2)</td>
</tr>
<tr>
<td>Beatty and Krell[12]</td>
<td>-</td>
<td>-</td>
<td>Case report</td>
<td>-</td>
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<tr>
<td>Reeh[123]</td>
<td>-</td>
<td>-</td>
<td>Case report</td>
<td>-</td>
</tr>
<tr>
<td>Beatty and Interian[11]</td>
<td>-</td>
<td>-</td>
<td>Case report</td>
<td>-</td>
</tr>
<tr>
<td>Friedman et al[49]</td>
<td>-</td>
<td>-</td>
<td>Case report</td>
<td>-</td>
</tr>
<tr>
<td>Stroner et al[145]</td>
<td>-</td>
<td>-</td>
<td>Case report</td>
<td>-</td>
</tr>
</tbody>
</table>

* Number in parenthesis is the percentage of cases in which two canals joined to form one.
† Number in parenthesis is the percentage of cases in which one canal divided to form two.
‡ Three canals reconfigured to form two.
§ Three canals reconfigured to form one.

### Table 7-26 -- Studies of Apical Canal Configurations of the Mandibular Second Molar

<table>
<thead>
<tr>
<th>AUTHORS</th>
<th>ROOT</th>
<th>ONE CANAL (%)</th>
<th>TWO CANALS (%)</th>
<th>THREE CANALS (%)</th>
<th>OTHER (%)</th>
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<td>Mesial</td>
<td>65 (38)</td>
<td>35 (9)</td>
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<td>-</td>
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<tr>
<td>Pineda and Kuttler[117]</td>
<td>Mesial</td>
<td>78.6 (21)</td>
<td>21.4 (8)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Caliskan et al[21]</td>
<td>Mesial</td>
<td>41.2 (19)</td>
<td>56.9</td>
<td>2</td>
<td>-</td>
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<tr>
<td>Weine et al[179]</td>
<td>Mesial</td>
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<td>40</td>
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<td>1.3 (one canal)</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>2.7 (C shaped)</td>
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<td>Manning[89]</td>
<td>Mesial</td>
<td>73.5 (32)</td>
<td>24.5 (10)</td>
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<td>-</td>
</tr>
<tr>
<td>Wells and Bernier[183]</td>
<td>Mesial</td>
<td>Case report</td>
<td>-</td>
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<td>-</td>
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</tbody>
</table>
Specific types of canal morphology appear to occur in different racial groups. For example, compared with white patients, black patients have a higher number of extra canals in both the mandibular first premolar (32.8% versus 13.7%) and the mandibular second premolar (7.8% versus 2.8%).\[154\] In addition, patients of Asian descent have different percentages of canal configurations than those reported in studies dominated by Caucasian and African populations.\[164\]\[165\]\[166\]\[170\] One well-recognized ethnic variant is the higher incidence of single-rooted and C-shaped mandibular second molars in Asians compared with other populations.\[90\] However, this is not always the case; the occurrence of two canals in the mesiobuccal root of maxillary first molars in Japanese patients is similar to that described for other ethnic groups.\[176\]

Examination of the pulp chamber floor can reveal clues to the location of orifices and to the type of canal system present. If only one canal is present, it usually is located in the center of the access preparation. All such orifices, particularly if oval shaped, must be explored thoroughly with apically precurved small K-files (Fig. 7–14). If only one orifice is found and it is not in the center of the root, another orifice probably exists, and the clinician should search for it on the opposite side (Fig. 7–15). The relationship of the two orifices to each other is also significant. The closer they are, the greater the chance the two canals join at some point in the body of the root. The direction a file takes when introduced into an orifice is also important. If the first file inserted into the distal canal of a mandibular molar points either to the buccal or to the lingual, the clinician should suspect a second canal. If two canals are present, they will be smaller than a single canal.
Whenever a root contains two canals that join to form one, the lingual/palatal canal generally is the one with direct access to the apex. This anatomy is best treated by preparing and obturating this canal to the apex and the buccal canal to the point of juncture. If both canals are enlarged to the apex, an hourglass preparation results; the point where the two canals join is more constricted than the preparation at the apex. Filling such a configuration leaves voids in the apical third and invites treatment failure, particularly if microorganisms or their byproducts remain in the canal. Rotary nickel-titanium files must be used cautiously with this type of anatomy because instrument separation can occur as the file traverses the sharp curvature into the common part of the canal. When one canal separates into two, the division is buccal and palatal/lingual, and the lingual canal generally splits from the main canal at a sharp angle, sometimes nearly a right angle (Fig. 7–16). Slowey recommends visualizing this configuration as a lower case letter h. The buccal canal is the straight-line portion of the h; the lingual canal exists about midroot at a sharp angle from the buccal canal. This requires modification of the access to achieve unobstructed passage of instruments into the lingual canal.

Figure 7-14 An oval orifice must be explored with apically curved small instruments. The clinician should place the file tip in the orifice with the tip to buccal when trying to locate the buccal canal. A curved file tip is placed toward the palate to explore for the palatal canal.

Figure 7-15 A, In a mandibular second molar with two canals, both orifices are in the mesiodistal midline. B, If two orifices are not directly in the mesiodistal midline, a search should be made for another canal on the opposite side using Krasner and Rankow’s laws of anatomy.
Figure 7-16  A, Mesial view of a mandibular premolar with a Vertucci type V canal configuration. The lingual canal separates from the main canal at nearly a right angle. B, This anatomy requires widening of access in a lingual direction to achieve straight-line access to the lingual canal. This should be done using the DOM.
ANATOMY OF THE APICAL ROOT

The classic concept of apical root anatomy is based on three anatomic and histologic landmarks in the apical region of a root: the apical constriction (AC), the cementodentinal junction (CDJ), and the apical foramen (AF). Kuttler’s description of the anatomy of the root apex has the root canal tapering from the canal orifice to the AC, which generally is 0.5 to 1.5 mm inside the AF (Fig. 7–17). The AC generally is considered the part of the root canal with the smallest diameter; it also is the reference point clinicians use most often as the apical termination for shaping, cleaning, and obturation. Pulp blood vessels are narrow at the AC, which makes successful treatment of inflammation in the canal difficult. Postoperative discomfort generally is greater when this area is violated by instruments or filling materials, and the healing process may be compromised.

The CDJ is the point in the canal where cementum meets dentin; it is the point where pulp tissue ends and periodontal tissues begin. The location of the CDJ in the root canal varies considerably. It generally is not in the same area as the AC, and estimates place it approximately 1 mm from the AF.

From the AC, or minor apical diameter, the canal widens as it approaches the AF, or major apical diameter. The space between the major and minor apical diameters has been described as funnel shaped or hyperbolic or as having the shape of a morning glory. The mean distance between the major and minor apical diameters is 0.5 mm in a young person and 0.67 mm in an older individual. The distance is greater in older individuals because of the buildup of cementum.

The AF is the “circumference or rounded edge, like a funnel or crater, that differentiates the termination of the cemental canal from the exterior surface of the root.” The diameter of the foramen was 502 µm in

Figure 7-17  Morphology of the root apex. From its orifice the canal tapers to the apical constriction, or minor apical diameter, which generally is considered the narrowest part of the canal. From this point the canal widens as it exits the root at the apical foramen, or major apical diameter. The space between the minor and major apical diameters is funnel shaped.
individuals 18 to 25 years of age and 681 µm in those over age 55, which demonstrates the growth of the AF with age. By comparison, these sizes are larger than the cross-sectional diameter of #50 and #60 endodontic files, respectively. The AF does not normally exit at the anatomic apex but rather is offset 0.5 to 3 mm. This variation is more marked in older teeth through cementum apposition. Studies have shown that the AF coincides with the apical root vertex in 17% to 46% of cases. 

The location and diameter of the CDJ differ from those of the AF in maxillary anterior teeth. The extension of cementum from the AF into the root canal differs considerably, even when opposite canal walls are compared. Cementum reaches the same level on all canal walls in only 5% of cases. The greatest extension generally occurs on the concave side of the canal curvature. This variability confirms that the CDJ and the AC generally are not in the same area and that the CDJ should be considered just a variable junction at which two histologic tissues meet in the root canal. The diameter of the canal at the CDJ varied considerably; it was determined to be 353.2 µm for the central incisors, 292.25 µm for the lateral incisors, and 298.16 µm for the canines. These measures approximate the size of #30 to #35 endodontic files.

In maxillary anterior teeth, the root apex and main AF coincided in 16.7% of examined central incisors and canines and in 6.7% of lateral incisors. Both the root apex and the AF of the central incisors and canines were displaced distolabially, whereas those of the lateral incisors were displaced distolingually. The perpendicular distance from the root apex to the AC and both mesiodistal and labiolingual root canal diameters at the AC are shown in Table 7-5. The labiolingual diameter in all maxillary anterior teeth is approximately 0.05 mm larger than the mesiodistal diameter. This has definite implications for shaping and cleaning procedures because only the mesiodistal diameter is evident on radiographs.

<table>
<thead>
<tr>
<th>TEETH</th>
<th>MESIODISTAL (MM)</th>
<th>LABIOLINGUAL (MM)</th>
<th>VERTICAL (MM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central incisor</td>
<td>0.37</td>
<td>0.428</td>
<td>0.863</td>
</tr>
<tr>
<td>Lateral incisor</td>
<td>0.307</td>
<td>0.369</td>
<td>0.825</td>
</tr>
<tr>
<td>Canine</td>
<td>0.313</td>
<td>0.375</td>
<td>1.01</td>
</tr>
</tbody>
</table>


Scanning electron microscopy has been used to determine the number and size of main apical foramina, their distance from the anatomic apex, and the size of accessory foramina. In one study, more than one main foramen was found in all teeth except the palatal root of maxillary molars and the distal root of mandibular molars. No main foramen was seen in 24% of maxillary premolars and 26% of maxillary incisors. The mesial roots of mandibular molars (50%), the maxillary premolars (48.3%), and the mesial roots of maxillary molars (41.7%) had the highest percentage of multiple main foramina. This finding is consistent with observations that blunted roots usually have more than one root canal. The mean values for the size of the main foramen are listed in Table 7-6. Sizes ranged from 210 µm for the maxillary premolars to 392 µm for the distal roots of the mandibular molars.

<table>
<thead>
<tr>
<th>TEETH</th>
<th>MEAN VALUES (U)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maxillary incisors</td>
<td>289.4</td>
</tr>
<tr>
<td>Mandibular incisors</td>
<td>262.5</td>
</tr>
<tr>
<td>Maxillary premolars</td>
<td>210</td>
</tr>
<tr>
<td>Mandibular premolars</td>
<td>268.25</td>
</tr>
<tr>
<td>Maxillary molars</td>
<td></td>
</tr>
<tr>
<td>Palatal</td>
<td>298</td>
</tr>
<tr>
<td>Mesiobuccal</td>
<td>235.05</td>
</tr>
<tr>
<td>Distobuccal</td>
<td>232.2</td>
</tr>
<tr>
<td>Mandibular molars</td>
<td></td>
</tr>
<tr>
<td>Mesial</td>
<td>257.5</td>
</tr>
<tr>
<td>Distal</td>
<td>392</td>
</tr>
</tbody>
</table>

All groups of teeth had at least one accessory foramen. The maxillary premolars had the most and the largest accessory foramina (mean value, 53.4 µm) and the most complicated apical morphologic makeup. The mandibular premolars had strikingly similar characteristics, a possible reason why root canal therapy may fail in premolar teeth.

The morphology of the apical root varies tremendously; it includes numerous accessory canals; areas of resorption and repaired resorption; attached, embedded, and free pulp stones; and varying amounts of irregular secondary dentin. Primary dentinal tubules are found less often than in the coronal dentin and are more or less irregular in direction and density. Some areas are completely devoid of tubules. Fine tubular branches (300 to 700 mm in diameter) that run at a 45-degree angle to the main tubules and microbranches (25 to 200 mm in diameter) that run at a 90-degree angle to the main tubules are often present (Fig. 7-18). This variable structure in the apical region presents challenges for root canal therapy. Obturation techniques that rely on the penetration of adhesives into dentinal tubules may not provide successful sealing in the apical region. Therefore the formation of a hybrid layer may become an important part of adhesive systems used in the apical root canal.

Considerable controversy exists over the exact termination point for root canal therapy. Clinical determination of apical canal morphology is difficult at best. The existence of an AC may be more conceptual than real. Several studies have reported that a traditional single AC was present less than half the time, particularly when apical root resorption and periradicular pathosis were factors. The apical root canal often is tapered or walls are parallel to each other or the canal has multiple constrictions. Some authors therefore have recommended the following termination points: 1 mm from the apex when no bone or root resorption has occurred; 1.5 mm from the apex when only bone resorption has occurred; and 2 mm from the apex when both bone and root resorption have occurred.

Because locating the AC and AF is difficult clinically, some researchers contend that the radiographic apex is a more reliable reference point. These authors recommend that root canal procedures terminate at or 3 mm from the radiographic apex, depending on the pulpal diagnosis. For vital cases, clinical and biologic evidence indicates that a favorable point to terminate therapy is 2 to 3 mm short of the radiographic apex. This leaves an apical pulp stump, which prevents extrusion of irritating filling materials into the periradicular tissues. With pulp necrosis, bacteria and their byproducts may be present in the apical root canal, which could jeopardize healing. Studies have shown that, in these cases, a better success rate is achieved when therapy ends at or within 2 mm of the radiographic apex. When therapy ended short of the 2 mm point or extended past the radiographic apex, the success rate declined by 20%. For retreatment cases, therapy should extend to or preferably 1 to 2 mm short of the radiographic apex to prevent overextension of instruments and filling materials into the periradicular tissues.

Other investigators who evaluated apical and periradicular tissues after root canal therapy concluded that the most favorable prognosis was obtained when procedures were terminated at the AC, and the worst prognosis was produced by treatment that extended beyond the AC. Procedures terminated more than 2 mm from the AC had the second worst prognosis. These findings occurred with vital and necrotic tissue and when bacteria were present beyond the AF. Sealer or gutta-percha (or both) in the periradicular tissues, lateral canals, and apical ramifications always caused a severe inflammatory reaction. However, the authors of the studies acknowledge the difficulty of locating the AC clinically. Some researchers recommend that clinicians terminate all therapy at or beyond the radiographic apex and fill all apical ramifications and lateral canals.

Figure 7-18 Fine tubules and microbranches can be seen in the apical part of the root. (From Mjör IA, Nordahl I: Arch Oral Biol 41:401, 1996.)
The apical limit of instrumentation and obturation continues to be the subject of major controversy in root canal therapy. However, modern electronic apex locators are reliable instruments that can help the clinician determine the working length of the root canal.

Two hallmarks of the apical region are its variability and unpredictability. The tremendous variation in canal shapes and diameters complicates cleaning and shaping procedures in all dimensions. Successful treatment depends on the anatomy of the root canal system, the dimensions of the canal walls, and the final size of enlarging instruments.

Sometimes the initial file chosen for exploring the canal anatomy and for binding in the canal is used as a measure of the diameter of the apical root canal. However, this technique does not accurately gauge the size of oval-shaped apical root canals. In one study, file binding occurred in 75% of such cases when the file contacted only one side of the apical canal wall, and it occurred without any apical wall contact in the remaining 25%. In 90% of the canals, the diameter of the initial instrument was smaller than the short diameter of the canal. Consequently, using the first file to bind for gauging the diameter of the apical canal and as guidance for apical enlargement is not reliable. More recent studies have suggested that this problem could be remedied by removing the interferences in the coronal and middle thirds of the canal. For example, radicular flaring before canal exploration removes interferences and increases the initial file size that is snug at the apex (almost two file sizes greater). Early flaring gives the clinician a better sense of the size of the apical canal, allowing better decisions about the final diameter needed for apical shaping and cleaning. This is another advantage of the crown-down instrumentation technique.

The correlations between maximum canal diameters and instrument diameters varied considerably in a study that compared the shape of the apical root canal of maxillary first molars with the D0 diameter of endodontic instruments. Evaluation of the root canal diameter showed that a circular shape (the two diameters were equal) predominated in the palatal and MB-2 canals; a flat shape (the larger diameter exceeded the smaller by more than the radius) occurred most often in the main mesiobuccal (MB-1) canal; and both circular and flat shapes were found in the distobuccal canal. Flat and ribbon-shaped canals persisted near the apex even in elderly patients and mainly in the MB-1 canal. This finding was believed to arise from concentric narrowing of ribbon-shaped canals, primarily along the smaller diameter. Oval canals narrowed mainly along the larger diameter and tended to become more circular. The authors of this study concluded that the maxillary first molar has a very complicated canal shape at the apical limit and that this anatomy makes shaping, cleaning, and obturation difficult, particularly in the MB-1 and distobuccal canals. Because of this variability, guidelines for instrument calibers that would guarantee adequate canal preparation are virtually impossible to establish.

One comprehensive study reviewed the apical root canal diameters and tapers of each tooth group and demonstrated that root canals often are long oval or ribbon shaped in the apical 5 mm. A long oval canal was defined as having a long-to-short canal diameter ratio greater than 2. This type of canal morphology was found to occur in 25% of the cross sections studied. In these roots the buccal/lingual diameter is larger than the mesial/distal diameter. This finding held true for all canals except the palatal canal of maxillary molars. These canal measurements suggest that apical preparations should be taken to larger sizes than previously recommended.

### Table 7-7 -- Median Canal Diameter (in mm) at 1, 2, and 5 mm from Apex

<table>
<thead>
<tr>
<th>TOOTH (CANAL) POSITION</th>
<th>Buccal/Lingual</th>
<th>Mesial/Distal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 MM</td>
<td>2 MM</td>
</tr>
<tr>
<td>Maxillary</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central incisor</td>
<td>0.34</td>
<td>0.47</td>
</tr>
<tr>
<td>Lateral incisor</td>
<td>0.45</td>
<td>0.6</td>
</tr>
<tr>
<td>Canine</td>
<td>0.31</td>
<td>0.58</td>
</tr>
<tr>
<td>Premolar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single canal</td>
<td>0.37</td>
<td>0.63</td>
</tr>
<tr>
<td>Buccal</td>
<td>0.3</td>
<td>0.4</td>
</tr>
<tr>
<td>Palatal</td>
<td>0.23</td>
<td>0.37</td>
</tr>
<tr>
<td>Molar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single mesiobuccal</td>
<td>0.43</td>
<td>0.46</td>
</tr>
<tr>
<td>First mesiobuccal</td>
<td>0.19</td>
<td>0.37</td>
</tr>
<tr>
<td>Second mesiobuccal</td>
<td>0.19</td>
<td>0.31</td>
</tr>
</tbody>
</table>
The authors of another study concluded that “because of long oval canals, larger canal tapers in the buccal-lingual direction, wider ranges in the apical diameters of canals, and the lack of technology to measure these diameters, it is very difficult if not impossible to adequately debride all canals by instrumentation alone.” [167] This fact was further emphasized by research that showed that neither the balanced force instrumentation method nor rotary NiTi files allowed controlled preparation of the buccal and lingual extensions of oval canals. [126][186] The instruments created a round bulge in the canal, leaving the extensions unprepared and filled with smear layer and debris. Another series of studies evaluated the effectiveness of five nickel-titanium rotary instrumentation systems on canal debridement and found that all techniques left 35% or more of the canal surface area unchanged [114][116].

The results of all these studies are fairly predictable, considering the highly variable and irregular morphology of root canal systems and the endodontic intracanal instruments currently in use, which cannot contact all the recesses present along canal walls. These instruments do a good job of shaping the canal but a poor job of accomplishing total canal debridement.

Attempting to find better ways to clean and disinfect root canals, one group of investigators determined that enlarging canals above the traditional recommended apical sizes was the only way to remove culturable bacteria from the canal effectively. [23] The larger apical sizes optimized irrigation and disinfection and facilitated mechanical elimination of microbes. A similar study concluded that an increase in the size of canal instrumentation at working length produced an increase in canal cleanliness [155]. Irrigant volume, the number of instrument changes, and the depth of penetration of irrigant needles were less important factors contributing to canal debridement. A potential adverse effect of enlarging the apical canal diameter may be an increased risk of procedural errors or root fractures or both. Further research in this area is required.

As a supplement to these procedures, acoustic streaming by sonic and ultrasonic irrigation appears to enhance the cleanliness of oval canals (Fig. 7–19) [65][83]. However, further research must be done to determine the best treatment techniques for a highly variable root canal system.

![Figure 7-19 A](http://home.mdconsult.com.eprxy1.lib.hku.hk/das/book/body/0/1357/4...)

**Figure 7-19 A**, Cross section of a mandibular anterior tooth showing pulp remnants in the recesses of root canal walls in the apical...
A recent study has used high-resolution computerized tomography to create a detailed, 3-D model of the root canal system. This method permits precise measurement of canal volume, area, and dimensions. The mean canal diameters in the apical 0.5 mm of maxillary molars were measured for the MB-1 canal (188 ± 5 µm), the distobuccal canal (174 ± 12 µm), and the palatal canal (318 ± 23 µm). Such information goes a long way toward the establishment of final instrumentation sizes for cleaning and shaping.

The apical anatomy studies also indicate that the root apex should be resected 2 to 3 mm during surgical procedures; this removes most of the unprepared and unfilled accessory canals, eliminating a potential reservoir of pathogens. In one study, researchers used a bevel perpendicular to the long axis of the root, and apical ramifications and accessory canals increasingly were eliminated by 1 mm of root resection (52% and 40%, respectively), 2 mm of root resection (78% and 40%), and 3 mm of root resection (98% and 93%). This showed that root-end resections of 3 mm are most effective for eliminating most of these structures.

In root-end resections a bevel perpendicular to the long axis of a root exposes a small number of microtubules. However, a root resection with a 45-degree bevel exposes a significantly greater number of tubules, increasing the chance of leakage into and out of the root canal. To prevent this, root-end cavity preparations should extend coronally to the height of the bevel (Fig. 7-20).

The root apex contains a variety of anatomic structures and tissue remnants. Intercanal connections can become exposed, and a single foramen may become multiple foramina. Treatment results are poor if this altered anatomy is not recognized, prepared, and obturated. One study evaluated the root apex of teeth with refractory apical periodontitis that did not respond to root canal therapy and found that 70% had significant apical ramifications. This incidence strongly suggests a close relationship between the anatomic complexity of the root canal system and the persistence of periradicular pathosis.

An isthmus is a narrow, ribbon-shaped communication between two root canals that contains pulp or pulpally derived tissue. All isthmi must be found, prepared, and filled during surgery, because they can function as bacterial reservoirs. Any root with two or more canals may have an isthmus. Therefore the presence of an isthmus should be suspected whenever multiple canals are seen on a resected root surface. In one study, the authors recommended that methylene blue dye be used to aid visualization of the outline of the resected root surface and thus detection of an isthmus.
In one study, isthmi in the mesiobuccal root of maxillary first molars were found most often 3 to 5 mm from the root apex. A complete or partial isthmus was found at the 4 mm level 100% of this time. In another study, partial isthmi were found more often than complete isthmi.

Identification and treatment of isthmi are vital to the success of surgical procedures. Kim et al identified five types of isthmi that can be found on a beveled root surface (Fig. 7–21).

Figure 7–21  Schematic representation of isthmus classifications described by Kim et al. Type I is an incomplete isthmus; it is a faint communication between two canals. Type II is characterized by two canals with a definite connection between them (complete isthmus). Type III is a very short, complete isthmus between two canals. Type IV is a complete or incomplete isthmus between three or more canals. Type V is marked by two or three canal openings without visible connections.

Isthmi are found in 15% of anterior teeth; in maxillary premolar teeth, they are found in 16% at the 1 mm resection level and in 52% at the 6 mm resection level. The prevalence of isthmi increases in the mesiobuccal root of the maxillary first molar from 30% to 50% as the root is resected from the 2 to 4 mm level. Eighty percent of the mesial roots of mandibular first molars have isthmi at the 3 to 4 mm resection level, whereas 15% of distal roots have isthmi at the 3 mm level. Microsurgical endodontic techniques have enabled clinicians to visualize the resected root surface and identify the isthmus, prepare it with ultrasonic tips, and fill the root-end preparation with acceptable materials. The recognition and microendodontic treatment of canal isthmi have significantly reduced the failure rate of endodontic surgery.
OBJECTIVES AND GUIDELINES FOR ACCESS CAVITY PREPARATION

Objectives

Access is the first and arguably most important phase of nonsurgical root canal treatment. A well-designed access preparation is essential for a good endodontic result. Without adequate access, instruments and materials become difficult to handle properly in the highly complex and variable root canal system. The objectives of access cavity preparation are (1) to achieve straight- or direct-line access to the apical foramen or to the initial curvature of the canal; (2) to locate all root canal orifices; and (3) to conserve sound tooth structure.

A properly prepared access cavity creates a smooth, straight-line path to the canal system and ultimately to the apex (Fig. 7-22). When prepared correctly the access cavity allows complete irrigation, shaping and cleaning, and quality obturation. Ideal access results in straight entry into the canal orifice, with the line angles forming a funnel that drops smoothly into the canal(s). Projection of the canal center line to the occlusal surface of the tooth indicates the location of the line angles. Connection of the line angles creates the outline form. Modifications of the outline form may be needed to facilitate location of canals and to create a convenience form. The clinician must find a balance between creating adequate access and removing too much dentin, which could compromise the final restoration or promote crown fracture.

Guidelines

The guidelines described in the following sections are essential to the completion of an ideal access preparation.

Visualization of the Likely Internal Anatomy

Because internal anatomy dictates access shape, the first step in preparing an access cavity is visualization of the position of the pulp space in the tooth. This requires evaluation of angled periapical radiographs and examination of the coronal and cervical tooth anatomy. Diagnostic radiographs help the clinician estimate the position of the pulp chamber, the degree of chamber calcification, the number of roots and canals, and the approximate canal length. Palpation along the attached gingiva aids the determination of root location and direction. The clinician uses the information from these assessments to choose the direction of initial bur penetration.
Evaluation of the Cementoenamel Junction and Occlusal Anatomies

Traditionally, access cavities have been prepared in relation to the occlusal anatomy. However, complete reliance on the occlusal anatomy is dangerous, because this morphology can change as the crown is destroyed by caries and reconstructed with various restorative materials. Complete dependence on the occlusal anatomy may explain the occurrence of some procedural errors. In a study involving 500 pulp chambers, Krasner and Rankow[74] found that the cementoenamel junction (CEJ) was the most important anatomic landmark for determining the location of pulp chambers and root canal orifices. The study demonstrated the existence of a specific and consistent anatomy of the pulp chamber floor. These authors proposed five guidelines, or laws, of pulp chamber anatomy to help clinicians determine the number and location of orifices on the chamber floor (Fig. 7-23).

First law of symmetry: Except for the maxillary molars, canal orifices are equidistant from a line drawn in a mesiodistal direction through the pulp chamber floor.

Second law of symmetry: Except for the maxillary molars, canal orifices lie on a line perpendicular to a line drawn in a mesiodistal direction across the center of the pulp chamber floor.

Law of color change: The pulp chamber floor is always darker in color than the walls.

First law of orifice location: The orifices of the root canals are always located at the junction of the walls and the floor.

Second law of orifice location: The orifices of the root canals are always located at the angles in the floor-wall junction.

Third law of orifice location: The orifices of the root canals are always located at the terminus of the roots’ developmental fusion lines.

More than 95% of the teeth Krasner and Rankow examined conformed to these laws.[74] Slightly fewer than 5% of mandibular second and third molars did not conform because of the occurrence of C-shaped anatomy.

Preparation of the Access Cavity through the Lingual and Occlusal Surfaces

Access cavities on anterior teeth usually are prepared through the lingual tooth surface, and those on posterior teeth are prepared through the occlusal surface. These approaches are the best means of achieving straight-line access and diminishing esthetic and restorative concerns. Some authors have recommended that the traditional anterior access for mandibular incisors be moved from the lingual surface to the incisal surface. This allows better access to the lingual canal and improves canal debridement (Fig. 7-24).
Removal of All Defective Restorations and Caries before Entry into the Pulp Chamber

The clinician must remove all defective restorations before entering the root canal system. With an open preparation, canals are much easier to locate, and shaping, cleaning, and obturation are much easier to perform. Working through restorations also allows restorative debris to become more easily lodged in the canal system (see Fig. 7–74, D).

Figure 7-24 An incisal access cavity on mandibular anterior teeth may allow for improved straight-line access and canal debridement.

Figure 7-74 A, Poor access placement and inadequate mesial extension leave both mesial orifices uncovered. Information about the position and location of pulp chambers can be obtained through evaluation of preoperative radiographs, especially bite-wing radiographs, and assessment of the tooth anatomy at the CEJ. B, Inadequate extension of the distal access cavity leaves the distobuccal canal orifice unexposed. All developmental grooves must be traced to their termination and must not be allowed to disappear into an axial wall. C, Gross overextension of the access cavity weakens the coronal tooth structure and compromises the
All carious dentin must be removed during access preparation. This prevents irrigation solutions from leaking past the rubber dam into the mouth and blocks carious dentin and its bacteria from entering the root canal system. If a chamber wall is perforated during removal of carious dentin, allowing leakage of saliva into the pulp spaces, the wall must be repaired immediately with a temporary filling material, preferably from inside the cavity preparation. Sometimes removal of extensive defective restorations and carious dentin may not leave enough tooth structure for placement of a rubber dam clamp and seal against salivary contamination. A crown lengthening procedure should be performed to correct this situation before the root canal procedure is begun.

Removal of Unsupported Tooth Structure

The preparation of an access cavity results in the removal of part of the central portion of the tooth; this reduces the tooth’s resistance to stress. After completing the preparation, the clinician should remove all unsupported tooth structure to assess restorability and to prevent tooth fracture. Unnecessary removal of sound tooth structure should be avoided.

Creation of Access Cavity Walls That Do Not Restrict Straight- or Direct-Line Passage of Instruments to the Apical Foramen or Initial Canal Curvature

Complete clinician control over all enlarging and filling instruments is vital. Sufficient tooth structure must be removed to allow instruments to be placed easily into each canal orifice without interference from canal walls, particularly when a canal curves severely or leaves the chamber floor at an obtuse angle. The walls of the root canal, rather than the walls of the access preparation, must guide the passage of instruments down the canal. Failure to follow this guideline results in treatment errors, including root perforation, misdirection of an instrument from the main canal (ledge formation), instrument separation, or creation of an incorrect canal shape (apical transportation). Following this guideline minimizes the occurrence of procedural errors and maximizes the effectiveness of shaping, cleaning, and obturation instruments.

Delay of Dental Dam Placement until Difficult Canals Have Been Located and Confirmed

Difficulty can arise in gaining access into teeth that are crowded and rotated, fractured to the “gum line,” heavily restored and calcified, or part of a fixed prosthesis. In these situations the clinician’s best course of action may be to prepare the initial part of the access cavity before placing the dental dam so that the inclination of root eminences can be visualized; this information can be used as an indicator of the direction of the long axis of the treated tooth. Micro-Openers (Dentsply Maillefer, Tulsa, OK) (Fig. 7-25) are excellent instruments for locating canal orifices when a dental dam has not been placed. These flexible, stainless steel hand instruments have #.04 and #.06 tapered tips. They also have offset handles that provide enhanced visualization of the pulp chamber.

The dental dam must be placed once the roof of the pulp chamber has been penetrated and the canals identified.
Location, Flaring, and Exploration of All Root Canal Orifices

A sharp endodontic explorer is used to locate canal orifices and to determine their angle of departure from the pulp chamber. Next, all canal orifices and the coronal portion of the canals are flared to make instrument placement easier. The canals are then explored with small, precurved K-files (#6, #8, or #10). The clinician must take care to keep these instruments within the confines of the canal system until the working length has been accurately determined. A lubricating agent (e.g., RC-Prep [Premier Dental Products, Norristown, PA]), a water-based preparation that will not congeal vital pulp tissue, may be used on instruments and introduced into the canal. Congealed pulp tissue may form a collagen plug that blocks the apex, preventing complete shaping and cleaning.

Inspection of the Pulp Chamber Using Magnification and Adequate Illumination

Magnification and illumination are particularly important in root canal therapy, especially for determining the location of canals, negotiating constricted, curved, and calcified canals, and debriding and removing tissue and calcifications from the pulp chamber. Enhanced vision allows the clinician to see internal dentin color changes and subtle landmarks that may not be visible to the unaided eye. Surgical loupes, endodontic endoscopes,[3] and the DOM are some of the commercially available instruments that can help the clinician accomplish these goals. A practitioner trained in microscopic techniques has a better chance of locating and negotiating intricate root canal systems.

Tapering of Cavity Walls and Evaluation of Space Adequacy for a Coronal Seal

A proper access cavity has tapering walls and is widest at the occlusal surface. In such a preparation occlusal forces do not push the temporary restoration into the cavity and disrupt the seal. At least 3.5 mm of temporary filling material (e.g., Cavit [Premier Dental Products]) is needed to provide an adequate coronal seal for a short time.[17] Recently, orifice plugs of composite glass ionomer (MTA [Dentsply – Tulsa Dental, Tulsa, OK]) have shown promise in enhancing the coronal seal (i.e., reducing the risk of bacterial contamination).
MECHANICAL PHASES OF ACCESS CAVITY PREPARATION

Armamentaria

The preparation of an access cavity requires the following equipment:

- Magnification and illumination
- Handpieces
- Burs
- Endodontic explorer (DG-16, DE-17)
- Endodontic operative spoon
- #17 Explorer
- Ultrasonic unit and tips

Magnification and Illumination

The access cavity cannot be prepared adequately without the use of magnification and an appropriate light source. At the least the clinician needs surgical loupes with an auxiliary light source (see Chapter 6). The DOM is the preferred means of magnification and illumination.

Handpieces

An experienced clinician with good tactile awareness is likely to perform most phases of access preparation with a high-speed handpiece. After penetration of the dentin, a less experienced clinician may benefit from the increased tactile awareness offered by a slow-speed handpiece. For challenging access cavity preparations, especially those involving calcified and receded pulp chambers, even experienced clinicians may sacrifice cutting speed and efficiency in favor of the increased cutting control of the slow-speed handpiece or an ultrasonic tip used with the DOM.

Burs

Numerous burs have been developed to assist the clinician with access cavity preparation. Providing a detailed, unabridged list of these burs would be difficult, and most clinicians have their own set of preferred access burs. In reality, creating an access cavity that meets the previously stated guidelines is more important than worrying about which burs are used in the process. This discussion therefore covers some of the more common access burs.

Round carbide burs (sizes #2, #4, and #6) (Fig. 7-26) are used extensively in the preparation of access cavities. They are used to remove caries and to create the initial external outline shape. They also are useful for penetrating through the roof of the pulp chamber and for removing the roof. Some clinicians prefer to use a fissure carbide bur (Fig. 7-27) or a diamond bur with a rounded cutting end (Fig. 7-28) to perform these procedures. The advantage of the fissure carbide and diamond round-end burs is that they also can be used for some of the axial wall extensions of the access cavity preparation. However, when these burs are used for this purpose by inexperienced clinicians, their cutting ends can gouge the pulp floor and axial walls (see Fig. 7-75, A).
Figure 7-26 Access burs: #2, #4, and #6 round carbide burs.

Figure 7-27 Access bur: #57 fissure carbide bur.

Figure 7-28 Access bur: round-end cutting tapered diamond bur.
Fissure carbide and diamond burs with safety tips (i.e., they do not have a cutting end) (Fig. 7–29) are safer choices for axial wall extensions. They can be used to extend and favorably orient the axial walls of the pulp chamber. Because they have no cutting end, the burs can be allowed to extend to the pulp floor, and the entire axial wall can be moved and oriented all in one plane from the enamel surface to the pulp floor. Such a technique produces axial walls free of gouges as the final access extensions are created. Fissure carbide and diamond burs also can be used to level off cusp tips and incisal edges, which are used as reference points for the working length.

Figure 7–75 A, Overzealous tooth removal caused by improper bur angulation and failure to recognize the lingual inclination of the tooth. This results in weakening and mutilation of the coronal tooth structure, which often leads to coronal fractures. B, Inadequate opening; the access cavity is positioned too far to the gingival with no incisal extension. This can lead to bur and file breakage, coronal discoloration because the pulp horns remain, inadequate instrumentation and obturation, root perforation, canal ledging, and apical transportation. C, Labial perforation caused by failure to extend the preparation to the incisal before the bur shaft entered the access cavity. D, Furcation perforation caused by failure to measure the distance between the occlusal surface and the furcation. The bur bypasses the pulp chamber and creates an opening into the periodontal tissues. Perforations weaken the tooth and cause periodontal destruction. They must be repaired (Fig. 7–72) as soon as they are made for a satisfactory result. E, Perforation of the mesial tooth surface caused by failure to recognize that the tooth is tipped and failure to align the bur with the long axis of the tooth. This is a common error in teeth with full crowns. Even when these perforations are repaired correctly, they usually cause a permanent periodontal problem because they occur in a difficult maintenance area.
Round diamond burs (sizes #2 and #4) (Fig. 7–30) are needed when endodontic access must be made through porcelain or ceramometal restorations. Diamond burs are less traumatic to porcelain than carbide burs and are more likely to penetrate the porcelain without cracking or fracturing it. They should always be used with water spray to control heat buildup in porcelain restorations. After penetrating the porcelain the clinician should switch to a carbide bur for metal or dentin penetration because of this bur’s greater cutting efficiency.

Many teeth requiring access cavity preparations have metal restorations that must be penetrated. These restorations may be amalgams, all-metal cast restorations, or metal copings of porcelain fused to metal crowns. A transmetal bur (Fig. 7–31) is excellent for this purpose because of its exceptional cutting efficiency. To penetrate a metal restoration, the clinician should always use a new transmetal bur with water spray for maximum cutting effect.
If a tooth has a receded pulp chamber and calcified orifices, the clinician often must cut into the root to locate and identify the canal orifices. Extended-shank round burs, such as the Mueller bur (Brasseler, Savannah, GA) (Fig. 7–32, A) and the LN bur (Caulk/ Dentsply, Milford, DE) (Fig. 7–32, B), are very useful for this purpose. The extra-long shank of these burs moves the head of the handpiece away from the tooth, improving the clinician’s visibility during this delicate procedure. As an alternative, ultrasonic units offer good visibility with precise cutting areas.

Once the orifices have been located, they should be flared or enlarged and blended into the axial walls of the access cavity. This process permits the intracanal instruments used during shaping and cleaning to enter the canal(s) easily and effortlessly. Gates-Glidden burs can be used for this purpose, starting with smaller sizes and progressing to the larger sizes (Fig. 7–33). More recently, #.12 tapered rotary endodontic files (Fig. 7–34) have been used for the flaring and blending procedure.
Various hand instruments are useful for preparing access cavities. The DG-16 endodontic explorer (Fig. 7–35) is used to identify canal orifices and to determine canal angulation. The CK-17 endodontic explorer (Fig. 7–35) (C-K Dental, San Diego, CA) serves the same purpose, but its thinner, stiffer tip can be useful for identifying calcified canals. The endodontic spoon (Fig. 7–36) can be used to remove coronal pulp and carious dentin. A #17 operative explorer is useful for detecting any remaining pulp chamber roof, particularly in the area of a pulp horn (Fig. 7–37).
Ultrasonic Unit and Tips

An ultrasonic unit (Fig. 7–38) and tips specifically designed for endodontic procedures can be valuable aids in the preparation of access cavities. Ultrasonic tips (Fig. 7–39) can be used to trough and deepen developmental grooves to remove tissue and explore for canals. Ultrasonic systems provide excellent visibility compared with conventional handpiece heads, which typically obstruct vision. Fine ultrasonic tips are smaller than conventional round burs, and their abrasive coatings allow clinicians to sand away dentin and calcifications conservatively when exploring for canal orifices.

Figure 7-35  Access instruments: DG-16 endodontic explorer (top), CK-17 endodontic explorer (bottom).

Figure 7-36  Access instrument: Endodontic spoon

Figure 7-37  Removal of the pulp horn is evaluated with a #17 operative explorer.

Ultrasonic Unit and Tips
Access Cavity Preparations

Anterior Access Cavity Preparations

Many of the same steps are used in similar tooth types to prepare an access cavity. The following discussion outlines the steps for maxillary and mandibular anterior teeth. Tooth-specific access concerns are illustrated and discussed in Section Morphology and Access Cavity Preparations for Individual Teeth later in the chapter.

Removal of Caries and Permanent Restorations.

Caries typically is removed early, before the pulp chamber is entered. This minimizes the risk of contamination of the pulp chamber or root canal(s) with bacteria. Defective permanent restorations, whether amalgams, composite resins, or crowns, must be removed entirely to prevent coronal leakage from contaminating the pulp chamber, the root canal(s), or both after the endodontic appointment. Removal of defective permanent restorations also permits straight-line access and prevents restorative fragments from becoming lodged in the root canal system (see Fig. 7–74, D). If recurrent decay is detected or suspected, the permanent restoration must be removed entirely to prevent coronal contamination of the pulp chamber.

The management of intact permanent restorations when recurrent caries is not present requires some judgment. Amalgam and composite restorations typically are removed entirely to improve visibility for the search for root canal orifices. However, the clinician may want to retain the proximal portion of a Class II restoration that extends subgingivally to aid in rubber dam isolation. When parts of existing permanent restorations are not removed, the clinician usually can widen the access opening larger than ideal at the expense of removing restorative material, not sound tooth structure. The remaining permanent restoration

Figure 7-38  Endodontic ultrasonic unit. (Courtesy Sybron Endodontics, Orange, CA.)

Figure 7-39  Endodontic ultrasonic tips.

Access Cavity Preparations

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material is removed at the end of the appointment before the temporary restoration is placed.

Often clinicians decide to perform endodontic therapy through intact crowns rather than removing or replacing them. These access cavities are repaired after completion of the root canal procedure. The patient and the clinician must realize that visibility can be compromised in these circumstances, particularly if a DOM is not used. The clinician can enhance visibility by beveling the crown’s cavosurface margins and by making sure all axial walls are glassy smooth.

**Initial External Outline Form.**

Once caries and restorations have been addressed, the clinician creates an initial external outline opening on the lingual surface of the anterior tooth. This step often is performed during the removal of caries and restorations. For an intact tooth, the clinician should begin in the center of the lingual surface of the anatomic crown (Fig. 7-40, A). A #2 or #4 round bur or a tapered fissure bur is used to penetrate through the enamel and slightly into the dentin (approximately 1 mm). An outline form is created, similar in geometry to an ideal access shape for the particular anterior tooth (Fig. 7-40, B); it is one half to three fourths the projected final size of the access cavity. Because most of this step involves removal of enamel, the high-speed handpiece is used for cutting efficiency. The bur is directed perpendicular to the lingual surface as the external outline opening is created (Fig. 7-40, C).

![Figure 7-40](image)

**Figure 7-40** A, In anterior teeth the starting location for the access cavity is the center of the anatomic crown on the lingual surface (X). B, Preliminary outline form for anterior teeth. The shape should mimic the expected final outline form, and the size should be one half to three fourths the size of the final outline form. C, The angle of penetration for the preliminary outline form is perpendicular to the
Penetration of the Pulp Chamber Roof.

Experienced clinicians can comfortably perform this step with a high-speed handpiece, but less experienced clinicians may find the increased tactile sensation of a slow-speed handpiece a safer option. Continuing with the same round or tapered fissure bur, the clinician changes the angle of the bur from perpendicular to the lingual surface to parallel to the long axis of the root (Fig. 7–40, D). Penetration into the tooth is accomplished along this root’s long axis until the roof of the pulp chamber is penetrated; frequently a drop-in effect is felt when this occurs. The clinician should measure the distance from the incisal edge to the roof of the pulp chamber on a dimensionally accurate preoperative radiograph and limit penetration to this distance. If the drop-in effect is not felt at this depth, the clinician should evaluate the situation carefully to prevent a gouge or perforation. The depth and angle of penetration should be assessed for any deviation away from the long axis of the root in both the mesiodistal and buccolingual dimensions, and the penetration angle should be realigned if necessary. If all looks good, the clinician should probe the access opening with an endodontic explorer using magnification and illumination. Often the sharp explorer tip penetrates through the pulp chamber roof with firm pressure. Angled radiographs should be taken to assess progress if any confusion or doubt exists. A little cautiousness and concern at this stage can prevent an iatrogenic mishap (see Fig. 7–75, C).

Complete Roof Removal.

Once the pulp chamber has been penetrated, the remaining roof is removed by catching the end of a round bur under the lip of the dentin roof and cutting on the bur’s withdrawal stroke (Fig. 7–40, E). Because each tooth has a unique pulp chamber anatomy, working in this manner allows the internal pulp anatomy to dictate the external outline form of the access opening. In vital cases pulp tissue hemorrhage can impair the clinician’s ability to see the internal anatomy. In such cases, as soon as enough roof has been removed to allow instrument access, the coronal pulp should be amputated at the orifice level with an endodontic spoon or round bur and the chamber irrigated copiously with sodium hypochlorite. If the hemorrhage continues, a tentative canal length can be established by measuring the preoperative radiograph. A small broach coated with a chelating agent then can be introduced into the canal and rotated, which amputates the radicular pulp at a more apical level. This procedure is followed by irrigation with sodium hypochlorite. After hemorrhage has been controlled, allowing visibility, all of the pulp chamber roof, including the pulp horns, must be removed and all internal walls must be flared to the lingual surface of the tooth. Complete roof removal is confirmed with a #17 operative explorer if no “catches” are discovered as the explorer tip is withdrawn from the pulp chamber along the mesial, distal, and facial walls.

Identification of All Canal Orifices.

After the pulp chamber has been unroofed, the canal orifices are located with an endodontic explorer (Fig. 7–41). This instrument is to the endodontist what a periodontal probe is to the periodontist. Used for reaching, feeling, and often digging at the hard tissue, it is the tactile extension of the clinician’s fingers. Natural anatomy indicates the usual places for orifices, but restorations, dentinal protrusions, and dystrophic calcifications can dictate the actual configuration the clinician encounters. While probing the chamber floor, the explorer often penetrates or dislodges calcific deposits blocking an orifice. It also can be used to evaluate straight-line access. Positioning the explorer in an orifice allows the clinician to check the shaft for clearance from the axial walls and to determine the angle at which a canal departs the main chamber (Fig. 7–42).
The endodontic explorer is preferred over the rotating bur as the instrument for locating canal orifices because its double-ended design offers two angles of approach. The clinician should keep in mind the probability of finding additional canals in the tooth and the most likely anatomic location of these canals.

Removal of the Lingual Shoulder and Orifice and Coronal Flaring.

Once the orifice(s) has been identified and confirmed, the lingual shoulder is removed. This is the lingual shelf of dentin that extends from the cingulum to a point approximately 2 mm apical to the orifice (Fig. 7-43). Its removal aids straight-line access and allows for more intimate contact of files with the canals walls for effective shaping and cleaning.

Figure 7-41 An endodontic explorer is used to search for canal orifices.

Figure 7-42 Root canal orifices are explored to assess straight-line access and determine the path of insertion for endodontic instruments.
The lingual shoulder can be removed with a tapered safety-tip diamond or carbide bur or with Gates-Glidden burs. The tip of a fine safety-tip diamond bur is placed approximately 2 mm apical to the canal orifice and inclined to the lingual during rotation to slope the lingual shoulder. The clinician must be careful when using this bur to avoid placing a bevel on the incisal edge of the access preparation (Fig. 7-44). When Gates-Glidden burs are used, the largest that can passively be placed 2 mm apical to the orifice is used first. During rotation the bur is leaned against the lingual shoulder and withdrawn. The clinician can increase the size of these burs sequentially, depending on the size of the canal, and repeat the shaping of the lingual wall until the lingual shoulder of dentin has been eliminated.

Figure 7-43  Lingual shoulder of the anterior tooth, extending from the cingulum to 2 mm apical to the orifice.
During this process the orifice should also be flared so that it is contiguous with all walls of the access preparation. This can be done using small to large Gates-Glidden burs. These burs are used in a circumferential filling motion, flaring each wall of the canal in sequence. To prevent iatrogenic mishaps on thin walls facing a root concavity, these burs should be placed passively into the canal and rotated as they are gently leaned against a canal wall and withdrawn.

Another approach to flaring the orifice involves the use of rotary nickel-titanium orifice openers; they should be used at slow speeds and low torque.

**Straight-Line Access Determination.**

After the lingual shoulder has been removed and the orifice(s) flared, the clinician must determine whether straight-line access has been achieved. Ideally, an endodontic file can approach the apical foramen or the first point of canal curvature undeflected. Unnecessary deflection of the file can result in numerous consequences related to loss of instrument control. Deflected instruments function under more stress than undeflected instruments and are more susceptible to separation during the shaping and cleaning process (Fig. 7-45). Deflected instruments also lack access to critical areas of the canal and therefore do not shape and clean effectively. Attempts to shape and clean without straight-line access often lead to procedural errors such as ledging, transportation, and zipping (Fig. 7-46). A ledge is an iatrogenically created root canal wall irregularity that may impede placement of an intracanal instrument to the apex. Transportation occurs in the portion of the canal apical to a curvature when canal wall structure opposite the curve is removed, tending to straighten the canal curvature. Zipping, or elliptication of the apical foramen, occurs when an overextended file transports the outer wall of the apical foramen. Conversely, undeflected instruments provide better tactile sensation, which is necessary for “feeling” the canal anatomy and “feeling” how the file is performing in...
the root canal system.

Figure 7-45  Separation of a rotary endodontic instrument as a result of underextended access preparation rather than canal binding.

Figure 7-46  Inadequate access preparation. The lingual shoulder was not removed, and incisal extension is incomplete. The file has begun to deviate from the canal in the apical region, creating a ledge.

Straight-line access is evaluated by inserting into the canal the largest file that fits passively to the apical foramen or the point of the first canal curvature. This internal length can be determined by measuring a diagnostic preoperative periapical radiograph. The file is inserted gently and withdrawn as the clinician “feels” for canal binding or deflection. If deflection is detected, the clinician must reevaluate the adequacy of lingual shoulder removal before changing the incisal edge position of the access preparation. Inadequate removal of the lingual shoulder causes the file to deflect in a facial direction, and an inexperienced clinician may overextend the incisal edge of the access preparation in an attempt to achieve straight-line access (Fig. 7-47). If the lingual shoulder has been adequately removed and the file still binds on the incisal edge, the access cavity should be extended farther incisally until the file is not deflected. The final position of the incisal wall of the access cavity is determined by two factors: (1) complete removal of the pulp horns and (2) straight-line access.
Visual Inspection of the Access Cavity.

The clinician should inspect and evaluate the access cavity using appropriate magnification and illumination. Although this can be done during any stage of the preparation, it should always be done at this point. The axial walls at their junction with the orifice must be inspected for grooves that might indicate an additional canal. The orifice and coronal canal must be evaluated for a bifurcation (see Fig. 7–14).

Refinement and Smoothing of Restorative Margins.

The final step in the preparation of an access cavity is to refine and smooth the cavosurface margins. Rough or irregular margins can contribute to coronal leakage through a permanent or temporary restoration. Proper restorative margins are important because anterior teeth may not require a crown as the final restoration. Definite, smooth cavosurface margins allow the clinician to place and finish a composite resin final restoration with the precision necessary to minimize coronal leakage. Such leakage could jeopardize the success of the root canal procedure.

Another factor the clinician must consider when finalizing the access margins of a maxillary anterior tooth is that the final composite resin restoration will be placed on a functional tooth surface. The incisal edges of the mandibular anterior teeth slide over these maxillary lingual surfaces during excursive jaw movement. Therefore the restorative margins of maxillary anterior teeth should be created to allow a bulk of restorative material at the margin. Butt joint margins are indicated rather than beveled margins, which produce thin composite edges that can fracture under excursive functional loads and ultimately result in coronal leakage. Obviously, if the anterior tooth requires a crown as the final restoration, the access cavosurface margin becomes a less critical factor.

Individual Anterior Teeth.

Please see the figures in the section Morphology and Access Cavity Preparations for Individual Teeth later in the chapter.
Posterior Access Cavity Preparations

The process of preparing access cavities on posterior teeth is similar to that for anterior teeth, but enough differences exist to warrant a separate discussion.

Removal of Caries and Permanent Restorations.

The discussion of caries and permanent restoration removal presented in the Anterior Access Cavity section applies equally to posterior teeth. Posterior teeth requiring root canal therapy typically have been heavily restored or the carious process is extensive. Such conditions, along with the complex pulp anatomy of posterior teeth, can make the access process challenging.

Initial External Outline Form.

The removal of caries and existing restorations often accomplishes this step. As with anterior teeth, the pulp chamber of posterior teeth is positioned in the center of the tooth at the level of the CEJ. An access starting location must be determined for an intact tooth. In maxillary premolars this point is on the central groove between the cusp tips (Fig. 7–48). The clinician must keep in mind that the crowns of mandibular premolars are tilted linguually relative to their roots (Fig. 7–49), and the starting location must be adjusted to compensate for this tilt (Fig. 7–50). In mandibular first premolars the starting location is halfway up the lingual incline of the buccal cusp on a line connecting the cusp tips. Mandibular second premolars require less of an adjustment because they have less lingual inclination. The starting location for this tooth is one third the way up the lingual incline of the buccal cusp on a line connecting the buccal cusp tip and the lingual groove between the lingual cusps.
Figure 7-48  

A, Starting location for access to the maxillary premolar (X).  
B, Initial outline form (dark) and projected final outline form (dotted line).
Figure 7-49  The crown of a mandibular premolar is tilted lingually relative to the root.
To determine the starting location for molar access cavity preparations, the clinician must establish the mesial and distal boundary limitations (Fig. 7-51). Evaluation of bite-wing radiographs is an accurate method of assessing the mesiodistal extensions of the pulp chamber. The mesial boundary for both the maxillary and mandibular molars is a line connecting the mesial cusp tips. Rarely are pulp chambers found mesial to this imaginary line. A good initial distal boundary for maxillary molars is the oblique ridge. For mandibular molars the initial distal boundary is a line connecting the buccal and lingual grooves. For molars the correct starting location is on the central groove halfway between the mesial and distal boundaries.

Figure 7-50  A, Mandibular first premolar and access starting location (X) (occlusal view). B, Mandibular first premolar and starting location (proximal view). C, Mandibular second premolar and access starting location (X) (occlusal view). D, Mandibular second premolar and starting location (proximal view).
Penetration through the enamel into the dentin (approximately 1 mm) is performed using a #2 round bur for premolars and a #4 round bur for molars. A tapered fissure bur may be used instead of round burs. The bur is directed perpendicular to the occlusal table, and an initial outline shape is created at about one half to three fourths its projected final size. The premolar shape is oval and widest in the buccolingual dimension. The molar shape is also oval initially; it is widest in a buccolingual dimension for maxillary molars and in a mesiodistal direction for mandibular molars. The final outline shape for molars is triangular (for three canals) or rhomboid (for four canals); however, the canal orifices dictate the position of the corners of these geometric shapes. Therefore, until the orifices have located, the initial outline form should be left as an oval.

**Penetration of the Pulp Chamber Roof.**

Continuing with the same round or tapered fissure bur, the clinician changes the angle of penetration from perpendicular to the occlusal table to an angle appropriate for penetration through the roof of the pulp chamber. In premolars the angle is parallel to the long axis of the root(s) both in the mesiodistal and buccolingual directions. Failure to analyze this penetration angle carefully can result in gouging or perforation, because premolar roots often are tilted relative to the occlusal plane. In molars the penetration angle should be toward the largest canal, because the pulp chamber space usually is largest just occlusal to the orifice of this canal. Therefore, in maxillary molars the penetration angle is toward the palatal orifice, and in mandibular molars it is toward the distal orifice (Fig. 7-52).
As with anterior teeth, penetration is limited to the distance measured on a preoperative radiograph to just penetrate the roof of the pulp chamber. If the drop-in effect is not felt at this depth, the clinician should carefully evaluate the angle of penetration before drilling deeper. In multirooted posterior teeth, the clinician must guard against lateral and furcation perforations. Aggressive probing with an endodontic explorer often can help locate the pulp chamber.

**Complete Roof Removal.**

A round bur, a tapered fissure bur, or a safety-tip diamond or carbide bur is used to remove the roof of the pulp chamber completely, including all pulp horns (Fig. 7–53, A and B). Visibility problems caused by vital pulp hemorrhage should be handled as described in the section for anterior teeth. The goal is to funnel the corners of the access cavity directly into the orifices, and a safety-tip diamond or carbide bur performs this task nicely; it can be set on the pulp floor and the entire axial wall shaped at one time with little chance of gouging (Fig. 7–54). The safety-tip diamond or carbide bur is passed between the orifices along the axial walls to remove the roof, taper the internal walls, and create the desired external outline shape simultaneously.
Identification of All Canal Orifices.

In posterior teeth with multiple canals, the canal orifices play an important role in determining the final extensions of the external outline form of the access cavity. Ideally, the orifices are located at the corners of the final preparation to facilitate the shaping and cleaning process. Internally, the access cavity should have all orifices positioned entirely on the pulp floor and should not extend into an axial wall. Extension of an orifice into the axial wall creates a mouse hole effect (Fig. 7–55), which indicates internal underextension and

**Figure 7-53**  
A, Pulp roof/pulp horn removal. The round bur hooks under the lip of the pulp horn. B, The bur is rotated and withdrawn in an occlusal direction to remove the lip. C, Removal of a cervical dentin bulge. A Gates-Glidden bur is placed just apical to the orifice and withdrawn in a distoocclusal direction. D, A safety-tip tapered diamond bur is used to blend and funnel the axial wall from the cavosurface margin to the orifice.

**Figure 7-54** Safety-tip carbide bur is used to shape the axial wall in one plane from the orifice to the cavosurface margin.
impedes straight-line access. In such cases the orifice must be repositioned onto the pulp floor without interference from axial walls.

Removal of the Cervical Dentin Bulges and Orifice and Coronal Flaring.

In anterior teeth the lingual shoulder is the internal anatomic structure that must be removed as an impediment to straight-line access. In posterior teeth the internal impediments are the cervical dentin bulges and the natural coronal canal constriction. The cervical bulges are shelves of dentin that frequently overhang orifices in posterior teeth, restricting access into root canals and accentuating existing canal curvatures. These bulges can be removed with safety-tip diamond or carbide burs or Gates-Glidden burs. The instruments should be placed at the orifice level and leaned toward the dentin bulge to remove the overhanging shelf (Fig. 7–53, C and D).

After the shelf has been removed, the orifice and constricted coronal portion of the canal can be flared with Gates-Glidden burs, which are used in a sweeping upward motion with lateral pressure away from the furcation. An alternate method is to use a #.10 or #.12 tapered engine-driven nickel-titanium file to establish the upper canal shape. As the orifice is enlarged, it should be tapered and blended into the axial wall so that the clinician can slide from the corner of the external outline form down the axial wall into the orifice without encountering any obstructions (Fig. 7–56).
Straight-Line Access Determination.

As with anterior teeth, straight-line access is paramount to successful shaping. Files must have unimpeded access to the apical foramen or the first point of canal curvature to perform properly during shaping and cleaning. The clinician must assess each canal for straight-line access and make all adjustments necessary to achieve this goal (Fig. 7–56, O).

Visual Inspection of the Pulp Chamber Floor.

Please see this section under Anterior Access Cavity Preparations; also see Fig. 7–57.
Refinement and Smoothing of the Restorative Margins.

In both temporary and interim permanent restorations, the restorative margins should be refined and smoothed to minimize the potential for coronal leakage. The final permanent restoration of choice for posterior teeth that have undergone root canal therapy is a crown or onlay.

Individual Posterior Teeth.

Please see the figures in the section Morphology and Access Cavity Preparations for Individual Teeth later in the chapter.
CHALLENGING ACCESS PREPARATIONS

Teeth with Minimal or No Clinical Crown

Several factors can cause the loss of a significant portion of a tooth’s clinical crown. Caries left untreated can cause loss of coronal tooth structure. Badly decayed teeth typically can fracture under occlusal function because of the undermined and unsupported remaining tooth structure. Similarly, teeth that have been heavily restored with amalgam, composite resin, or glass ionomer restorative materials can have minimal coronal tooth structure. These restorative materials provide no extracoronal support for the tooth, and the fillings can fall out during occlusal function, leaving little or no clinical crown remaining. External trauma can cause the clinical crown to fracture, sometimes shearing off to the free gingival margin.

Creating an access cavity on a tooth with little or no clinical crown might seem to be a simple procedure. In young teeth traumatic fractures often expose the pulp chamber, making preparation easy. However, in older teeth that have had caries or large restorations, the pulp chambers typically have receded or calcified. Loss of significant coronal anatomy to guide penetration angles can make access quite difficult.

Before beginning an access cavity on these teeth, the clinician should study their root angulation on preoperative radiographs and examine the cervical crown anatomy with an explorer (Fig. 7–58). Pulp chambers are located at the center of the crown at the level of the CEJ. Access often is started without a dental dam in place so that root eminences can be visualized and palpated as access is attempted (Fig. 7–59). The depth of penetration needed to reach the pulp canal is measured on a preoperative radiograph. If the clinician reaches this depth without locating the canal, two radiographs should be taken before the process proceeds. A straight-on radiograph shows whether the preparation is deviating in a mesial or distal direction. Applying the buccal-object rule, an angled radiograph shows a buccal or lingual deviation in penetration. After checking these radiographs, the clinician can redirect the penetration angle if necessary and move the preparation apically. As soon as the pulp canal is identified, the dental dam must be placed and the access preparation finalized using the guidelines discussed earlier in this chapter.

Figure 7-58  The cervical area of the tooth is explored before access is started.
Heavily Restored Teeth (Including Those with Full Veneer Crowns)

Restorative materials often alter the external anatomic landmarks on the crown of a tooth, making access preparation difficult. Restorative materials and full crowns rarely reproduce the original tooth anatomy in the exact same position. The crown/root angulation often is altered when large restorations or crowns correct occlusal discrepancies (Fig. 7–60). Most restorative materials block the passage of light into the internal aspects of the tooth, resulting in poor visibility during preparation of the access cavity. All these factors, singly or together, complicate the preparation of access cavities on heavily restored teeth. The DOM and transillumination of the cervical area of a heavily restored tooth can greatly improve visibility and reveal landmarks that otherwise would be missed (Fig. 7–57).

Figure 7-59  Access cavity preparation when the anatomic crown is missing. A, A mandibular first premolar with the crown missing. B, An endodontic explorer fails to penetrate the calcified pulp chamber. C, A long-shank round bur is directed in the assumed long axis of the root. D, Perforation of the root wall (arrow), resulting from the clinician’s failure to consider root angulation. E, Palpation of the buccal root anatomy without a dental dam in place to determine root angulation. F, Correct bur angulation after repair of the perforation with MTA (Dentsply-Tulsa Dental, Tulsa, OK). The dental dam is placed as soon as the canal is identified.
In most cases complete removal of large amalgam, composite resin, or glass ionomer restorations is the wisest course (Fig. 7–61). These restorations often have leaky, defective margins or recurrent caries or both. Removing the restoration allows the clinician better visibility of the internal anatomic structures through direct visualization and increased light penetration. With increased visibility the clinician can check for recurrent caries and fracture lines on the pulp chamber walls or floor. Better visibility also makes locating receded or calcified canals easier.

**Figure 7-60** Access cavity error resulting from alteration of the original tooth contours by a full veneer crown. **A,** Original crown contour of the tooth. **B,** A full veneer crown is used to change the original crown contour for esthetic purposes. **C,** Access perforation resulting from reliance on the full veneer crown contour rather than the long axis of the root.
Coronal leakage often occurs when parts of large restorations are left in the tooth because the fillings are loosened by the vibration of the access drilling. Another reason to remove these restoration remnants completely is to prevent pieces of the restorative material from falling into the root canal. Instruments can rub against restoration fragments during shaping and cleaning, creating filings that can be carried into the canal system (see Fig. 7-74). Complete removal prevents these problems.

Complete removal of an extensive restoration from the cervical region of the tooth permits a more direct access to the root canal(s). For example, Class V restorations often cause calcification of the coronal canal, making location of the canal through the occlusal approach quite difficult. Removal of the Class V restoration allows more direct access to the calcified canal, which makes location and treatment much easier. Any remaining canals can be treated through the conventional occlusal access cavity (Fig. 7-62).

Figure 7-61 A, In a heavily restored maxillary second molar that requires root canal therapy, the clinician may attempt access to the canals. Preoperative radiographs demonstrate three important factors: (1) a reinforcing pin is in place (arrow); (2) at least two thirds of the coronal portion is restorative material; and (3) the mesiobuccal canal appears calcified (arrow). These factors suggest complete excavation. B, A patient may ask the clinician to attempt an unexcavated search for the canals; this may result in a furcal perforation, compromising the prognosis. In such cases the patient should be engaged in the decision to continue treatment, which unquestionably involves removal of the existing restoration. C, A safer, more conservative approach is to remove the amalgam, the pin, and any old cements. Careful excavation, using enhanced vision, results in access to the pulp chamber. D, The clinician now can perform sound root canal therapy, followed by internal reinforcement and full coverage.
When an extensive restoration is a full or partial veneer crown, the restoration must be evaluated thoroughly. If any concerns arise about recurrent decay or leaky margins, the crown should be removed before the access cavity is prepared. Removal of the crown allows elimination of all recurrent caries and improves the visibility of the pulp spaces.

Creation of an access through an intact full or partial veneer crown should be done with caution. When such restorations are placed, they often change the crown to root angulation to correct preexisting occlusal discrepancies. Full veneer crowns also can alter tooth rotation. Both these situations make the preparation of access cavities challenging. Preoperative radiographs can be helpful, but the metal in the full veneer crown often masks the underlying pulp chamber. In these situations the clinician’s best approach is to stay as centered in the tooth as possible, using all available clinical and radiographic information. The DOM and transillumination of the CEJ are valuable aides in this process.

Metal veneer crowns are best penetrated with new, sharp carbide burs. Round burs work well, but transmetal burs are more efficient. These carbide crosscut fissure burs are specifically designed to cut through metal restorative materials. Porcelain or ceramometal restorations must be handled delicately to minimize the potential for fracture. The clinician should use a round diamond bur and copious water spray to penetrate the porcelain. When this has been done, a transmetal bur and copious water spray should be used to penetrate the metal coping; the water spray minimizes heat buildup, which could fracture the porcelain (Fig. 7–63).
Many practitioners tend to be too conservative when preparing an access cavity through a veneer crown. An attempt to save the crown often leads to an underextended preparation. All the guidelines for access cavity preparations discussed earlier must be followed. When the preparation is complete, the clinician should search the margins and internal spaces for caries, leakage, and fractures. If no problems are discovered, the clinician may proceed with shaping and cleaning, leaving the full veneer crown in place.

**Teeth with Calcified Canals**

A preoperative radiograph (Figs. 7-64 and 7-65) often appears to reveal total or nearly total calcification of the pulp chamber and radicular canal spaces. Unfortunately, these spaces have adequate room to allow passage of millions of microorganisms. Chronic inflammatory processes (e.g., caries, medications, occlusal trauma, and aging) often cause narrowing of the root canal system. Canals become less calcified as they approach the root apex. Despite severe coronal calcifications, the clinician must assume that all canals exist and must be shaped, cleaned, and obturated to the canal terminus.

**Figure 7-63** Access cavity preparation through a ceramometal crown. A, A round diamond bur is used to penetrate the porcelain. B, After the access outline has been made with the round diamond bur, an end-cutting or a round carbide bur is used to cut through the metal. C, Prepared access cavity, which allows a direct approach to the canals. D, Test files can be placed on the access cavity walls without impingement.

**Figure 7-64** Radiograph taken when a patient’s symptoms; i.e., nonlingering cold sensitivity and sensitivity to sweets, first appeared (1976). The mandibular first molar was not treated endodontically because tests showed it to be vital. Caries was removed from under the mesial amalgam, and calcium hydroxide was placed over the cavity proximal to the pulp space.
Teeth with severe pulp calcification may present problems with locating and negotiating root canals. The use of magnification and transillumination, as well as careful examination of color changes and pulp chamber shapes, can help the clinician safely locate canals. The practitioner should search for root canal orifices only after completely preparing the pulp chamber and cleaning and drying its floor (70% denatured ethanol is useful for drying the floor and enhancing visibility). A fiberoptic light directed through the CEJ can reveal subtle landmarks and color changes that may not otherwise be visible. The chamber floor is darker in color than its walls, and developmental grooves connecting orifices are lighter in color than the chamber floor. The clinician must be aware of these color differences when searching for calcified orifices and must keep in mind that root canal orifices are located at the angles formed by the floor and walls and at the end points of developmental grooves. Additional aids for locating calcified root canals include staining the pulp chamber floor with 1% methylene blue dye, performing the sodium hypochlorite “champagne bubble” test and searching for canal bleeding points.

In severely calcified teeth, calcified dentin must slowly be removed down the root. The clinician can use long, thin ultrasonic tips under the high magnification of a DOM to avoid removing too much tooth structure. As the search moves apically, two radiographs must be taken, one from the straight-on direction and the other from an angled direction. A very small piece of lead foil placed at the apical extent of the penetration can provide a radiographic reference.

Uncovering calcified canals is a challenge. When the canal is located, a small K-file or Hedstrom file (#6, #8, or #10) coated with a chelating agent should be introduced into the canal to determine patency. This file should not be removed until some canal enlargement has occurred. It should be used in short up and down movements and in a selective circumferential filing motion with most of the lateral pressure directed away from the furcation. This safely enlarges the coronal canal and moves it laterally to avoid the furcation. It also creates a path of insertion for larger files and for preflaring burs. Figs. 7–64, 7–65, 7–66, 7–67, 7–68, 7–69, 7–70, 7–71 illustrate several methods that can be used to locate calcified spaces. For the most successful results, the sequences should be followed as shown.
Figure 7-67  Excavation of a restoration and base material. The clinician should extend the cavity preparation toward the assumed location of the pulp chamber, keeping in mind that pulp chambers are located in the center of the tooth at the level of the cementoenamel junction (CEJ).

Figure 7-68  The clinician uses a long-shank #2 or #4 round bur to remove dentin, attempting to locate calcified canals by following Krasner and Rankow’s anatomic laws.

Figure 7-69  An endodontic explorer is used to probe the pulp floor. A straight ultrasonic tip may be used to remove dentin. Angled radiographs must be taken to monitor progress.
The wise clinician stops excavating dentin if a canal orifice cannot be found to avoid weakening the tooth structure. Serious errors can arise from overzealous or inappropriate attempts to locate canals. Root wall or furcation perforations can occur even with the most careful search. In such cases the communication with the periodontal tissues must be repaired immediately (Fig. 7-72). Retrograde surgical procedures become conservative compared with perforations or root fractures. No rapid technique exists for dealing with calcified root canals. Painstaking removal of small amounts of dentin with the aid of the DOM and radiographic confirmation has proved to be the safest approach.

**Figure 7-70** At the first indication of a canal space, the smallest instrument (i.e., a #.06 or #.08 file) should be introduced into the canal. Gentle passive movement, both apical and rotational, often produces some penetration. A slight pull, signaling resistance, usually is an indication that the canal has been located. This should be confirmed by radiographs.

**Figure 7-71** A small hand K-file negotiates the canal to its terminus. An apex locator or radiograph is used to confirm the file’s position.

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Crowded Teeth

Conventional access preparations may not be possible in patients with crowded teeth. The decision regarding an alternate approach must be based on straight-line access principles and conservation of tooth structure. In certain circumstances a buccal access preparation may be the treatment of choice (Fig. 7-73). Modern restorative materials have made repair of this access esthetically acceptable.

Figure 7-72 Perforation repair. A, Access is gained into two canals, but the calcified canal orifice has not been located. B, Minute furcal perforation noted during the search for the canal. C, Absorbent points are used to control hemorrhage. D, CollaCote (Sulzer Dental, Plainsboro, NJ) is introduced to provide a base for repair material. E, MTA (Dentsply-Tulsa Dental, Tulsa, OK) is introduced. F, Location of the calcified canal; enhanced vision, including the DOM, is recommended.
Rotated Teeth

Rotated teeth can present problems for the clinician during access cavity preparation because of the altered crown-to-root relationships. According to Moreinis,[100] diagnostic periapical radiographs, although only two dimensional, are indispensable for “determining the anatomic relationship of the crown to the root and the angle of the root in the arch.” When these factors are identified, the clinician should visualize likely access variations before entering the tooth. Perforations in rotated teeth during access preparation usually occur because of faulty angulation of the bur with respect to the long axis of the root.

Other problems also can occur when tooth angulations are not considered during preparation of an access cavity. Such problems include the following:

- Mistaken identification of an already located canal, resulting in a search in the wrong direction for additional canals. Whenever a difficult canal is located, a file should be placed in the canal and an angled radiograph taken. This determines which canal has been located. A search for another canal orifice can then begin in the correct direction.
- Failure to locate a canal or extra canals.
- Excessive gouging of coronal or radicular tooth structure.
- Instrument separation during attempts to locate an orifice.
- Failure to debride all pulp tissue from the chamber.

The best way to handle these problems is to prevent them from occurring. A thorough radiographic examination is crucial. The initial outline form occasionally can be created without the dental dam; this facilitates positioning of the bur with the long axis of the tooth. Bur penetration for both depth and angulation should be confirmed frequently with radiographs.
ERRORS IN ACCESS CAVITY PREPARATION

Unfortunately errors can occur in the preparation of an access cavity. Most are the result of failure to follow the access guidelines; others reflect a lack of understanding of the internal and external tooth morphology. Common errors are discussed and illustrated in Figs. 7-74, 7-75, 7-76.

Figure 7-76  A, The most embarrassing error, with the greatest potential for medical and legal damage, is entering the wrong tooth because of incorrect dental dam placement. When the crowns of teeth appear identical, the clinician should begin the access cavity before placing the dental dam. B, Burs and files can be broken if used with an improper motion, excessive pressure, or before the access cavity has been properly prepared. A broken instrument may lock into the canal walls, requiring excessive removal of tooth structure to retrieve it. Occasionally fragments may not be retrievable.
MORPHOLOGY AND ACCESS CAVITY PREPARATIONS FOR INDIVIDUAL TEETH

The anatomy shown in the following figures was obtained from human teeth through the use of recently developed 3-D imaging techniques. The teeth were scanned in a high-resolution, microcomputer-assisted tomographic scanner. The data were then manipulated with proprietary computer programs to produce the 3-D reconstructions and visualization. The following individuals made this project possible:

- **Tomographic scan:** Courtesy Michael J. Flynn, PhD, Director, X-Ray Imaging Research Laboratory, Henry Ford Health Sciences, Detroit, MI; also professor (adjunct) of nuclear engineering and radiological science, Ann Arbor, University of Michigan.
- **3-D reconstructions and visualizations:** Courtesy Kevin Montgomery, PhD, technical director, Stanford-NASA National Biocomputation Center, Palo Alto, CA.
- **Facilitator:** Dr. Paul Brown.
- **Radiographs:** Courtesy Dr. L. Stephen Buchanan, Santa Barbara, CA; Dr. John Khademi, Durango, CO; Dr. Raed S. Kasem, Clearwater, FL; Dr. Gary Manasse, Jacksonville, FL; Dr. Michael DeGrood, DeBary, FL; and Dr. Kevin Melker, Clearwater, FL.
- **Access cavity illustrations:** Designed and formatted by Dr. Richard Burns, San Mateo, CA; and Dr. Eric Herbranson, San Leandro, CA.

### Maxillary Central Incisor

The root canal system outline of the maxillary central incisor reflects the external surface outline. A newly erupted central incisor has three pulp horns, and the pulp chamber is wider mesiodistally than buccolingually. A lingual shoulder usually is present, and it must be removed to gain access to the lingual wall of the root canal. The lingual shoulder prevents direct access to the root canal and deflects files labially, often resulting in a ledge or perforation. In cross section, the root canal at the CEJ is triangular in young teeth and oval in older teeth. It gradually becomes round as it approaches the apical foramen. Multiple canals are rare (Table 7–8), but lateral canals are common.

The external access outline form for the maxillary central incisor is a rounded triangle with its base toward the incisal aspect (Fig. 7–78). The width of the triangular base is determined by the distance between the mesial and distal pulp horns. The mesial and distal external walls should converge toward the cingulum. All internal walls should funnel to the root canal orifice. If the lingual shoulder has been removed properly, the entire orifice should be seen through the access opening. The incisal internal wall should approach the lingual surface of the tooth in a near butt joint to allow for a bulk of restorative material on this functional surface.

![Figure 7-78 Access cavity for a maxillary central incisor as viewed through the DOM. A, ×3.4 magnification. B, ×8.4 magnification.](http://home.mdconsult.com.eproxy1.lib.hku.hk/das/book/body/0/1357/5...)
Variation

The outline form of the access cavity changes to a more oval shape as the tooth matures and the pulp horns recede because the mesial and distal pulp horns are less prominent.

Figure 7-77  Maxillary central incisor. Development and anatomic data. Average time of eruption: 7 to 8 years. Average age of calcification: 10 years. Average length: 22.5 mm. Root curvature (most common to least common): Straight, labial, distal.

Figure 7-79  Curved accessory canal with an intersecting straight lateral canal.

Figure 7-80  Parallel accessory canal to main canal with a simple lateral canal.

Figure 7-81  Double lateral canals.
Maxillary Lateral Incisor

The pulp chamber outline of the maxillary lateral incisor is similar to that of the maxillary central; however, it is smaller, and two or no pulp horns may be present. This tooth is wider mesiodistally than buccolingually. Cross section at the CEJ shows a pulp chamber centered in the root, and its shape may be triangular, oval, or round. The clinician must know the anatomy of the pulp chamber before starting the access cavity. From the CEJ the pulp canal becomes round in cross section in the midroot and apical areas. The lingual shoulder of dentin must be removed before instruments can be used to explore the canal. Normally only one root canal is present, but two and three canals have been reported (Table 7-9).

The external access outline form for the maxillary lateral incisor may be a rounded triangle or an oval, depending on the prominence of the mesial and distal pulp horns (Fig. 7-83). When the horns are prominent, the rounded triangular shape is compressed mesiodistally relative to a central incisor, producing a more slender triangle. The outline form usually is oval if the mesial and distal pulp horns are not prominent. All other aspects of the access preparation are the same as those for the central incisor.

Figure 7-83  Access cavity for a maxillary lateral incisor as viewed through the DOM. A, ×3.4 magnification. B, ×5.1 magnification with cervical fiberoptic transillumination.

Figure 7-82  Maxillary lateral incisor. Development and anatomic data. Average time of eruption: 8 to 9 years. Average age of calcification: 11 years. Average length: 22 mm. Root curvature (most common to least common): distal, straight.
Maxillary Canine

The root canal system of the maxillary canine is similar in many ways to that of the maxillary incisors. A major difference is that it is wider labiolingually than mesiodistally. Another difference is that it has no pulp horns. Its smallest pointed incisal edge corresponds to the single cusp. The pulp chamber outline at the CEJ is oval. A lingual shoulder is present, which may prevent shaping and cleaning of the root canal in its lingual dimension. From this point, the root canal remains oval until it approaches the apical third of the root, where it becomes constricted. Because of this oval shape, the clinician must take care to circumferentially file labially and palatally to shape and clean the canal properly. Usually one root canal is present, although two canals have been reported (Table 7–10). The thin buccal bone over the canine eminence often disintegrates, and fenestration is an occasional finding. Accurate determination of the length is critical. Another effect of this fenestration is a slight, permanent apical pressure sensitivity that occasionally occurs after root canal therapy. This sensitivity can best be corrected with apical root surgery.

The external access outline form is oval or slot shaped because no mesial or distal pulp horns are present (Fig. 7–87). The mesiodistal width of the slot is determined by the mesiodistal width of the pulp chamber. The incisogingival dimension is determined by straight-line access factors and removal of the lingual shoulder. The incisal extension often approaches to within 2 to 3 mm of the incisal edge to allow for straight-line access. The incisal wall meets the lingual surface of the canine in a butt joint to provide adequate thickness for a restorative material, because this tooth is heavily involved in excursive occlusal guidance and function. All internal walls funnel to the orifice.
Figure 7-87 Access cavity for a maxillary canine as viewed through the DOM. (×5.1 magnification with cervical fiberoptic transillumination.)

Figure 7-86 Maxillary canine. Development and anatomic data. Average time of eruption: 10 to 12 years. Average age of calcification: 13 to 15 years. Average length: 26.5 mm. Root curvature (most common to least common): distal, straight, labial.

Figure 7-88 Canine with multiple accessory foramina.
Maxillary First Premolar

The pulp chamber of the maxillary first premolar is considerably wider buccolingually than mesiodistally. In the buccolingual dimension the chamber outline shows a buccal and a palatal pulp horn. The buccal pulp horn usually is larger. From the occlusal level the chamber maintains a similar width to the floor, which is located just apical to the cervical line. The palatal orifice is slightly larger than the buccal orifice. In cross section at the CEJ, the palatal orifice is wider buccolingually and kidney shaped because of its mesial concavity. From the floor, two root canals take on a round shape at midroot and rapidly taper to their apices, usually ending in extremely narrow, curved root canals. The palatal canal usually is slightly larger than the buccal canal. The maxillary first premolar may have one, two, or three roots and canals; it most often has two (Table 7–11). If two canals are present, they are labeled buccal and palatal; three root canals are designated mesiobuccal, distobuccal, and palatal. Directional positioning of endodontic pathfinder files can help identify the anatomy. The roots are considerably shorter and thinner than in the canines. In double-rooted teeth the roots most often are the same length. The buccal root can fenestrate through the bone, leading to the same problems that arise with canines (i.e., inaccurate apex location, chronic postoperative sensitivity to palpation over the apex, and an increased risk of an irrigation accident).

The maxillary first premolar is prone to mesiodistal root fractures and fractures at the base of the cusps, particularly the buccal cusp. If a fracture is suspected, all restorations should be removed and the coronal anatomy inspected with fiberoptic light and magnification. Full occlusal coverage is required after root canal therapy to prevent cuspal and crown and root fracture.

The access preparation for the maxillary first premolar is oval or slot shaped (Fig. 7–91, A to C). It also is wide buccolingually, narrow mesiodistally, and centered mesiodistally between the cusp tips. In fact, the mesiodistal width should correspond to the mesiodistal width of the pulp chamber. The buccal extension typically is two thirds to three fourths up the buccal cusp incline. The palatal extension is approximately halfway up the palatal cusp incline. The buccal and palatal walls funnel directly into the orifices. Because of the mesial concavity of the root, the clinician must take care not to overextend the preparation in that direction, as this could result in perforation.
Variation

When three canals are present, the external outline form becomes triangular with the base on the buccal aspect. The mesiobuccal and distobuccal corners of the triangle should be positioned directly over the corresponding canal orifices (Fig. 7–91, D).

Figure 7-91  Access cavity for a maxillary first premolar as viewed through the DOM. A, ×3.4 magnification. B, ×5.1 magnification. C, ×8.4 magnification with cervical fiberoptic transillumination. D, Schematic representation of a three-canal access preparation.
Maxillary First Premolar

Figure 7-90  Maxillary first premolar. Development and anatomic data. Average time of eruption: 10 to 11 years. Average age of calcification: 12 to 13 years. Average length: 20.6 mm. Root curvature (most common to least common): buccal root—lingual, straight, buccal; palatal root—straight, buccal, distal; single root—straight, distal, buccal.

Figure 7-92  Lateral bony lesion associated with a filled lateral canal.

Figure 7-93  Two canals that have fused and then redivided.

Figure 7-94  Three canals.

Maxillary Second Premolar

The root canal system of the maxillary second premolar is wider buccolingually than mesiodistally. This tooth may have one, two, or three roots and canals (Table 7-12). Two or three canals can occur in a single root. Directional positioning of the endodontic pathfinder or a small file can help identify the anatomy. The mesiodistal and buccolingual aspects of the pulp chamber are similar to those of the first premolar. A buccal and a palatal pulp horn are present; the buccal pulp horn is larger. A single root is oval and wider buccolingually than mesiodistally. The canal(s) remain oval from the pulp chamber floor and taper rapidly to the apex.

The roots of the maxillary second premolar are approximately as long as those of the first premolar, and apical curvature is common, particularly with large maxillary sinus cavities. The proximity of this tooth to the sinus can lead to drainage of a periapical abscess into the sinus and exposure of the sinus during apical root surgery.
Like the maxillary first premolar, the second premolar is prone to mesiodistal root fractures and fractures at the base of the cusps, usually the buccal cusp. If a fracture is suspected, all restorations in the tooth should be removed and the coronal anatomy inspected with a fiberoptic light and magnification. Full occlusal coverage is required after root canal therapy to prevent cusp and crown root fracture.

When two canals are present, the maxillary second premolar access preparation is nearly identical to the first premolar. Since this tooth usually has one root, if two canals are present, they are nearly parallel to each other and the external outline form must have a greater buccolingual extension to permit straight line access to these canals than the first premolar with two roots and diverging canals. If only one canal is present, the buccolingual extension is less and corresponds to the width between the buccal and palatal pulp horns (Fig. 7–96). If three canals are present, the external access outline form is the same triangular shape illustrated for the maxillary first premolar (see Fig. 7–91, D).

Figure 7-96  Access cavity for a maxillary second premolar as viewed through the DOM. (×5.1 magnification with cervical fiberoptic transillumination.)

Figure 7-95  Average time of eruption: 10 to 12 years. Average age of calcification: 12 to 14 years. Average length: 21.5 mm. Root curvature (most common to least common): distal, bayonet, buccal, straight.

Figure 7-97  Second premolar with three canals and a large lateral canal.
Maxillary First Molar

The maxillary first molar is the largest tooth in volume and one of the most complex in root and canal anatomy. The pulp chamber is widest in the buccolingual dimension, and four pulp horns are present (mesiobuccal, mesiopalatal, distobuccal, and distopalatal). The pulp chamber’s cervical outline form has a rhomboid shape, sometimes with rounded corners. The mesiobuccal angle is an acute angle; the distobuccal angle is an obtuse angle; and the palatal angles are basically right angles. The palatal canal orifice is centered palatally; the distobuccal orifice is near the obtuse angle of the pulp chamber floor; and the main mesiobuccal canal orifice (MB-1) is buccal and mesial to the distobuccal orifice and is positioned within the acute angle of the pulp chamber. The second mesiobuccal canal orifice (MB-2) is located palatal and mesial to the MB-1. A line drawn to connect the three main canal orifices (MB orifice, distobuccal [DB] orifice, and palatal [P] orifice) forms a triangle, known as the molar triangle.

The three individual roots of the maxillary first molar (i.e., mesiobuccal root, distobuccal root, and palatal root) form a tripod. The palatal root is the longest, has the largest diameter, and generally offers the easiest access. It can contain one, two, or three root canals (Table 7–13). The palatal root often curves buccally at the apical one third, which may not be obvious on a standard periapical radiograph. From its orifice the palatal canal is flat, ribbonlike, and wider in a mesiodistal direction. The distobuccal root is conical and may have one or two canals (Table 7–14). From its orifice, the canal(s) first is oval and then becomes round as it approaches the apical third of the root. The mesiobuccal root has generated more research and clinical investigation than any other root in the mouth. It may have one, two, or three root canals (Table 7–15). A single mesiobuccal canal is oval and wider buccolingually; two or three canals are more circular. Generally, a concavity exists on the distal aspect of the mesiobuccal root, which makes this wall very thin. The clinician must take care not to instrument the wall excessively because a strip perforation may result.

The DOM has been used to study the location and pathway of the MB-2 canal in maxillary first and second molars.[52] The clinician must always keep in mind that the location of the MB-2 canal varies greatly; this canal generally is located mesial to or directly on a line between the MB-1 and palatal orifices, within 3.5 mm palatally and 2 mm mesially of the MB-1 orifice (Fig. 7–101). These authors found that not all MB-2 orifices lead to a true canal. A true MB-2 orifice was present in only 84% of molars in which a second orifice was identified (Fig. 7–102).[144]
Negotiation of the MB-2 canal often is difficult; a ledge of dentin covers its orifice, the orifice has a mesiobuccal inclination on the pulp floor, and the canal’s pathway often takes one or two abrupt curves.

**Figure 7-101** The two locations of the MB-2 canal orifices in a maxillary first molar.

**Figure 7-102** Access cavity for a maxillary first molar as viewed through the DOM. A, Four apparent orifices, with a projection of dentin covering the mesial groove. (×3.4.) B, Removal of the mesial projection and troughing of the mesial groove to locate the MB-2 canal. (×5.1.) C, Despite deepening of the mesial groove, the MB-2 canal cannot be located (×8.5.) D, The MB-2 canal cannot be found even after removal of the mesial groove. (×13.6.)
in the coronal part of the root. Most of these obstructions can be eliminated by *trouging* or *countersinking* with ultrasonic tips mesially and apically along the mesiobuccal pulpal groove (Fig. 7–103). This procedure causes the canal, when present, to shift mesially, meaning that the access wall must be moved farther mesially. Trouging may need to be 0.5 to 3 mm deep. Care must be taken to avoid furcal wall perforation of this root. Apical to the trouging level the canal may be straight or may curve sharply to the distobuccal, buccal, or palatal.

*Figure 7-103* Access preparation for a maxillary first molar as viewed through the DOM. A, Four apparent orifices located under ×3.4 magnification. B, The MB-2 canal is located by deepening the mesial groove. (×5.1.) C, Four distinct canal orifices can be seen. (×5.1 magnification with cervical fiberoptic transillumination.)

Because the maxillary first molar almost always has four canals, the access cavity has a rhomboid shape, with the corners corresponding to the four orifices (MB-1, MB-2, DB, and P) (Fig. 7–103). One study demonstrated that the access cavity should not extend into the mesial marginal ridge. Distally, the preparation can invade the mesial portion of the oblique ridge, but it should not penetrate through the ridge. The buccal wall should be parallel to a line connecting the MB-1 and DB orifices and not to the buccal surface of the tooth.

*Figure 7-100* Average time of eruption: 6 to 7 years. Average age of calcification: 9 to 10 years. Average length: 20.8 mm. Root curvature (most common to least common): mesiobuccal root—distal, straight; distobuccal root—straight, mesial, distal; palatal root—buccal, straight.

*Figure 7-104* Four canals with loops and accessory canals.
Maxillary Second Molar

Coronally the maxillary second molar closely resembles the maxillary first molar. The root and canal anatomy are similar to those of the first molar, although differences occur. The distinguishing morphologic feature of the maxillary second molar is that its three roots are grouped closer together and are sometimes fused. Also, they generally are shorter than the roots of the first molar and not as curved. The second molar usually has one canal in each root; however, it may have two or three mesiobuccal canals, one or two distobuccal canals, or two palatal canals (Tables 7–16, 7–17, 7–18). Four canals are less likely to be present in the second molar than in the first molar. The three main orifices (MB, DB, P) usually form a flat triangle and sometimes almost a straight line (Fig. 7–108, A). The mesiobuccal canal orifice is located more to the buccal and mesial than in the first molar; the distobuccal orifice approaches the midpoint between the mesiobuccal and palatal orifices; and the palatal orifice usually is located at the most palatal aspect of the root. Generally the canal orifices in the maxillary second molar are closer mesially to each other than they are in the maxillary first molar.

The floor of the pulp chamber is markedly convex, which gives the canal orifices a slight funnel shape. Occasionally the canals curve into the chamber at a more horizontal angle, requiring removal of a lip of
dentin so that a canal can be entered more in a direct line with the axis. Teeth with fused roots occasionally have only two canals; in rare cases, they have only one. Teeth with two canals usually have a buccal and a palatal canal of equal length and diameter (Fig. 7–108, B). These parallel root canals are frequently superimposed radiographically, but they can be imaged by exposing the radiograph from a distal angle. To enhance radiographic visibility, especially when interference arises from the malar process, a more perpendicular and distoangular radiograph may be exposed. When two roots are present, each root may have one canal or the buccal root may have two canals that join before reaching a single foramen. One study found that two palatal roots and two palatal canals occur in 1.47% of these teeth.[113]

When four canals are present, the access cavity preparation of the maxillary second molar has a rhomboid shape and is a smaller version of the access cavity for the maxillary first molar (Fig. 7–109). If only three canals are present, the access cavity is a rounded triangle with the base to the buccal. As with the maxillary first molar, the mesial marginal ridge need not be invaded. Because the tendency in maxillary second molars is for the distobuccal orifice to move closer to a line connecting the MB and P orifices, the triangle becomes more obtuse and the oblique ridge usually is not invaded.

![Figure 7-109](http://home.mdconsult.com.eproxy1.lib.hku.hk/das/book/body/0/1357/5...

If only two canals are present, the access outline form is oval and widest in the buccolingual dimension. Its width corresponds to the mesiodistal width of the pulp chamber, and the oval usually is centered between the mesial pit and the mesial edge of the oblique ridge.

![Figure 7-107](http://home.mdconsult.com.eproxy1.lib.hku.hk/das/book/body/0/1357/5...)
Maxillary Third Molar

Loss of the maxillary first and second molars often is the reason the third molar must be considered as a strategic abutment. Another indication for root canal therapy and full coverage is a fully functioning mandibular third molar in an arch that has sufficient room for full eruption and oral hygiene.

Careful examination of the root morphology is important before treatment is determined. The radicular anatomy of the third molar is completely unpredictable, and it may be advisable to explore the root canal morphology to evaluate the likelihood and degree of success. Even so, many third molars have adequate root formation; given reasonable accessibility, they can serve well as functioning dentition after root canal therapy.

The root anatomy of the maxillary third molar varies greatly. This tooth can have one to four roots and one to six canals, and C-shaped canals also can occur. The third molar usually has three roots and three root canals (Table 7–19). The tooth may be tipped significantly to the distal, the buccal, or both, which creates an even greater access problem than with the second molar.

The access cavity form for the third molar can vary greatly. Because the tooth typically has one to three canals, the access preparation can be anything from an oval that is widest in the buccolingual dimension to a rounded triangle similar to that used for the maxillary second molar. The MB, DB, and P orifices often
lie nearly in a straight line as the DB orifice moves even closer to the line connecting the MB and P orifices. The resultant access cavity is an oval or very obtuse triangle.

Figure 7-113  Average time of eruption: 17 to 22 years. Average age of calcification: 18 to 25 years. Average length: 17 mm.

Figure 7-114  Canals that have fused into a single canal. Multiple accessory canals can be seen in the second molar.

Figure 7-115  Distal bridge abutment with major accessory canal.

The mandibular incisors, because of their small size and internal anatomy, may be the most difficult access cavities to prepare. The external outline form may be triangular or oval, depending on the prominence of the mesial and distal pulp horns (Fig. 7-117). When the form is triangular, the incisal base is short and the mesial and distal legs are long incisogingivally, creating a long, compressed triangle. Without prominent mesial and distal pulp horns, the oval external outline form also is narrow mesiodistally.

Mandibular Central and Lateral Incisors

The root canal systems and access cavities for the two mandibular incisors are so similar they are discussed together. As with the maxillary incisors, a lingual shoulder must be eliminated to allow direct-line access. The shoulder conceals the orifice to a second canal which, if present, is found immediately beneath it. Unlike the maxillary incisors, the pulp outline of the mandibular incisors is wider labiolingually. At the CEJ the pulp outline is oval, wider labiolingually than mesiodistally. At midroot the canal outline is still oval, but the canal is more constricted and narrower labiolingually. Most mandibular incisors have a single root with what radiographically appears to be a long, narrow canal. However, it is a very broad canal labiolingually. Often a dentinal bridge is present in the pulp chamber that divides the root into two canals. The two canals usually join and exit through a single apical foramen, but they may persist as two separate canals. Occasionally one canal branches into two canals, which subsequently rejoin into a single canal before reaching the apex (Table 7-20). One study determined that a relationship existed between crown size (expressed as the M-D/F-L index) and the incidence of bifid root canals in these teeth. [169] Double root canals occur more often in teeth with a smaller index.
and long incisogingivally. Complete removal of the lingual shoulder is critical, because this tooth often has two canals that are buccolingually oriented, and the lingual canal most often is missed. To avoid missing this canal, the clinician should extend the access preparation well into the cingulum gingivally. Because the lingual surface of this tooth is not involved with occlusal function, butt joint junctions between the internal walls and the lingual surface are not required.

**Figure 7-117** Access cavity for the mandibular incisors as viewed through the DOM. **A**, One canal orifice. (×8.5 magnification with cervical fiberoptic transillumination.) **B**, Two canal orifices. (×8.5 magnification with cervical fiberoptic transillumination.)

**Figure 7-116** Average time of eruption: 6 to 8 years. Average age of calcification: 9 to 10 years. Average length: 20.7 mm. Root curvature (most common to least common): straight, distal, labial.

**Figure 7-118** Double-rooted mandibular lateral incisor.
Mandibular Canine

The root canal system of the mandibular canine is very similar to that of the maxillary canine, except that the dimensions are smaller, the root and root canal outlines are narrower in the mesiodistal dimension, and the mandibular canine occasionally has two roots and two root canals located labially and lingually (Table 7–21). The root canal of the mandibular cuspid is narrow mesiodistally but usually very broad buccolingually. A lingual shoulder must be removed to gain access to the lingual wall of the root canal or to the entrance of a second canal. The lingual wall is almost slitlike compared with the larger buccal wall, which makes the canal a challenge to shape and clean.

The access cavity for the mandibular canine is oval or slot shaped (Fig. 7–121). The mesiodistal width corresponds to the mesiodistal width of the pulp chamber. The incisal extension can approach the incisal edge of the tooth for straight-line access, and the gingival extension must penetrate the cingulum to allow a search for a possible lingual canal. As with the mandibular incisors, butt joint relationships between internal walls and the lingual surface are not necessary.

Figure 7-121 Access preparation for a mandibular canine as viewed through the DOM. (×5.1.)
Figure 7-120  Average time of eruption: 9 to 10 years. Average age of calcification: 13 years. Average length: 25.6 mm. Root curvature (most common to least common): straight, distal, labial.

Figure 7-122  One canal with a sharp mesial curvature at the apex.

Figure 7-123  Two canals with the lateral canal above the crest of bone; the lateral canal is probably responsible for the pocket depth.
As a group, the mandibular premolars are very difficult to treat. They have a high flare-up and failure rate. A possible explanation may be the extreme variations in root canal morphology in these teeth. The root canal system of the mandibular first premolar is wider buccolingually than mesiodistally. Two pulp horns are present: a large, pointed buccal horn and a small, rounded lingual horn. At the cervical line the root and canal are oval; this shape tends to become round as the canal approaches the middle of the root. If two canals are present, they tend to be round from the pulp chamber to their foramen. In another anatomic variation, a single, broad root canal may bifurcate into two separate root canals. Direct access to the buccal canal usually is possible, whereas the lingual canal may be very difficult to find. The lingual canal tends to diverge from the main canal at a sharp angle. In addition, the lingual inclination of the crown tends to direct files buccally, making location of a lingual canal orifice more difficult. To counter this situation, the clinician may need to extend the lingual wall of the access cavity farther lingually; this makes the lingual canal easier to locate. The mandibular first premolar sometimes may have three roots and three canals (Table 7–22). One study reported a C-shaped canal anatomy in this tooth.\[5\]
The oval external outline form of the mandibular first premolar typically is wider mesiodistally than its maxillary counterpart, making it more oval and less slot shaped (Fig. 7-127). Because of the lingual inclination of the crown, buccal extension can nearly approach the tip of the buccal cusp to achieve straight-line access. Lingual extension barely invades the poorly developed lingual cusp incline. Mesiodistally the access preparation is centered between the cusp tips. Often the preparation must be modified to allow access to the complex root canal anatomy frequently seen in the apical half of the tooth root.

Figure 7-127 Access cavity for a mandibular first premolar as viewed through the DOM: one orifice. (×5.1.)

Figure 7-126 Average time of eruption: 10 to 12 years. Average age of calcification: 12 to 13 years. Average length: 21.6 mm. Root curvature (most common to least common): straight, distal, buccal.

Figure 7-128 Two canals.
Mandibular Second Premolar

The mandibular second premolar is similar to the first premolar, with the following differences: the lingual pulp horn usually is larger; the root and root canal are more often oval than round; the pulp chamber is wider buccolingually; and the separation of the pulp chamber and root canal normally is distinguishable compared with the more regular taper in the first premolar. The canal morphology of the mandibular second premolar is similar to that of the first premolar with its many variations: two, three, and four canals and a lingually tipped crown. Fortunately, these variations are found less often in the second premolar (Table 7–23).

The access cavity form for the mandibular second premolar varies in at least two ways in its external anatomy. First, because the crown typically has a smaller lingual inclination, less extension up the buccal cusp incline is required to achieve straight-line access. Second, the lingual half of the tooth is more fully developed, therefore the lingual access extension typically is halfway up the lingual cusp incline. The mandibular second premolar can have two lingual cusps, sometimes of equal size. When this occurs, the access preparation is centered mesiodistally on a line connecting the buccal cusp and the lingual groove between the lingual cusp tips. When the mesiolingual cusp is larger than the distolingual cusp, the lingual extension of the oval outline form is just distal to the tip of the mesiolingual cusp (Fig. 7–132).

Figure 7-129  Single canal that has divided into two.

Figure 7-130  Three canals.

Figure 7-132  Access cavity for a mandibular second premolar as viewed through the DOM: one canal orifice. (×5.1 magnification with cervical fiberoptic transillumination.)
Figure 7-131  Average time of eruption: 11 to 12 years. Average age of calcification: 13 to 14 years. Average length: 22.3 mm. Root curvature (most common to least common): straight, distal, buccal.

Figure 7-133  Two canals.

Figure 7-134  Single canal that has divided at the apex.

Figure 7-135  Single canal that has divided and crossed over at the apex.

Figure 7-136  Single canal with a lateral accessory canal.
The earliest permanent posterior tooth to erupt, the mandibular first molar seems to be the tooth that most often requires root canal treatment. It often is extensively restored, and it is subjected to heavy occlusal stress. Therefore the pulp chamber frequently has receded or is calcified. The tooth usually has two roots, but occasionally it has three, with two or three canals in the mesial root and one, two, or three canals in the distal root (Tables 7-24 and 7-25). The canals in the mesial root are the MB and ML canals; a middle mesial (MM) canal sometimes is present in the developmental groove between the MB and ML canals. The incidence of an MM canal ranges from 1% (156) to 15% (51). The canals in the distal root are the distal canal (if only one canal is present) and the DB, DL, and middle distal (MD) canals (if more than one is present). The orifices to these canals are connected by a developmental groove. Orifices to all canals usually are located in the mesial two thirds of the crown, and the pulp chamber floor is roughly trapezoid or rhomboid. Usually four pulp horns (MB, ML, DB, and DL) are present.

The presence of two separate distal roots is rare but does occur. In such cases the DL root is smaller than the DB root and usually more curved. Also, the DL root often has a sharp apical hook toward the buccal that is not obvious on radiographs. The mesial root, the wider of the two roots, curves mesially from the cervical line to the middle third of the root and then angles distally to the apex. The buccal and lingual surfaces are convex throughout their length, whereas the distal surface of the mesial root and the mesial surface of the distal root have a root concavity, which makes the dentin wall very thin. Care must be taken to minimize instrumentation against these walls, because overzealous cutting of the concavity can lead to a strip perforation of the root.

The mesial canal orifices usually are well separated within the main pulp chamber and connected by a developmental groove. The MB orifice commonly is under the mesiobuccal cusp, whereas the ML orifice generally is found just lingual to the central groove. Occasionally an MM canal orifice is present in the groove between the MB and ML orifices (Fig. 7-138). The clinician must always check for such an orifice after shaping and cleaning the main root canals. A bur is used to remove any protuberance from the mesial axial wall that would prevent direct access to the developmental groove between the MB and ML orifices. The clinician should use magnification to explore this developmental groove carefully with the sharp tip of an endodontic explorer. If a depression or orifice is located, the groove can be throughed with ultrasonic tips, at the expense of the mesial aspect, until a small file can negotiate the canal. This is best accomplished using the DOM (Fig. 7-139).

Figure 7-138 Access cavities for the mandibular first molar. A, Three mesial canal orifices and one distal canal orifice. MB, mesiobuccal orifice; MM, middle mesial orifice; ML, mesiolingual orifice; D, distal orifice. B, Two mesial and two distal canal orifices. DB, distobuccal orifice; DL, distolingual orifice.
When only one distal canal is present, the orifice is oval buccolingually and the opening generally is located distal to the buccal groove. This orifice usually can be explored from the mesial with either an endodontic explorer or a small K-file. If the file tip takes a sharp turn in a distobuccal or distolingual direction, the clinician should search for yet another orifice; in rare cases an MD canal orifice is present.

If three root canals (MB, ML, and D) are present in this tooth, each is oval in the cervical and middle thirds of the root and round in the apical third. If two canals (DB and DL) are present in the distal root, they usually are more round than oval for their entire length. The mesial root canals usually are curved, with the greatest curvature in the MB canal. This canal can have a significant curvature in the buccolingual plane that may not be apparent on radiographs. Such a curvature usually can be detected with precurved pathfinder instruments.

Multiple accessory foramina are located in the furcation of the mandibular molars. These foramina usually are impossible to clean and shape directly; they are rarely seen, except occasionally on a postoperative radiograph if they have been filled with root canal sealer or thermoplastic filling material. Because sodium hypochlorite solutions can dissolve organic debris, the pulp chamber should be thoroughly exposed to allow the solution to reach the tiny openings. Fractures occasionally occur on proximal marginal ridges and extend down the root or under the lingual cusps.

The access cavity for the mandibular first molar typically is trapezoid or rhomboid regardless of the number of canals present. When four or more canals are present, the corners of the trapezoid or rhombus should correspond to the positions of the main orifices. Mesially the access need not invade the marginal ridge. Distal extension must allow straight-line access to the distal canal(s). The buccal wall forms a straight connection between the MB and DB orifices, and the lingual wall connects the ML and DL orifices without bowing.
Mandibular Second Molar

The mandibular second molar is somewhat smaller coronally than the first molar and tends to be more symmetric. This tooth is identified by the proximity of its roots. The two roots often sweep distally in a gradual curve, with the apices close together. In some cases only one root is present. The degree of canal curvature and the configuration were studied in the mesial roots of 100 randomly selected mandibular first and second molars; 100% of the specimens showed curvature in both lingual and mesiodistal views.\(^\text{[32]}\)

The pulp chamber and canal orifices of the mandibular second molar generally are not as large as those of the first molar. This tooth may have one, two, three, or four root canals (Table 7–26). The two mesial orifices are located closer together. In some mandibular second molars with single or fused roots, a file placed in the mesiobuccal canal may appear to be in the distal canal. This happens because the two canals sometimes are connected by a semicircular slit, a variation of the $C$-shaped canal (Fig. 7–144, A) that often occurs in this tooth. The distal aspect of the mesial root and the mesial aspect of the distal root have concavities, which must be evaluated during cleaning and shaping procedures. The apices of this tooth often are very close to the mandibular canal; therefore the clinician must take care not to allow instruments or filling material to invade this space, because paresthesia may result.

Figure 7-140  Two mesial and two distal canals.

Figure 7-141  Four roots and four canals with wide division of the distal roots.

Figure 7-142  Three mesial canals.

Figure 7-144  Access cavity for a mandibular second molar as viewed through the DOM. A, Two canal orifices (M and D). (×
Mandibular second molars may have one to six canals, although the most prevalent configurations are two, three, and four canals (Fig. 7-144). When three canals are present, the access cavity is very similar to that for the mandibular first molar, although perhaps a bit more triangular and less rhomboid. The distal orifice is less often ribbon shaped buccolingually; therefore the buccal and lingual walls converge more aggressively distally to form a triangle. The second molar may have only two canals, one mesial and one distal, in which case the orifices are nearly equal in size and line up in the buccolingual center of the tooth. The access cavity for a two-canal second molar is rectangular, wide mesiodistally and narrow buccolingually. The access cavity for a single-canal mandibular second molar is oval and is lined up in the center of the occlusal surface.

**Figure 7-143** Average time of eruption: 11 to 13 years. Average age of calcification: 14 to 15 years. Average length: 19.8 mm. Root curvature (most common to least common): mesial root—distal, straight; distal root—straight, distal, mesial, buccal; single root—straight, distal, bayonet, lingual.

**Figure 7-145** Anastomosis of all canals into one.

**Figure 7-146** Two canals with an accessory canal at the distal root apex.

**Figure 7-147** Fusion of mesial canals at the apex.

### Mandibular Third Molar

The mandibular third molar is anatomically unpredictable and must be evaluated on the basis of its root formation. Fused short, severely curved, or malformed roots often support well-formed crowns. This tooth
may have one to four roots and one to six canals (Table 7–27). C-shaped canals also can occur. Most of these teeth can be successfully treated endodontically regardless of anatomic irregularities; however, the long-term prognosis is determined by the root surface volume in contact with bone. The clinician must weigh the benefit of treatment against the prognosis.

The anatomy of the mandibular third molar is very unpredictable; therefore the access cavity can take any of several shapes. When three or more canals are present, a traditional rounded triangle or rhomboid shape is typical. When two canals are present, a rectangular shape is used. For single-canal molars, an oval shape is customary.

Figure 7-148 Average time of eruption: 17 to 21 years. Average age of calcification: 18 to 25 years. Average length: 18.5 mm.

Figure 7-149 Single canal with accessory foramina at the apex.

Figure 7-150 Complex curved root anatomy.

Figure 7-151 Complex apical anatomy.

Teeth with C-Shaped Root Canal Systems

The C-shaped root canal system was first reported in 1979. Most C-shaped canals occur in the mandibular second molar (Fig. 7–153, A), but they also have been reported in the mandibular first molar, the maxillary first and second molars, and the mandibular first premolar. Two investigators reported the first case of a C-shaped canal in a maxillary molar. One study reported the incidence of C-shaped canal anatomy in maxillary first molars as 2 in 2175 (0.092%); this study also determined that the DB and palatal orifices were connected by a common groove (Fig. 7–153, B). Investigators who examined 309 Chinese maxillary second molars found C-shaped root canals in 4.9%.
C-shaped mandibular molars are so named because of the cross-sectional morphology of their roots and root canals. Instead of having several discrete orifices, the pulp chamber of a molar with a C-shaped root canal system is a single, ribbon-shaped orifice with an arc of 180 degrees or more. It starts at the mesiolingual line angle and sweeps around either to the buccal or the lingual to end at the distal aspect of the pulp chamber (Fig. 7-153, A). Below the orifice, the root structure can show a wide range of anatomic variations. These can be classified into two basic types: those with a single, ribbonlike, C-shaped canal from orifice to apex, and those with three or more distinct canals below the usual C-shaped orifice. Fortunately, molars with a single swath of canal are the exception rather than the rule. More common is the second type, with discrete canals that take unusual forms. Other investigators determined that C-shaped canals in mandibular second molars can vary in shape and number along the root length. This makes cleaning, shaping, obturation, and restoration of these teeth difficult.

One study reported a case of a mandibular first molar with a normal mesiolingual orifice and a C-shaped groove that ran continuously from the mesiobuccal orifice along the buccal wall to the distal canal orifice. The groove ran continuously down the root to the apical third, where it divided into two canals. Other researchers reported a C-shaped groove in a mandibular first molar that extended from the DL to the DB orifice and across the buccal surface to the MB orifice. The ML orifice remained separate. Four separate apical foramina were noted. One investigator evaluated 811 endodontically treated mandibular second molars and found that 7.6% had C-shaped canals. Several variants of the C-shaped canal morphology were noted, the most common being two or three canals that merged and exited as one canal

Significant ethnic variation can be seen in the incidence of C-shaped root canal systems. This anatomy is much more common in Asians than Caucasians. Investigators in Japan and China found a 31.5% incidence of C-shaped canals. Others found the occurrence of C-shaped canals in a Chinese population to be 23% in mandibular first molars and 31.5% in mandibular second molars. Another study found a 19.1% rate in Lebanese subjects, whereas a different investigation found that 32.7% of Koreans had a C-shaped canal morphology in mandibular second molars.

The access cavity for teeth with a C-shaped root canal system varies considerably and depends on the pulp morphology of the specific tooth. Teeth with C-shaped anatomy pose a considerable technical challenge; however, use of the DOM, sonic and ultrasonic instrumentation, and plasticized obturation techniques have made treatment successful.

Figure 7-152  C-shaped canal anatomy: one continuous canal from pulp chamber floor to apex.

Figure 7-154  Mandibular second molar with multiple foramina.

Figure 7-155  Mandibular second molar with interconnecting canal anatomy.
Figure 7-156  Preoperative appearance of a mandibular first molar with a C-shaped canal.

Figure 7-157  Root canal obturation showing the ribbonlike canal space.
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Chapter 8 - Instruments, Materials, and Devices

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Root canal systems resemble river systems in many ways. Both follow highly variable and unpredictable pathways. Mark Twain once said, “The Mississippi river will always have its own way; no engineering skill can persuade it to do otherwise.” [55] In attempting to control bacteria, clinicians face a similarly formidable task. The canal morphology often is complex and unpredictable, severely limiting the practitioner’s capabilities and posing challenges to modern medicines, materials, and instruments. The clinician who is knowledgeable about canal morphology and the science of dental equipment and materials will be able to practice safer, more efficient, and more effective techniques.

The past decade has seen many changes in the practice of endodontics, such as in materials, techniques, equipment, instrument design, and the types of metals used to manufacture endodontic instruments. However, the goals of endodontics, as stated so clearly by Schilder,[246] have not changed: “Root canal systems must be cleaned and shaped: cleaned of their organic remnants and shaped to receive a three dimensional hermetic (fluid-tight seal) filling of the entire root canal space.” The goal for cleaning and shaping of the root canal system is to obtain a continuously tapering funnel from the coronal access (widest diameter) to the apex (narrowest diameter) that flows with the shape of the original canal. [246] Preparation of the canal, especially the apical segment, without weakening the remaining dentin or perforating the root is essential to proper infection control and obturation and to long-term success. [114] [199] An important finding in a recent clinical study is that these goals were better achieved and the success rate was higher when nickel-titanium instruments were used rather than instruments made of stainless steel. [219] The ultimate goal (infection control) of all clinicians is to rid the canal and periapical tissues of bacteria.

DIAGNOSTIC MATERIALS AND DEVICES

Radiography is an essential part of endodontic diagnosis. Modern technology is rapidly shifting toward digital filmless imaging and other new image-enhancing methods (see Chapter 26). [1] Therefore the clinician must be well versed in this diagnostic field.

* References [29] [127] [188] [187] [206] and [211].

Pulp Testing Materials

Materials for Thermometric Evaluation

Pulp stimulation with cold or heat is the oldest method of evaluating the pulp’s health and its ability to respond to external stimulation. However, evaluation of pulpal response must not be confused with vitality testing, which requires assessment of pulpal circulation. A cold test commonly is done by applying ice, a liquid refrigerant, or dry ice. Ice (32° F [0° C]) has only a limited usefulness because it normally is effective only on intact teeth in the anterior part of the mouth. Ethyl chloride is not normally sufficient for stimulating a tooth with extensive restorations or full crown coverage. Liquid refrigerants, such as 1,1,1,2-tetrafluoroethane (Endo Ice; Hygienic Corp., Akron, OH) (-21° F [-30° C]), are a good means of lowering the tooth temperature [57] (Fig. 8–1). Dry ice (-108° F [-78° C]) is also an excellent stimulant (Figs. 8–2 and 8–3). Endo Ice and carbon dioxide (CO2) snow are equally reliable when used in adults. [94]
Seeking a means to improve the sensitivity and specificity of thermal tests, Leffingwell et al. conducted a
study involving a prototype apparatus capable of precisely controlling the temperature delivered to the tooth. These researchers found that the device may show promise for the testing of longitudinal pulp dynamics. They also concluded that tetrafluoroethane seemed to perform best in distinguishing teeth with increased pulpal irritation.

A cold water bath is the most effective testing method, because this technique is the only one in which the tooth is immersed in chilled water, often producing a true reproduction of the patient’s chief complaint. Therefore, regardless of the restoration, the ice cold water test is effective. (See Chapter 1 for more details.)

The heat test is performed by applying heated gutta-percha to the tooth (this stimulus may reach 168.8° F [76° C] before burning). Special care must be taken not to damage the pulp with excessive heat. (Other methods of performing a heat test, such as a warm water bath or the use of electrical devices, are described in Chapter 1.)

Although the levels of cold (-108° F [-78° C]) and heat (168.8° F [76° C]) are extreme, the health of the pulp is not jeopardized if testing is done with care. An understanding of pain responses to thermometric pulp testing is based on the hydrodynamic theory of the sensitivity of dentin, because the pulp has no thermosensing nerve endings. Therefore a sensation of pain requires the existence of some intact pulp tissue, including odontoblasts, for the hydrodynamic mechanisms to function. In other words, the cold- or heat-induced sensation depends on the presence of remnants of a morphologically intact pulp.

Electrometric Pulp Tester

Electrical pulp testing is often overused and poorly understood. Mumford and Björn described some of the requirements for successful use of this testing method: “The basic requirements are an adequate stimulus, an adequate technique of applying this to the teeth, and a careful interpretation of the result.” Unfortunately, these standards often are not met.

Responding nerve endings can be evaluated with an electrical pulp tester (Figs. 8–4 and 8–5). However, an electrical pulp tester is only as good as the person interpreting the patient’s response. The sensation the patient may feel when an electrical current is passed through the tooth is the result of direct nerve stimulation. However, no reasonable assurance exists that these nerves are located in an intact pulp. Necrotic and disintegrating pulp tissue often leaves an excellent electrolyte in the pulp space. This electrolyte can easily conduct the electrical current to nerves farther down into the pulp space, simulating a normal pulp response. The situation becomes even more complicated with a multirooted tooth, in which the health status of the pulp may vary from root to root. A positive response to electrometric recordings alone should not be used for differential diagnosis of pulpal disease. Provided the examination was conducted properly, a lack of response suggests the lack of responding nerve endings. In most cases this means pulp necrosis. If the nerves to the pulp were transected during surgery, the pulp may still be vital.
Pulp tissue is much more sensitive to electrical stimulation than gingival or periapical tissue. Most modern pulp testers cannot put out sufficient current to stimulate periradicular tissues.

Several types of pulp testers are commercially available. Some units have both electrical pulp testing and electronic apex locator capabilities. Studies have shown that a pulsating direct current with a duration of 5 to 15 ms provides the best nerve stimulation. Optimal stimulation is achieved when the cathode is used to provide the stimulus. The faster the current rises, the more effective the stimulation, and the less compensation takes place in the nerves.

Somewhat simplified, Ohm’s law (E = R × I) (E = electromotive force, R = resistance and I = current flowing through resistance) applies to electrical pulp testing, although the response most likely is a combination of impedance and resistance. Pulp testers operate at a relatively high-potential difference (i.e., several hundred volts) but at a very low current (mA). Enamel and dentin constitute very high resistance in the electrical circuit through the tooth. Of the two, enamel has the highest resistance. In dentin the lowest resistance occurs parallel with the tubules. The product of E and I (E × I) results in the neural response. This energy can be “consumed” in the hard-tissue part of the tooth, leaving too low a level of stimulation for the pulpal nerves. Therefore the tooth electrode must be applied at the same location and with the same conduction for each recording if the recordings are to be compared accurately. Clinical conditions make this practically impossible.

Electrometric recordings are often used to monitor traumatic injuries to the teeth. Under these conditions, the clinician must keep in mind that the need to increase stimulation from one observation time to another very often suggests increased hard-tissue formation in the pulp space rather than real changes in the pulp’s ability to respond.

The tooth must be kept very dry when electrometric recording is performed. Because of the high electrical potential used, the current tends to creep along any wet external tooth surface to the gingiva, creating a short circuit and leaving too little energy for the pulp. For the same reason, critical recordings must be done after the teeth have been isolated from the saliva with a rubber dam and insulated from each other by the insertion...
of Mylar strips through the contact points.

A recent study found that the chance that a nonresponsive pulp was necrotic was 89% with cold testing, 48% with heat testing, and 88% with electrical testing. This study also found that the chance that a positive response represented a vital pulp was 90% with cold testing, 83% with heat testing, and 84% with electrical testing. Therefore the electrometric pulp tester should not be the instrument of choice for assessing pulpal health. A positive result on cold testing is a more accurate response that is easier to interpret. A positive result on either cold testing or electrical testing does not guarantee that the pulp is vital or healthy.

Pulp Vitality Testing

Vitality testing requires the measurement of pulpal blood flow. Several devices are used in the medical field to evaluate circulatory changes, and a number of these have been used experimentally to evaluate pulpal health. Several studies have reported successful use of laser Doppler flowmetry to study human pulpal blood flow. The value of this method has been well documented, but its high cost and difficulty of use in clinical situations have prevented widespread use.

The pulse oximeter offers a nondestructive means of monitoring pulp vitality by recording the oxygenation of pulpal blood flow. A preliminary investigation found that this device performed satisfactorily as a clinical tool. Special sensors have been developed to study blood flow and blood oxygenation in vitro. However, further attempts to apply the technology to a clinically useful device have been disappointing. Photoplethysmography of pulpal blood flow also has been evaluated for assessment of pulp vitality.

Doppler techniques, pulse oximetry, and photoplethysmography are all used in medicine and in dental research. However, they have been less successfully applied to routine endodontic care, because the circulatory system of the pulp is encased in a rigid structure and therefore is difficult to study without the removal of hard tissue. Consequently, the need for an absolute rigid observation point in the Doppler technique and the interference of extrapulpal circulatory systems in pulse oximetry and photoplethysmography have limited the introduction of these methods to endodontic practice.

Mechanical Probing Test

Running an explorer across dentin or into a carious lesion is a mechanical test of pulpal status. Some pain is expected; however, an extremely sharp pain or a lingering pain that does not resolve with removal of the stimulus is considered abnormal.

Periapical Tissue Testing Materials

Although the materials used to test the periapical tissues are “low tech,” they can provide some of the most important diagnostic data. Percussion and palpation are tests of periapical tissues (see Chapter 1).

Percussion

In percussion, pressure is applied to the tooth to try to stimulate the periapical tissues. If inflammation is present, the patient feels discomfort. Traditionally a mirror handle has been used for the percussion test, but other instruments also may be used. Tapping must be done in a vertical direction with the long axis of the root. An equivalent tooth (i.e., a control) must be tested first to establish a normal response for that particular patient. Before testing the problematic tooth, the clinician should instruct the patient to raise a hand if the sensation is different from that felt in the control tooth. If the patient is in acute pain, it is best to avoid tapping the tooth with a mirror. The clinician (or even the patient) can use a finger to tap the tooth to help determine the source of pain. However, symptoms often are difficult to reproduce using this technique.

Having the patient chew on the wooden end of a cotton-tip applicator can be a great diagnostic technique; cotton rolls also have been suggested for this purpose. The patient is asked to chew on the stick while moving it around the quadrant. When a sensitive area is detected, the patient should leave the stick in position so that the clinician can document the tooth. Practitioners should not be fooled by referred pain; the problematic tooth may be in the maxilla or the mandible (also see Chapter 3). The Tooth Slooth (Fig. 8-6) has proved very useful for the differential diagnosis of various stages of incomplete crown fractures. The design of the device permits chewing force to be applied selectively to one cusp at a time, allowing the clinician to evaluate weaknesses in defined areas of a tooth. This device can be effective when cotton rolls or wooden sticks are...
Palpation

In palpation, the fleshy (ventral) part of the clinician’s index finger becomes the diagnostic instrument. One means of locating the apex is to place the finger on the marginal gingiva and run it up the root eminence until the apex is located. The patient should be asked to raise a hand if the sensation is different from that felt in the control tooth. Palatal and lingual tissues should be palpated, along with lymph nodes, muscles, and trigger points.

Figure 8-6  Tooth Slooth  (Courtesy SybronEndo, Orange, CA.)

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MATERIALS FOR ENDODONTIC FIELD ISOLATION

Please see Chapter 5.
ENDODONTIC INSTRUMENTS

Although most instruments used in general dentistry also can be used for endodontic therapy, some hand instruments are designed specifically for endodontic procedures. In addition, many different types of instruments have been designed for procedures performed inside the pulp space. These include manually operated instruments for root canal preparation, engine-driven and energized instruments for root canal preparation, instruments for root canal obturation, and rotary instruments for post space preparation.

Standardized specifications have been established to improve instrument quality. For example, the International Standards Organization (ISO) has worked with the Fédération Dentaire Internationale (FDI) through the Technical Committee 106 Joint Working Group (TC-106 JWG-l) to define specifications. These standards are designated with an ISO number. The American Dental Association (ADA) also has been involved in this effort, as has the American National Standards Institute (ANSI); these standards are designated with an ANSI number. However, new instrument designs have resulted in a need for reconsideration of the standards.

Two ISO standards pertain to endodontic instruments. ISO no. 3630-1 deals with K-type files (as does ANSI no. 28), Hedström files (ANSI no. 58), and barbed broaches and rasps (ANSI no. 63). ISO no. 3630-3 deals with condensers, pluggers, and spreaders (ANSI no. 71).

Hand Instruments

Traditional hand instruments sometimes are modified for endodontic uses. A typical set of endodontic instruments might include a mouth mirror, a D-5 explorer, a D-16 endodontic explorer, cotton pliers, a spoon excavator, a series of pluggers, a plastic instrument, a hemostat, a periodontal probe, and a ruler. The endodontic explorer has two straight, very sharp ends that are angled in two different directions from the long axis of the instrument.

Several types of endodontic spoons are available. These spoons have a much longer offset from the long axis of the instrument (for better reach inside constricted pulp chambers) than regular dental spoons. The spoons are used to remove carious material and to excise pulp tissue; therefore, they should be kept well sharpened (Fig. 8–7). The exact type and number of instruments usually depend on the techniques used and clinician’s preference.
Instruments for Pulp Space Preparation

The purposes of this section are to provide and consolidate the principles the clinician needs both to understand the design of instruments and to choose and use current and future instruments to the greatest effect. Most instructional materials mistakenly attempt to teach step-by-step techniques rather than explain the physics of instruments. However, an increasing number of new products and their advocates has created confusion in the selection process, and products become obsolete before they can be thoroughly evaluated. For these reasons, the clinician must understand the scientific principles of instrumentation.

The two primary goals of root canal instrumentation are (1) to provide a biologic environment (infection control) conducive to healing and (2) to develop a canal shape receptive to sealing. Historically most instruments used to shape the canal were designed to be used by hand. Although not universally used, rotary instrumentation has gained considerable interest and most often is used in combination with hand instruments. The information in the following sections should facilitate the most efficient use of rotary instruments, minimizing the chance of failure and allowing the clinician to achieve treatment ideals.

An understanding of the physics of rotary technology can provide financial rewards, save time and, most important, enhance the quality of treatment while avoiding inherent risks. However, one point must be strongly emphasized: these improvements are not derived from quickness or ergonomics; rather, they are the result of increased control and of the ability both to anticipate the optimal approach and to eliminate the less-than-optimal, the unnecessary, and the sometimes counterproductive elements of a technique.

Classification of Instruments Used for Pulp Space Preparation

Endodontic instruments for root canal preparation can be divided into three groups:

- **Group I:** Hand- and finger-operated instruments, such as barbed broaches and K-type and H-type instruments.
- **Group II:** Low-speed instruments on which the latch type of attachment is part of the working section. Typical instruments in this group are Gates-Glidden (GG) burs and Peeso reamers.
- **Group III:** Engine-driven instruments similar to the hand- and finger-operated instruments. However, the handles of these engine-driven instruments have been replaced with attachments for a latch type of handpiece. In the past, few instruments were included in this group because rotary root canal files were rarely used. In recent years, however, the use of nickel-titanium rotary instruments has become popular, and although not standardized, these instruments are included in this category.

Terminology for the Physical Properties of Instruments

Successful use of an instrument depends on the ways in which the material, design, and technique relate to the forces exerted on the instrument. The following terms quantify the actions and reactions to these forces.

**Stress:** The deforming force measured across a given area.

**Stress concentration point:** An abrupt change in the geometric shape of a file, such as a notch, which results in a higher stress level at that point than along the surface of the file where the shape is more continuous.

**Strain:** The amount of deformation a file undergoes.

**Elastic limit:** A set value representing the maximal strain that, when applied to a file, allows the file to return to its original dimensions. After the strain is removed, the residual internal forces return to zero.

**Elastic deformation:** The reversible deformation that does not exceed the elastic limit.

**Shape memory:** A condition that exists when the elastic limit is substantially higher than is typical for conventional metals. It allows an instrument to regain its original form after being deformed.

**Plastic deformation:** Permanent bond displacement, which occurs when the elastic limit is exceeded. The file does not return to its original dimensions after strain is removed.

**Plastic limit:** The point at which a plastic-deformed file breaks.

Manually Operated Instruments

Manually operated instruments are all instruments that are generically called files. Defining endodontic instruments by function, files are instruments that enlarge canals with reciprocal insertion and withdrawal motions. Reamers cut and enlarge canals with rotational motions. Before using either instrument, the clinician
must make sure that the canal is patent.

The first mechanical rotary files were formed from straight piano wire, which were ground and then twisted, producing the file configuration still used today. Files were first mass-produced by the Kerr Manufacturing Co. of Romulus, Michigan, in the early 1900s, hence the name K-type file (or K-file) and K-type reamer (K-reamer).

K-files and K-reamers originally were manufactured by the same process. Three or four equilateral, flat surfaces were ground at increasing depths on the sides of a piece of wire, producing a tapered pyramidal shape; the wire then was stabilized on one end and the distal end was rotated to form the spiral instrument (Fig. 8–8). The number of sides and the number of spirals determine whether the instrument is best suited for filing or reaming. Generally, a three-sided configuration with fewer spirals is used for reaming; a three- or four-sided configuration with more spirals is used for filing.

Figure 8-8 The two ends of a blank, tapered pyramidal wire are stabilized (top), and then one end is rotated to create a spiral shape on the file’s working surface (middle). Multiple rotations produce the final spiral shape (bottom). (Courtesy John T. McSpadden, Lookout Mountain, GA.)

At first, root canal instruments were manufactured from carbon steel. However, chemicals (e.g., iodine, chlorine) and steam sterilization caused significant corrosion (Fig. 8–9). Subsequently, the use of stainless steel greatly improved the quality of instruments (Fig. 8–10). More recently, the introduction of the nickel-titanium (NiTi) alloy in the manufacture of endodontic instruments has resulted in significant changes in the specialty (this metal is described later in the chapter).
Figure 8-9 Effect of chlorine and steam sterilization on carbon steel file. A, Untreated file. B, Five minutes’ exposure to 5% sodium hypochlorite (NaOCl) followed by water rinse, drying, and autoclave sterilization. C, Same treatment as in B but repeated three times. Note the severe damage to the file. (Courtesy Dr. Evert Stenman, Umea, Sweden.)
Barbed Broaches and Rasps.

Dating from the early to mid-nineteenth century, broaches and rasps were the earliest endodontic instruments used to extirpate the pulp and enlarge the canal (Fig. 8–11). Still used today, these instruments are manufactured by hacking a round, tapered wire with a blade to form sharp, projecting barbs that cut or snag tissue. Specifications have been set for both the barbed broach and the rasp (ANSI/ADA standard no. 63, ISO/FDI standard no. 3630/1).

Figure 8-10  Effect of chlorine and steam sterilization on a stainless steel file. A, Untreated file. B, Five minutes’ exposure to 5% NaOCl followed by water rinse, drying, and autoclave sterilization. C, Same treatment as in B but repeated three times. The file shows no damage. (Courtesy Dr. Evert Stenman, Umea, Sweden.)

Barbed broach (Union Broach, York, PA).

Figure 8-11  Barbed broach (Union Broach, York, PA).
Although similar in design, broaches and rasps show some significant differences in taper and barb size. The broach has a taper of #.007 to #.01 taper and the rasp has a taper of #.015 to #.02 taper. Barb height is much greater in the broach than in the rasp; because the barb derives from the instrument’s core, the broach therefore is a much weaker instrument than the rasp. A barbed broach does not cut or machine dentin; however, it is an excellent tool for removing cotton or paper points that have accidentally become lodged in the root canal. These instruments are mostly used to engage and remove soft tissue from the canal, and they frequently are used in sonic or reciprocating handpieces to enlarge canals. They also have the potential, as demonstrated by prototypes, to become effective NiTi rotary instruments. The evolutionary development of endodontic instruments is far from over.

**K-Type Instruments.**

The K-file and K-reamer are the oldest useful instruments for cutting and machining dentin (Figs. 8–12 and 8–13). As mentioned previously, traditionally they have been made from a steel wire that is ground to a tapered square or triangular cross section and then twisted to create either a file or a reamer. During this process the steel is work hardened. A file has more flutes (see Components of a File) per length unit than a reamer.

![K-file with a blunt tip](http://home.mdconsult.com.eproxy1.lib.hku.hk/das/book/body/0/1357/5...)

_Figure 8-12_ K-file with a blunt tip. An instrument fresh from the box shows a significant amount of debris. This is not an uncommon finding with many brands of instruments, therefore new instruments should be cleaned before they are sterilized and used.

![K-file #40](http://home.mdconsult.com.eproxy1.lib.hku.hk/das/book/body/0/1357/5...)

_Figure 8-13_ K-file #40 (Maillefer Instruments SA, Ballaigues, Switzerland). Note the clean surface and rounded tip.

K-type instruments are useful for penetrating and enlarging root canals. The instrument works primarily by compression-and-release destruction of the dentin surrounding the canal. Generally, a reaming motion causes less transportation than a filing motion. (Transportation is the excessive loss of dentin from the outer wall of a curved canal in the apical segment. This procedural error can lead to perforation of the root canal system.) A stainless steel K-file can be precurved to a desired form to facilitate insertion and minimize transportation. Permanent deformation occurs when the flutes become wound more tightly or opened more widely. (Fig. 8–14.) Instruments fracture during clockwise motion after plastic deformation; this occurs when the instrument becomes bound while the force of rotation continues. Interestingly, although the force required for failure is the same in both directions of rotation, failure occurs in the counterclockwise direction at half the number of rotations required for failure in the clockwise direction. Therefore K-type instruments should be operated more carefully when pressure is applied in a counterclockwise direction.
H-Type Instruments.

An H-type instrument has spiral edges arranged to allow cutting only during a pulling stroke. An example is a Hedstrom file. H-type instruments are better for cutting than a K-type instrument because it has a more positive rake angle (see Components of a File) and a blade with a cutting rather than a scraping angle. Bending a Hedström file results in points of greater stress concentration than occurs with K-type instruments. These concentration points can lead to the propagation of cracks and fatigue failure. Clinically, fatigue happens without any external physical signs of stress, such as the flute changes seen in K-type instruments.

Currently all H-type instruments are ground from a tapered blank. Hedström files are formed by grinding a single continuous flute. Computer-assisted machining technology has allowed the development of H-type instruments with very complex forms. This process, called multiaxis grinding, allows adjustment of the rake angle, helix angle, multiple flutes, and tapers.

H-files cut the canal wall when pulled or rotated clockwise; the file is relatively ineffective when pushed or rotated counterclockwise. Because the H-file generally has sharper edges than the K-file, it has a tendency to screw into the canal during rotation, particularly if the instrument’s blades are nearly parallel. Awareness of screwing-in forces is important for avoiding instrument failure.

Figure 8-14  K-files stressed to deformation by clockwise and counterclockwise twisting (arrow indicates deformed areas). These instruments are close to fracture.

Figure 8-15  Hedström file #45 (Maillefer Instruments SA).

Figure 8-16  Hedström file #50 (Antaeos, Vereinigte Dentalwerke, München). This file has a steeper helix angle than the file in Fig. 8–15. Note the blunted tip, a common result of force used during attachment of the handle.
Instrument Design Modifications.

K-files and H-files can be modified into numerous designs. Often the instruments can be improved for more effective instrumentation by changing the geometric dimensions created by computerized multiaxis grinding machines. For example, changing the cross-sectional geometry of a K-type instrument from square to rhomboid enhances the instrument’s flexibility and rake angle (Fig. 8–18). However, the possible geometries can complicate adherence to ISO and ANSI standards (Figs. 8–19, 8–20, 8–21, 8–22, 8–23, 8–24).

Figure 8–17 Hedström file #100 (Roydent Dental Products, Rochester Hills, MI) The rake angle is close to neutral (arrow), which makes this instrument very efficient for machining strokes.

Figure 8–18 K-Flex file #35 (Kerr Manufacturing Co.). This file resembles a classic K-file with its twisted pattern (compare to the file shown in Fig. 8–16). The cross section of the blank is rhomboid, giving the instrument a small and a large diameter that can be clearly seen. Note the untwisted tip.

Figure 8–19 Flex-R file (Union Broach), a milled K-type file. The flutes are sharper and have a less negative rake than a traditional twisted K-file. The tip is rounded.
Figure 8-20  FlexoFile (Maillefer Instruments SA, Ballaiques, Switzerland), a milled K-type file. Note the smooth surface and well-formed tip.

Figure 8-21  Ultra Flex #30 (Zipperer, VDW, Munich, Germany), a milled K-type NiTi file. Note the coarse surface, a typical result of milling in NiTi alloy. The flutes are less sharp than in a steel counterpart and often are rolled over the edge.

Figure 8-22  Sureflex #30 (Caulk/Dentsply, Milford, DE), a milled, K-type NiTi file has a greater helix angle than the Ultra Flex (Fig. 8–21). Compare the design with that of the FlexoFile (Fig. 8–20).

Figure 8-23  Hyflex X-file (Hygenic Corp.), a Hedström-type NiTi file with a double helix.

Figure 8-24  Mity Turbo (JS Dental, Ridgefield, CT), a Hedström-type NiTi file with a tighter double helix than the Hyflex X-file. This file is much less efficient at machining a substrate than the Hyflex X-file. [139]
**Tip Design.**

Studies have shown that tip design can affect file control, efficiency, and outcome in the shaping of root canal systems. The tip of the original K-file resembled a pyramid (Fig. 8–25). The file can break if the clinician applies excessive torque while attempting to enlarge a canal with a smaller diameter than the noncutting portion of the file tip. Instrument tips have been described as cutting, noncutting, and partially cutting, although no clear distinction exists among the three types.

![Figure 8-25 K-type instrument with a pyramidal tip.](image)

The instrument tip has two functions: to enlarge the canal and to guide the file through the canal. A clinician who is unfamiliar with the tip design of a particular instrument is apt to do either of the following: (1) transport the canal (if the tip is capable of enlarging the canal and remains too long in one position) or (2) encounter excessive torsion and break the file (if a noncutting tip is forced into a canal with a smaller diameter than the tip). Transportation of the original axis of the canal can occur by remaining too long in a curved canal with a tip that has efficient cutting ability. On the other hand, with the H-file the clinician need not remain too long in one position, and the instrument’s efficient cutting can facilitate enlargement or negotiation of constricted or blocked canals.

The angle and radius of its leading edge and the proximity of the flute to its actual tip end determine the cutting ability of a file tip. Cutting ability and file rigidity determine the propensity to transport the canal. The clinician must keep in mind that as long as the file is engaged 360 degrees, canal transportation cannot occur. Only with overuse does the file begin to cut on one side, resulting in transportation. Most instrumentation occurs when the file tip is loose in the canal, which gives it a propensity to transport the canal.

A good beginner’s rule is this: If the canal is smaller than the file, a cutting tip is more efficient. If the canal is larger than the tip, using a less effective cutting tip can help prevent transportation (Fig. 8–26). Much has been written about the importance of various sophisticated tip modifications to prevent such ledging, but no scientific proof exists that any one design is better than another for clinical work.
Metal Alloys.

The development of nitinol, an equiatomic alloy composed of nickel and titanium, has proved a significant advancement in the manufacture of endodontic instruments. Nickel-titanium is called an exotic metal because it does not conform to the normal rules of metallurgy. Because it is a superelastic metal, the application of stress does not result in the usual proportional strain seen in other metals. When stress is initially applied to nickel-titanium, the result is proportional strain; however, the strain remains essentially the same as the application of additional stress reaches a specific level, forming what is called a loading plateau. Eventually, of course, application of more stress results in more strain, which increases until the file breaks. This unusual property is the result of a molecular crystalline phase transformation. External stresses transform the austenitic crystalline form of nickel-titanium into a martensitic crystalline structure that can accommodate greater stress without increasing the strain. As a result of its unique crystalline structure, a nickel-titanium file has shape memory, or the ability to return to its original shape after being deformed. Simply stated, nickel-titanium alloys currently are the only readily available, affordable materials with the flexibility and toughness for routine use as effective rotary endodontic files in curved canals.

One study reported that stainless steel was more resistant to fracture than nickel-titanium when angular deflection (fracture by twisting) was measured. Attempts to improve the nickel-titanium alloy continue, and it has been shown that the surface characteristics can be greatly improved by treating instrument surfaces. Electropolishing, surface coatings, and surface implantation (Fig. 8–27) have been used for this purpose.

![Figure 8-26 Instrument tips arranged in order from cutting to noncutting. (Courtesy John T. McSpadden, Lookout Mountain, GA.](http://home.mdconsult.com.eproxy1.lib.hku.hk/das/book/body/0/1357/5...)}
Low-Speed Rotary Instruments

Many types of rotary instruments are used during endodontic procedures. In addition to regular burs adapted for endodontics, various types of root canal reamers are used to prepare the root canal or to place or remove root canal filling materials and to prepare the post space.

**Burs.**

In addition to conventional burs, burs with extended shanks for low-speed contraangle handpieces (Fig. 8–28) are useful for providing good visibility during deep preparation of the pulp chamber. After access to the pulp chamber has been achieved, straight-line access to the initial point of curvature traditionally has been accomplished using rotary instruments such as Gates-Glidden burs and Peeso instruments. These reamers are available in a 32 mm length and a 28 mm length for posterior teeth (Fig. 8–29). Use of these instruments should be limited to the straight portion of the canal preparation. The risk of perforation with these instruments becomes a real possibility with attempts to instrument beyond the point of curvature or if the instruments are used to cut laterally. The risk of lateral cutting resulting in perforation is lower with Gates-Glidden burs than with the other instruments mentioned (Fig. 8–30). This risk is especially pronounced on the furcation sides of mesial roots of molars. Gates-Glidden instruments are also available in nickel-titanium (Fig. 8–31). The Peeso reamer is used mostly for post space preparation (Fig. 8–32).

![Figure 8-27 RaCe instrument before and after electropolishing. (Courtesy John T. McSpadden, Lookout Mountain, GA.)](http://home.mdconsult.com.eproxy1.lib.hku.hk/das/book/body/0/1357/5...)

![Figure 8-28 Various surgical length burs. The longer length of these burs allows a direct view. (From Johnson WT: Color atlas of endodontics, St. Louis, 2002, Saunders).](http://home.mdconsult.com.eproxy1.lib.hku.hk/das/book/body/0/1357/5...)

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**Figure 8-27** RaCe instrument before and after electropolishing. (Courtesy John T. McSpadden, Lookout Mountain, GA.)

**Figure 8-28** Various surgical length burs. The longer length of these burs allows a direct view. (From Johnson WT: Color atlas of endodontics, St. Louis, 2002, Saunders).
Figure 8-29 Gates-Glidden (GG) burs made of stainless steel. (From Johnson WT: Color atlas of endodontics, St. Louis, 2002, Saunders.)

Figure 8-30 Working part of a GG bur made of stainless steel. Note the rounded safety tip and the lack of sharp cutting edges. The instrument has a marginal land for centering the drill in the canal and to allow safer machining of the canal walls.

Figure 8-31 Working part of a NiTi Gates-Glidden bur (Tulsa Dental Products, Tulsa, OK). Left, Small size; right, large size. Compare the design with that of the LightSpeed rotary instrument in Fig. 8–42.
Rotary Instruments for Canal Preparation

Components of a File.

To make the best use of files, the clinician should know the parts of each file and understand how variations in design affect instrumentation (Fig. 8–33 and 8–34). The taper is usually expressed as the amount the file diameter increases each millimeter along its working surface from the tip toward the file handle. For example, a size #25 file with a .02 taper would have a 0.27 mm diameter 1 mm from the tip, a 0.29 mm diameter 2 mm from the tip, and a 0.31 mm diameter 3 mm from the tip. Some manufacturers express the taper in terms of percentage (e.g., a .02 taper is a 2% taper). Historically, as an ISO standard, a file was fluted and tapered at 2% for 16 mm, but now files incorporate a wide variation of lengths and tapers of working surfaces. The ability to determine cross-sectional diameter at a given point on a file can help the clinician determine the file size in the point of curvature and the relative stress being placed on the instrument.

Figure 8-32 Peeso reamer (Union Broach). Note the safety tip and guiding marginal lands on the machining surfaces.

Figure 8-33 Rotary ProFile NiTi instruments, sizes #3, #5, and #6 (Tulsa Dental Products). The instruments have marginal lands that guide the instrument in the center of the canals and around curvatures.

Figure 8-34 Components of an endodontic rotary instrument. (Courtesy John T. McSpadden, Lookout Mountain, GA.)

The flute of the file is the groove in the working surface used to collect soft tissue and dentin chips removed...
from the wall of the canal. The effectiveness of the flute depends on its depth, width, configuration, and surface finish. The surface with the greatest diameter that follows the groove (where the flute and land intersect) as it rotates forms the leading (cutting) edge, or the blade of the file. The cutting edge forms and deflects chips from the wall of the canal and severs or snags soft tissue. Its effectiveness depends on its angle of incidence and sharpness. If a surface projects axially from the central axis as far as the cutting edge between flutes, this surface is called the land (or sometimes the marginal width). The land reduces the tendency of the file to screw into the canal, reduces transportation of the canal, reduces the propagation of microcracks on its circumference, supports the cutting edge, and limits the depth of cut. Its position relative to the opposing cutting edge and its width determine its effectiveness. To reduce frictional resistance, some of the surface area of the land that rotates against the canal wall may be reduced to form the relief. The angle the cutting edge forms with the long axis of the file, called the helix angle, augers debris collected in the flute from the canal. This angle is important for determining which file technique to use (Fig. 8-35 and 8-36).

**Figure 8-35** Components of the ProTaper nickel-titanium rotary instrument (Dentsply – Tulsa Dental, Tulsa, OK). (Courtesy John T. McSpadden, Lookout Mountain, GA.)

**Figure 8-36** Components of the Quantec nickel-titanium instrument (SybronEndo, Orange, CA). (Courtesy John T. McSpadden, Lookout Mountain, GA.)
If a file is sectioned perpendicular to its long axis, the rake angle is the angle formed by the leading edge and the radius of the file. If the angle formed by the leading edge and the surface to be cut (its tangent) is obtuse, the rake angle is said to be positive or cutting. If the angle formed by the leading edge and the surface to be cut is acute, the rake angle is said to be negative or scraping (Fig. 8–37). However, the rake angle may not be the same as the cutting angle. The cutting angle, or the effective rake angle, is a better indication of a file’s cutting ability and is determined by measuring the angle formed by the cutting (leading) edge and the radius when the file is sectioned perpendicular to the cutting edge. If the flutes of the file are symmetric, the rake angle and the cutting angle are essentially the same.

![Figure 8-37](http://home.mdconsult.com.eproxy1.lib.hku.hk/das/book/body/0/1357/5...)

**Figure 8-37** Direction and action of the leading (cutting) edge. A negative angle (left) results in a scraping action, whereas a positive angle (right) results in a cutting action. Although cutting actions can be more efficient and require less force to enlarge a canal, a scraping action may have a smoother feel. The clinician erroneously may confuse smoothness with efficiency. However, applying excessive pressure to a cutting file could produce excessive torsion. (Arrows indicate the direction of the blade motion.) (Courtesy John T. McSpadden, Lookout Mountain, GA.)

The pitch of the file is the distance between a point on the leading edge and the corresponding point on the adjacent leading edge; or, it may be the distance between corresponding points within which the pattern is not repeated. The smaller the pitch or the shorter the distance between corresponding points, the more spirals the file has and the greater the helix angle. Most files have a variable pitch, one that changes along the working surface. Because the diameter increases from the file tip toward the handle, the flute becomes proportionately deeper, resulting in a core taper that is different from the external taper.

The cutting angles, helix angles, and external and core tapers may vary along the working surface of the file, and the ratios of these quantities can vary between instruments of the same series. A change in any of these features can influence the file’s effectiveness or its propensity for breakage as it progresses into the canal space and can explain why some files act uncharacteristically compared with other files in the same series. In one study, investigators using electric and air-driven handpieces with rotary nickel-titanium instruments found no significant difference in file distortion or breakage between the two handpieces at 150 revolutions per minute (rpm). Other researchers have shown that the ability to select precise rpm and torque settings affects the efficiency and durability of instruments. Determining a file’s rpm level is more difficult with an air handpiece than with an electric handpiece. For this reason the clinician would be wise to use an electric handpiece when instrumenting with rotary files. The popularity of electric handpieces among clinicians appears to support the conclusion that regardless of the design used for rotary nickel-titanium instruments, an electric handpiece, rather than an air-driven handpiece, should be used because it allows precise speed control (Fig. 8–38).
Instrument Designs.

Design changes are made in endodontic instruments to help prevent procedural errors, increase efficiency, and improve the quality of canal shaping. In many patients the apical canal is larger than the largest file used at working length; therefore, many design changes have been directed toward enabling the clinician to increase the size of the largest file used at working length.\[96\] The following design components can be used to prevent excess stress on instruments.

1. The difference between the file’s minimum and maximum diameters can be reduced so that the torque required for rotating the larger diameter does not exceed the plastic limit of the smaller diameter.
2. The space between the tip and the maximum diameter can be reduced so that the required torque does not exceed the ultimate strength of any part of the file.
3. A zero taper or nearly parallel and fluted working portion of the file can be provided for curved canals so that the apical portion of the canal can be enlarged without undue file stress and compression of debris.
4. The continuity of the blade engagement can be interrupted.
5. The number of flute spirals can be eliminated or reduced to the smallest number necessary to prevent excessive torque, which results from the accumulation of debris.
6. A means can be provided to complete the file function before the flutes fill with debris.
7. Any land width can be minimized to reduce abrasion on the canal surface.
8. The file can be given an asymmetric cross section to help maintain the central axis of the canal.
9. The number of flutes with similar helix angles can be reduced. When helix angles are dissimilar, screwing-in forces are reduced; when flutes have no helix angles, screwing-in forces are eliminated.
10. Positive cutting angles can be incorporated to enhance the efficiency of canal enlargement.
11. Blades can be made appendages or projections from the file shaft rather than ground into the shaft.
12. Channels can be cut along the long axis of the file to facilitate its removal if it breaks.

ProFile and ProFile GT.

ProFile rotary nickel-titanium instruments (Dentsply – Tulsa Dental, Tulsa, OK) are available in sizes with a #.02, #.04, #.06, or #.08 taper (Fig. 8-39). These instruments are distinguished by their trihelical, symmetric U-shaped flutes separated by lands (Figs. 8-40, 8-41, and 8-42). The blades have slightly negative rake angles. The ProFile and ProFile GT have essentially the same cross-sectional configuration. The ProFile has a 16 mm working length; in contrast, the length of each taper of the ProFile GT varies as a result of having the same tip sizes and maximum diameters. The ProFile GT has slightly more spirals at the tip portion of the instrument and slightly fewer at the handle portion. The ProFile GT series does not include #.02 tapers. As with most systems using a large taper, the instrument becomes rather stiff before the apical preparation has been sufficiently enlarged.\[96\] This puts limitations on the use of this instrument in narrow, curved root canals. ProFile GT instruments are divided into three primary size families (#20, #30, and #40) based on the tip size. Each series has four tapers (#.04, #.06, #.08, and #.10. The largest taper is also available in sizes #35, #50, and #70.
Figure 8-39  Rotary ProFile NiTi instruments, size #3 (Dentsply-Tulsa Dental).

Figure 8-40  Rotary ProFile NiTi instruments, size #5 (Tulsa Dental Products). Note the instruments’ wide marginal land (arrows).
LightSpeed.

The LightSpeed instrument (LightSpeed Technology, San Antonio, TX) has essentially the same cross-sectional design as the ProFile and ProFile GT. However, it has a unique, short, flame-shaped working portion and a reduced-diameter shaft similar to that of a Gates-Glidden drill. The long, unspiraled shaft provides good flexibility around canal curves. The minimal working surface requires higher rotation speeds (1000 to 2000 rpm) compared with other files. The tip has a long, noncutting pilot portion (Fig. 8-42). The LightSpeed instrument comes in sizes #020 to #140. It also includes “half” sizes (e.g., #022.5, #027.5) up to #060. In the smaller sizes the head is less well defined (Fig. 8-43). The design has been shown to vary with the instrument size. The manufacturer recently proposed that these instruments be used in a hybrid technique. Other instruments presented in this chapter would be used to shape the coronal segments of the root canal, and a limited number of LightSpeed instruments would be used to enlarge the apical segment. This suggestion is based on reports that larger-than-normal apical preparation sizes can be obtained with these instruments without compromising remaining dentin thickness in the more coronal segments of the canal. This capability takes on greater importance because increasing the size of the apical preparation has been shown to be directly related to the clinician’s ability to disinfect the critical segment of the infected canal. In one study, a combination of tapered rotary and LightSpeed instruments was used in 40 patients; the study showed that instrumentation to apical preparation sizes larger than those typically used (60 for molars and 80 for cuspids and premolars) more effectively removes culturable bacteria from canals.

![Figure 8-42](image_url) LightSpeed rotary NiTi instruments, size #90 (LightSpeed Technologies, San Antonio, TX). The instrument head and radial lands are well defined.

Quantec.

The Quantec instrument (SybronEndo, Orange, CA) has double helical, asymmetric flutes separated by lands, the width of which is reduced by a relief. The Quantec also has positive cutting blades on the working portion. The lands of the instrument are said to enhance the instrument’s strength (Fig. 8-44). The Quantec file is available with two tip designs, a cutting tip (Fig. 8-45) and a safety cutting tip. Instruments come in #.02, #.03, #.04, #.05, #.06, #.08, #.10, and #.12 taper. The instruments are available in #.02 taper in sizes #15 to #60.
Similar in concept to the Quantec, the K3 instrument (SybronEndo) has three asymmetric flutes separated by lands. A safety tip is incorporated into the design (Fig. 8–46). This instrument has the most positive cutting angles of the instruments currently available and is considered among the most resistant to fracture because of its cross-sectional geometry (Fig. 8–47). The instrument is available in #.02, #.04, and #.06 tapers. A series of body shapers in #.08, #.10, and #.12 is available and has become a common component of most instrument sets.

Figure 8-44 Quantec rotary NiTi instrument, size #10 with a #.02 taper (Analytic Endodontics, Orange, CA). Note the double land that characterizes the Quantec instrument. The higher marginal land (wide white bar) machines the root canal; the lower reduced peripheral surface (double white bars) contributes to peripheral strength. Note the sharp, blunt tip.

Figure 8-45 Quantec rotary NiTi orifice opener #1 with #.06 taper (Analytic Endodontics). Note the blunt, sharp tip of the instrument.

Figure 8-46 K3 instrument with safety tip. (Courtesy John T. McSpadden, Lookout Mountain, GA.)
The Hero 642 (MicroMega, Geneva) has trihelical, sharp flutes resembling a Hedström design (Fig. 8–48). The blades are followed by recessive lands that do not extend axially to the circumference, which is designed to reduce stress. Consequently, the recommended rotation speed is 500 to 600 rpm. The Hero 642 has a large central core that resembles that of the K3. This instrument is available in sizes #20 to #45. All sizes are available in #.02 taper, and sizes #20, #25, and #30 also are available in #.04 and #.06 taper.

**Figure 8–47** Comparison of the manufacturers’ illustrated cross-sectional design (left) with the actual cross-sectional shape at different levels on the working surface, at 1 mm, 6 mm, and 14 mm from the file tip (right). The photographs of sections at D1 and D6 were taken in the direction toward the tip ends; the sections of D14 appear as mirror images because these were directed toward the handle ends.

**Hero 642.**

The Hero 642 (MicroMega, Geneva) has trihelical, sharp flutes resembling a Hedström design (Fig. 8–48). The blades are followed by recessive lands that do not extend axially to the circumference, which is designed to reduce stress. Consequently, the recommended rotation speed is 500 to 600 rpm. The Hero 642 has a large central core that resembles that of the K3. This instrument is available in sizes #20 to #45. All sizes are available in #.02 taper, and sizes #20, #25, and #30 also are available in #.04 and #.06 taper.
RaCe.

The RaCe instrument (Brasseler, Savannah, GA, and FKG Dentaire, La-Chaux-de-Fonds, Switzerland) incorporates alternating nonspiraled and spiraled segments along its working length to minimize torsion of engagement and torsion resulting from screwing-in forces (thus its name, Reamer with Alternating Cutting Edges). In one study these instruments were found to do an excellent job of removing debris while maintaining the original canal curvature in extracted teeth.[244]

Sequence.

Resembling a K-reamer, the Sequence file (Brasseler, FKG Dentaire) has a slight corkscrew configuration with variable pitch and helix angles. This design reduces the amount of force with which some parts of the blades become engaged in the canal wall. These instruments are available in #.04 and #.06 taper. The tip design is said to be noncutting, with the first blade positioned 1 mm from the tip.

EZ-Fill Safesider.

EZ-Fill SafeSider instruments (Essential Dental Systems, South Hackensack, NJ) are said to be designed around the principle that when fewer blades engage the canal walls, less stress is placed on the instrument. The EZ-Fill SafeSider is a series of noncircular, uninterrupted flat-sided instruments. Stainless steel SafeSiders (sizes #15 through #40) are made with relieved twisted wires and have a D-shaped cross section. The newest instruments in the series are made of nickel-titanium. These instruments have been reported to reduce dentinal engagement and consequently the resistance of the instruments in the canal, shortening the time required for canal preparation compared with conventional instruments.[223]

Oscillating/Reciprocating Files.

The Giromatic handpiece, a rotary instrument in use since 1969, delivers 3000 quarter-turn reciprocating movements per minute. Rasps and barbed broaches are most often used in Giromatic handpieces, but K-type and H-type instruments also can be used. The Endo-Eze file system (Ultradent, South Jordan, Utah) is a recently introduced addition for Giromatic handpieces. The set has four instruments, which are designed to clean the middle third of the canal. The sizes and tapers are 0.10 # 0.025 taper, 0.13 # 0.35 taper, 0.13 # 0.45 taper and 0.13 # 0.06 taper The use of hand stainless steel instruments is suggested for the apical third of the canal.

Sonic and Ultrasonic Instruments

A radically different way of instrumenting root canals was introduced when clinicians became able to activate files by electromagnetic ultrasonic energy.[227] Piezoelectrical ultrasonic units are also available for this

Figure 8-48  Scanning electron microscopic (SEM) image of the Hero 642. Note the positive rake and the similarity to a trihelix Hedström file. (Courtesy MICRO-MEGA, Besancon, France.)
Two types of units, ultrasonic and sonic, are primarily available. Ultrasonic devices, which operate at 25 to 30 kHz, include the magnetostrictive Cavi-Endo (Caulk/ Dentsply, Milford, DE), the piezoelectrical ENAC (Osada, Tokyo), and the EMS Piezon Master 400 (Electro Medical Systems [EMS] Vallée de Joux, Switzerland). Sonic devices, which operate at 2 to 3 kHz, include the Sonic Air MM 1500 (Micro Mega, Prodonta, Geneva, Switzerland, the Megasonic 1400 (Megasonic corp, House Springs, MO), and the Endostar (Syntex Dental Products, Valley Forge, PA) (Figs. 8–49 and 8–50). Ultrasonic devices use regular types of instruments (e.g., K-files), whereas sonic devices use special instruments known as Rispi-Sonic, Shaper-Sonic, Trio-Sonic, or Heli-Sonic files.

Although similar in function, piezoelectrical units have some advantages over the magnetostrictive systems. For example, piezoelectrical devices generate little heat; therefore, no cooling is needed for the electrical handpiece. The magnetostrictive system generates considerable heat, and a special cooling system is needed in addition to the irrigation system for the root canal. The piezoelectrical transducer transfers more energy to the file than does the magnetostrictive system, making it more powerful.[11]

The file in an ultrasonic device vibrates in a sinus wave-like fashion. A standing wave has areas with maximal displacement (i.e., antinodes) and areas with no displacement (i.e., nodes). The tip of the instrument exhibits an antinode. If powered too high, the instrument may break because of the intense vibration. Therefore files must be used only for a short time, and the power must be sent carefully. The frequency of breakage in files used for longer than 10 minutes may be as high as 10%, and the breakage normally occurs at the nodes of vibrations.[4]

Ultrasonic devices have proved very efficient for irrigating root canal systems. During free ultrasonic vibration in a fluid, two significant physical effects are observed: cavitation and acoustic streaming. During oscillation in a fluid, a positive pressure is followed by a negative pressure. If the fluid’s tensile strength is exceeded during this oscillation of pressure gradients, a cavity is formed in the fluid in the negative phase. During the next positive pressure phase, the cavity implodes with great force; this is cavitation. Under normal clinical conditions the power of dental ultrasonic units is too low to create significant cavitation effects on the dentin.
Acoustic streaming creates small, intense, circular fluid movement (i.e., eddy flow) around the instruments. The eddying occurs closer to the tip than in the coronal end of the file, with an apically directed flow at the tip. Acoustic streaming increases the cleaning effect of the irrigant in the pulp space through hydrodynamic shear stress. The increased amplitude that occurs with the smaller file sizes enhances the acoustic streaming. This has proved valuable in the cleaning of root canals because conventional irrigation solutions do not penetrate small spaces well.

Acoustic streaming has little direct antimicrobial effect. Both cavitation and acoustic streaming are dependent on the free vibration of the file. The limits of the space in a root canal significantly inhibit the practical utility of ultrasonic devices for root canal cleaning. Depending on size and power the file tip may have amplitude of 20 to 140 mm, requiring a canal size of at least a #30 file through a #40 file for free oscillation. Any contact with the root canal walls dampens oscillation. As the contact with the canal wall increases, the oscillation is dampened and becomes too weak to maintain acoustic streaming. Using a small file size with minimal contact to the root canal wall provides optimal cleaning conditions.

Ultrasonic devices have proved disappointing as instruments for improving the removal of dentin from the root canal walls. They do improve the ability to clean the pulp space and difficult-to-debride areas through acoustic streaming. However, whether this can be achieved during regular preparation when the file is actively dampened and little acoustic streaming takes place is unclear. Cleaning is further enhanced by the excellent irrigation systems some of the devices provide. Application of a freely oscillating file with sodium hypochlorite (NaOCl) irrigation for a couple of minutes to aid pulp space disinfection is believed to be useful after complete biomechanical instrumentation of the pulp space.

Sonic devices are more useful for true hard-tissue removal during root canal preparation. Because the files operate like a conventional handpiece, the file vibrations are less likely to be dampened by contact with the root canal walls. Therefore the special files used in these systems are true bulk dentin removers. The Rispi-Sonic file is less aggressive than the Shaper-Sonic file. The instruments come in 17 to 29 mm lengths and in various sizes from #010 up. Because of their rasplike design, these instruments tend to leave a rougher canal surface than many other devices.

The working length and the apical part of the root canal normally are prepared with conventional files, after which the sonic files are used. Both sonic and ultrasonic instruments are prone to causing canal transport if used carelessly. Various and often conflicting techniques for using these instruments have been described; therefore the clinician should take time to become acquainted with the instrument.

### National and International Standards for Instruments

As a result of concerns that arose nearly 40 years ago, efforts were made to standardize endodontic files and root filling materials. As mentioned previously, this resulted in an international standard for endodontic files, known in the United States as ANSI standard no. 58 for Hedström files and ANSI standard no. 28 for K-files (Table 8-1). The standards have several similarities, but some important differences exist. Fig. 8-51 shows the important measurements dictated by the standards. The size designation is derived from the projected diameter at the tip of the instrument. This is an imaginary measurement and is not reflected in the real size of the working part of the instrument. The taper of the instruments is prescribed to be 0.02 taper of length, starting at the tip. Thus the working diameter is the product of taper and the length of the tip. Three standard lengths are available at 21 mm, 25 mm, and 31 mm. The working part of the instrument must be at least 16 mm. As stated previously, tapers other than #.02 and working parts of instruments less than 16 mm are now available and outside the standard.

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<td>025</td>
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Table 8-1 -- Dimensions of Standardized K-File, H-File, and Gutta-Percha Cones (ANSI No. 28, 58, and 78)
This system of numbering files with at least 15 different sizes replaced the old, somewhat imperfect system that numbered the sizes from 0 through #6. Although the new standard includes many sizes, astute clinicians may include fewer instrument sizes for their special work habits.

In recent years suggestions to change the numbering system for files with different sizes have been implemented by several manufacturers. One system has introduced “half” sizes in the range of #15 through #60, resulting in instruments in sizes #15, #17.5, #20, #22.5, and so on. Considering the fact that most manufacturers already are unable to size their instruments within the accepted range (Fig. 8-52), the introduction of half sizes seems unnecessary. However, if standards are strictly adhered to, the use of half sizes seems more reasonable for instrument systems such as the LightSpeed, in which the strength of the instrument is such that full-size increments may generate stresses beyond the tolerance of the instrument.

* Sizes in italics are only for files that are commercially available but that are not covered by American National Standards Institute (ANSI) regulation no. 28 or no. 58. Colors are not required for instrument handles or gutta-percha cones; however, the size must be printed on the handle. Tolerances are $\pm 0.02 \geq 30 \text{ mm} \pm 2 \text{ mm}$. 

**Figure 8-51** Measuring points for American National Standards Institute (ANSI) and American Dental Association (ADA) regulations #28 and #58, which cover K-type and H-type instruments. The measuring point for the diameter of the instrument (size) is imaginary ($D_0$) and projects the taper of the instrument at the tip. Therefore an instrument with a short tip is more true to its size than an instrument with a long tip. $D_{16}$ represents the diameter at the end of the working part, which must be at least 16 mm long.
The standards are overdue for reevaluation in light of recent technology changes.

Effectiveness and Wear of Instruments

Although the advertising literature is rich in claims of superiority of various file designs, few of these claims can be verified by well-designed studies in objective endodontic literature. No standards exist for either the cutting or machining effectiveness of endodontic files, nor have clear requirements been established for resistance to wear.

In any study of the effectiveness of an instrument, two factors must be investigated: (1) effectiveness in cutting or breaking loose dentin and (2) effectiveness in machining dentin. These two parameters are radically different. Methods exist for measuring machining, but currently no good method is available for measuring cutting. Some studies have attempted to evaluate cutting, but the methodologies have involved the use of a drilling motion with K-type instruments and at a speed higher than that used for clinical procedures.\[83\] [310]

Some studies of machining have evaluated the effectiveness of an instrument when used with a linear movement.\[1\] These studies showed that instruments can differ significantly not only when comparing brands and types but also within one brand and type. For K-files, effectiveness varies 2 to 12 times between files of the same brand. The variation for Hedström files is greater, ranging from 2.5 to more than 50 times.\[192\] [292]

The greater variation among Hedström files is easy to understand because the H-file is the result of more individual grinding during manufacture than the conventional K-file, which is difficult to alter much during the manufacturing process. For example, during the grinding of a Hedström file, the rake angle can be modified to neutral or even slightly positive; this is impossible to achieve with a K-file. The Hedström file, therefore, is approximately 10 times more effective at removing dentin than the K-file (Fig. 8-53).

![Figure 8-52](http://home.mdconsult.com.eproxy1.lib.hku.hk/das/book/body/0/1357/5...)
In the machining process, the rake edge shaves off dentin that accumulates in the grooves between the rake edges. The deeper and larger this space, the longer the stroke can be before the instrument is riding on its own debris, making it ineffective. These design variations and the rake angle of the edges determine the effectiveness of a Hedström file. Of the hybrid files, the K-Flex file, which is a modified K-file, shows variables similar to those of K-files. The Flex-R file, which is a ground instrument, more closely resembles the H-files in its variation in effectiveness. It also is much more effective at substrate removal than the K-files but cannot measure up to the H-files’ ability to machine.

Modern endodontic stainless steel instruments are fabricated from excellent metal alloys and have considerable resistance to fracture. The clinician who practices careful application of force and a strict program of discarding instruments after use should have few instrument fractures. Stainless steel files are so inexpensive that adequate cleaning and sterilization for reuse of files in sizes up to #60 may not be cost effective. Therefore files in the range up to #60 should be considered disposable instruments. Fig. 8–54 shows a file setup that provides efficient overview of the instruments. In a disposable file system, the sponge used to hold treatment instruments is disposed of along with the files.
Devices for Measuring Root Canal Length

Radiographs, tactile sensation, the presence of homebody fluids on paper points, and a knowledge of root morphology have been used to determine the length of root canal systems. Custer described the first device used for this purpose in 1918. In 1942 Suzuki studied the use of direct current to measure canal lengths. Sunada suggested that the apical foramen could be localized using a direct electrical current. Currently the apex locator is considered an accurate tool for determining working length. One study reported that the use of electronic apex locators in a dental student clinic resulted in a higher quality of obturation length control and an overall reduction in the number of radiographs taken. However, these devices must not be considered flawless, because several variables are known to affect their accuracy. For example, immature roots can present problems. One study found errors when the electronic devices were used in immature teeth. Once the roots had matured (i.e., formed a narrow apical foramen) and the instruments were able to contact the canal walls, the electronic apex locator’s accuracy greatly improved. These instruments apparently can be used to assess apical closure in teeth undergoing apexification procedures. Apical resorption may not have a significant effect on the accuracy of electronic measurement of canal lengths. Some investigators have found no statistical difference between roots with vital and necrotic tissue. Because apical root resorption is prevalent in necrotic cases with long-standing apical lesions, these researchers concluded that apical resorption does not have a significant effect on the accuracy of electronic apex locators.

Recently some clinicians have advocated the use of the electronically determined working length in place of radiographs with a file at the estimated length. However, joint use of the two techniques has resulted in greater accuracy. This was further demonstrated in a case study in which radiographs were not used, and the condition did not heal because of a missed canal.

The first two generations of electronic apex locators were sensitive to the contents of the canal and irrigants used during treatment. The development of an algorithm called the ratio measurement method distinguished the third generation of apex locators. To arrive at this method, the impedance of the canal was measured with two current sources of different frequencies, and a quotient was determined using the electrical potentials proportional to each impedance. This study found that electrolytes did not have a significant effect on the accuracy of the unit. Some third-generation apex locators are the Endex Plus, or Apit, (Osada, Los Angeles), the Root ZX (J. Morita, Kyoto), and the Neosono Ultima EZ (Satelec, Mount Laurel, NJ). The Endex device uses 1 and 5 kHz and provides apex location based on subtraction. The Root ZX emits currents at frequencies of 8 and 0.4 kHz and provides apex location based on the resulting quotient.

A fourth-generation apex locator was introduced with the Elements Diagnostic Unit and the Apex Locator (SybronEndo) and the Bingo 1020/Ray-X4 (Forum Engineering Technologies, Rishon Lezion, Israel). The Bingo uses only one of its two frequencies at a time (8 Hz or 400 Hz). According to the manufacturer, the

![Endodontic file organizer. (Courtesy JS Dental, Ridgefield, CT.)](http://home.mdconsult.com.eproxy1.lib.hku.hk/das/book/body/0/1357/5... 2007-1-20)
Elements unit (which operates at frequencies of 0.5 and 4 kHz) compares the resistance and capacitance information to a data base to determine the distance between the file and the apex. When the file tip reaches the area of the apical foramen, the apex locator emits a signal.

An apex locator typically has four parts: (1) the lip clip, (2) the file clip, (3) the instrument itself, and (4) a cord connecting the other three parts. A display indicates the advancement of the file toward the apex (Fig. 8–55).

These electrical instruments are generally safe. However, manufacturers’ instructions state that they should not be used on patients with pacemakers without consulting the patient’s cardiologist. When connected directly to cardiac pacemakers in vitro, four of five electronic apex locators did not interfere with the function of the pacemaker. One case report demonstrates the importance of paying attention to details: the patient swallowed the lip clip, which lodged in the oropharynx and had to be removed with the aid of a laryngoscope and forceps. Safety can be improved by not leaving the clip in place for the entire appointment and by checking that the clip is fully inserted into the cord.

**Instruments for Root Canal Obturation**

After the root canal has been properly cleaned and enlarged, the space is obturated with a manufactured material. A number of obturation methods are practiced, but lateral and vertical compactions are the two most common. Many specialized instruments are available for every type of method. Spreaders and pluggers are the significant instruments for obturation. The spreader is a tapered, pointed instrument intended to displace gutta-percha laterally for insertion of additional accessory gutta-percha cones. The plugger is similar but has a blunt end. In smaller sizes the spreader and plugger are often used interchangeably. These instruments are available with handles or as finger-held instruments (Fig. 8–56). The instruments with handles are potentially dangerous, because the tips of the working ends are offset from the long axes of the handles. This results in strong lateral wedging forces on the working ends if the instruments are not operated carefully.
The risk of vertical damage to the root is greatly reduced with finger spreaders and pluggers. Each clinician must choose the appropriate spreader and plunger according to personal working preferences. Standardized instruments are available with the same taper as the files (e.g., #.02). Considering the greater taper of standardized accessory gutta-percha cones (Table 8-2), nonstandardized spreaders with a larger taper sometimes may be used to better accommodate the gutta-percha. In recent years spreaders and pluggers have become available in nickel-titanium (Fig. 8-57). Nickel-titanium spreaders have been shown to reach deeper into canals than the stainless steel type when #.02 tapered gutta-percha is used in canals with a curvature of more than 20 degrees. When #.04 taper gutta-percha was used, the nickel-titanium spreaders were more effective regardless of the degree of curvature.\[32\]

### Table 8-2 -- Size Designations for Auxiliary Gutta-Percha Cones

<table>
<thead>
<tr>
<th>DESIGNATION</th>
<th>D(_3)</th>
<th>D(_{16})</th>
<th>TAPER</th>
</tr>
</thead>
<tbody>
<tr>
<td>XF</td>
<td>0.20</td>
<td>0.45</td>
<td>0.019</td>
</tr>
<tr>
<td>FF</td>
<td>0.24</td>
<td>0.56</td>
<td>0.025</td>
</tr>
<tr>
<td>MF</td>
<td>0.27</td>
<td>0.68</td>
<td>0.032</td>
</tr>
<tr>
<td>F</td>
<td>0.31</td>
<td>0.80</td>
<td>0.038</td>
</tr>
<tr>
<td>FM</td>
<td>0.35</td>
<td>0.88</td>
<td>0.041</td>
</tr>
<tr>
<td>M</td>
<td>0.40</td>
<td>1.10</td>
<td>0.054</td>
</tr>
<tr>
<td>ML</td>
<td>0.43</td>
<td>1.25</td>
<td>0.063</td>
</tr>
<tr>
<td>L</td>
<td>0.49</td>
<td>1.55</td>
<td>0.082</td>
</tr>
<tr>
<td>XL</td>
<td>0.52</td>
<td>1.60</td>
<td>0.083</td>
</tr>
</tbody>
</table>

XF, Extrafine; FF, fine-fine; MF, medium-fine; F, fine; FM, fine-medium; M, medium; ML, medium-large; L, large; XL, extralarge.

* The cones are pointed. The diameters 3 mm (D\(_3\)) and 16 mm (D\(_{16}\)) from the tip are prescribed. Tolerance is ±0.05 mm, and length is ≥30 mm ±2 mm.
Heat carriers are used for vertical compaction obturation techniques. Traditionally, heat carriers are handled similar to pluggers. They are used to transfer heat to the gutta-percha in the root canal, allowing apical and lateral displacement of the gutta-percha. Electrical heat carriers include Endotec (Caulk/ Dentsply), Touch ‘N Heat and System B (Analytic Endodontics). With these devices, heat carriers can be heated to controlled levels. Some also have different tips for various endodontic uses (Fig. 8-58).

A lentulo spiral (Fig. 8-59) may be used for placement of the sealer, cement, and calcium hydroxide dressings. The lentulo spiral is a safe instrument if used correctly. It must be operated clockwise in the handpiece and started or stopped outside the root canal. If started in the canal, it may cut into the wall of the root canal and break. This instrument effectively drives the paste into the root canal. However, for optimal effect the spiral must be as large as possible so that the paste is forced forward as the material is squeezed between the canal walls and the spiral. Endodontic files, paper points, and syringes also are commonly used to place sealer in the root canal system.

**Devices for Removing Root Canal Obstructions**

Please see Chapter 25 for details on these devices.
MATERIALS FOR DISINFECTING THE PULP SPACE

Irrigation Materials

Instrumentation of the root canal system must always be supported by an irrigation system capable of removing pulp tissue remnants and dentin debris.[116] In modern treatment systems the irrigation fluid is delivered with a fine-caliber needle in large volume, and the debris is aspirated with a good suction device.[3] The effervescence created by mixing NaOCl with hydrogen peroxide has been used to remove debris from the root canal, but this is not an effective method.[3] Liberal irrigation is essential for effective functioning of the files. Many anecdotal descriptions of the lubricating effect of irrigation fluids are merely the mistaken effects of debris transportation. Without irrigation, instruments rapidly become ineffective because of the accumulation of debris. Irrigation also is essential for reducing the number of bacteria in an infected root canal, but it has only a minimal antimicrobial effect on the infected root canal walls. Consequently, the antimicrobial effect of an irrigation fluid should not be the clinician’s only concern when choosing among suitable compounds. Surface tension and cleaning effectiveness are equally important qualities.

Quaternary ammonium compounds with a low surface tension have been extensively used as irrigation fluids. These fluids are detergents and therefore effective aids in pulp space cleaning because they remove lipid pulp breakdown products. However, they now are rarely used because of their toxicity.[28] Quaternary ammonium compounds are still used as additives to ethylenediamine tetra-acetic acid (EDTA) in EDTAC (EDTA and cetrimide) to provide some antimicrobial effect.

NaOCl has become the irrigant of choice worldwide. Its strong proteolytic effect makes it an excellent aid during instrumentation. Chlorhexidine has also been suggested as an irrigant, but it has few advantages over NaOCl during instrumentation. A 2% solution of chlorhexidine has proved more effective against Enterococcus faecalis than sodium hypochlorite. Chlorhexidine also differs from sodium hypochlorite in that it is relatively nontoxic and does not dissolve tissue. If applied to dentin, it binds effectively to hydroxyapatite, providing a lasting reservoir of chlorhexidine after the completion of treatment. Some have suggested that this long-term effect may be helpful in reducing the effect of postoperative coronal leakage.[140] One study showed that combined use of chlorhexidine and sodium hypochlorite resulted in a greater percentage of microbe reduction than was achieved with either used alone.[163]

New irrigants are being developed in an attempt to address some of the shortcomings of past and current materials. MTAD is a mixture of a tetracycline isomer (i.e., doxycycline), an acid, and a detergent. In an in vitro study, MTAD was found to be an effective solution for killing E. faecalis.[304]

Proteolytic Materials

The most commonly used proteolytic irrigation material is NaOCl, which became an important agent for the treatment of infected wounds in the early twentieth century.[51][64][65] NaOCl dissolves necrotic tissues and debris through a complex biochemical process. The amount of free chlorine is important for this breakdown of proteins into amino groups.[76] Higher temperatures also potentiate the antimicrobial and tissue-dissolving effects of NaOCl.[68][69][72]

The original concentration suggested by Dakin was 0.5%,[64][65] but concentrations as high as 5.25% have been used in dentistry. A 1% concentration provides sufficient tissue dissolution and antimicrobial effect if used freely. Higher concentrations of NaOCl affect living tissue and do not improve the reduction of bacteria during endodontic treatment (Fig. 8–60).[43][44] NaOCl has an antimicrobial effect as long as free chlorine is available in the solution. Because free chlorine is the important component consumed during tissue breakdown, the NaOCl must be replenished frequently, especially when low concentrations are used. This becomes even more important when the root canals are narrow and small.

Sodium hypochlorite does not effectively wet dentin, and small canals and canal extensions are poorly irrigated. Attempts have been made to change the surface tension of NaOCl but without significant success. NaOCl also has been shown to deplete dentin of organic compounds and to increase the permeability of dentin significantly. Pure NaOCl is a U.S. Pharmacopeia (USP) preparation and may be purchased from a pharmacy. However, dentists commonly use commercial 5.25% NaOCl (i.e., household bleach). At this concentration NaOCl is highly toxic, meaning that it unnecessarily necrotizes wound surface areas that should remain unharmed. The literature widely suggests that postoperative pain is no greater when high concentrations of NaOCl are used. However, this lack of correlation proves little, because tissue damage and clinical symptoms are poorly correlated.

Commercial NaOCl is buffered to a pH of approximately 12 to 13. This adds another toxic component, making the solution even more caustic. Therefore if commercial bleach is used as a base for preparing a 1% irrigation solution, it is better to use sterile 1% sodium bicarbonate as a diluent rather than water. This helps to adjust the pH to a less caustic level. Diluted, buffered NaOCl has a limited shelf life and should be stored in a dark, cool place for no longer than 1 to 2 weeks.

Few clinical complications are associated with the use of NaOCl. The most common one is accidental injection of NaOCl into periradicular tissue. This results in excruciating pain, periapical tissue bleeding, and extensive swelling. The pain normally subsides within 2 to 3 days. The swelling increases for the first day, after which healing occurs. The prognosis is usually good if no critical tissues, such as the mental nerve, have been damaged.

Sodium hypochlorite and hydrogen peroxide are known to release oxygen-free radicals and have the potential to reduce the bonding of resin to dentin. Alcohol, chlorhexidine, saline, EDTA, anesthetics, and sodium ascorbate do not seem to affect the bond strength of resin, and they may even remove or negate the oxygen-free radicals. One study found that short-term use of calcium hydroxide Ca(OH)2 did not affect dentin bond strengths when ethanol or acetone-based adhesive resin was applied.

**Detergents**

Detergents are often used as irrigation solutions because they are effective at removing the fatty tissue residues that are byproducts of tissue necrosis. Commonly used materials are included in the family of

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**Figure 8-60** Results of root canal disinfection, measured at the beginning of the second visit. I, Instrumented with 0.5% NaOCl (no dressing between visits). II, Similar treatment as in I, but 5% NaOCl also was used. III, Similar treatment as in I, but 5% NaOCl and ethylenediamine tetra-acetic acid (EDTA) were used. IV, Instrumented with 5% NaOCl and dressed with camphorated phenol or paramonochlorphenol. V, Similar treatment as in IV, but calcium hydroxide was used for the dressing.
quaternary ammonium compounds. These compounds were once considered optimal for antimicrobial therapy and effective in very low concentrations. However, this has been disproved, and the preparations have been shown to have a toxicity comparable with that of other irrigation solutions and a rather narrow bactericidal spectrum. Quaternary ammonium antiseptics normally are used in a water solution at 0.1% to 1%. Zephiran chloride has been commonly used as an endodontic irrigation solution. However, in light of its toxicity and low antimicrobial effectiveness, no reasons exist to use this detergent instead of a relatively less toxic irrigating solution (i.e., 1% or less NaOCl solution). Another group of antimicrobial agents with detergent effects are the iodophores. Wescodyne and Iodopax are common products in this line of antiseptics. These organic iodine products are effective at low concentrations. They are antimicrobially effective at an iodine concentration of 0.05% (volume/volume). Detergents have also been mixed with calcium hydroxide for irrigation.

Decalcifying Materials

A smear layer is formed during preparation of the root canal. No clear scientifically based understanding exists on whether this layer must be removed or can be left. However, a multitude of opinions have been offered on both sides of this question. In addition to weak acids, solutions for the removal of the smear layer include carbamide peroxide, aminoquinaldinium diacetate (i.e., Salvizol), and EDTA. In objective studies, carbamide peroxide and Salvizol appear to have little effect on smear layer buildup. A 25% citric acid solution also failed to provide reliable smear layer removal. EDTA is often suggested as an irrigation solution because it can chelate and remove the mineralized portion of smear layers. EDTA is normally used in a concentration of 17%. It removes smear layers in less than 1 minute if the fluid is able to reach the surface of the root canal wall. Reports suggest that under clinical conditions, the fluid should be kept in the root canal for at least 15 minutes for optimal results. The decalcifying process is self-limiting, because the chelator is used up. To achieve continuous effect, the EDTA must be replaced through frequent irrigation. For root canal preparation, EDTA has limited value as an irrigation fluid. It may open up a hair-fine canal if given the time to soften the 50 µm it is capable of decalcifying. This amount, at two opposite canal walls, results in 100 µm. This is equivalent to the tip of a #010 file.

The smear layer consists of both an organic and an inorganic component. EDTA alone normally cannot remove the smear layer effectively; a proteolytic component (e.g., NaOCl) must be added to remove the organic components of the smear layer. Commercial products with such combinations are available. EndoDilator N-Ø (Union Broach, York, PA) is a combination of EDTA and a quaternary ammonium compound. Such an irrigation fluid has a slight detergent effect in addition to the chelating effect. Two newer irrigating solutions, MTAD (Dentsply - Tulsa) and Smear Clear (SybronEndo), have recently been studied. Smear Clear, which is commercially available, is a clear, odorless, water-soluble solution containing water, 17% EDTA salts, a cationic surfactant (centrimide), and anionic surfactants.

Intracanal Disinfection Materials

Biomechanical instrumentation and irrigation with an antimicrobial solution are essential for disinfection of the pulp space, but some suggest that these techniques may not completely eradicate microorganisms in a necrotic pulp space and that further disinfection with an effective antimicrobial agent may be necessary. Phenol and phenol derivatives are the most commonly used intracanal disinfectants. Antiseptics with a chlorine or iodine base are also common. In recent years more attention has been given to the use of calcium hydroxide as an intracanal dressing for the treatment of infected pulp necrosis. Conventional antiseptics generally are toxic, and care must be taken not to cause undue tissue damage.
Phenolic Preparations

Phenol (C₆H₅OH), or carbolic acid, is one of the oldest antimicrobial agents used in medicine. Despite the severe toxicity of phenolic preparations, derivatives of phenol, such as paramonochlorophenol (C₆H₄OHCl), thymol (C₆H₃OHCH₃C₃H₇), and cresol (C₆H₄OHCH₃), remain available. One survey noted a decrease in the use of classic phenolic medicaments with a corresponding increase in the use of calcium hydroxide or no medication.[98] Phenol is a nonspecific protoplasm poison that has an optimal antibacterial effect at 1% to 2%. Many dental preparations use much too high a concentration of phenol (e.g., in the range of 30%). At such a concentration the antimicrobial effect in vivo is lower than optimal and of very short duration.[190]

Derivatives of phenol are stronger antiseptics and toxins than phenol. Phenolic compounds are often available as camphorated solutions. Camphoration results in a less toxic phenolic compound because it slows the release of toxins to the surrounding tissues.

Studies in vitro have shown that phenol and phenol derivatives are highly toxic to mammalian cells and that their antimicrobial effectiveness does not sufficiently balance their toxicity.[284][285] Experimentation in vivo also demonstrated that phenol and phenolic derivatives induce inflammatory changes at much lower concentrations than many other antimicrobial agents.[283]

Phenols are ineffective antiseptics under clinical conditions. In one study, 2 weeks of intracanal dressing (in which the canals were filled with camphorated phenol or camphorated parachlorophenol) failed to eliminate intracanal bacteria in one third of the cases.[42] Phenolic compounds are also unable to release an effective antimicrobial vapor and therefore are ineffective when placed on a cotton pellet in the pulp space.

Table 8-3 -- Degree of Tissue Irritation Caused by Antiseptics Used for Intracanal Dressings[8]

<table>
<thead>
<tr>
<th>DILUTION</th>
<th>IODINE POTASSIUM IODIDE 2% (mg)</th>
<th>CAMPHORATED PHENOL (mg)</th>
<th>FORMOCRESOL (mg)</th>
<th>CRESATIN (mg)</th>
<th>CAMPHORATED PARACHLOROPHENOL (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:16</td>
<td>26.9 ± 3</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>1:32</td>
<td>2.9 ± 0.3</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>1:64</td>
<td>3.3 ± 0.4</td>
<td>33.8 ± 3.1</td>
<td>21.6 ± 0.8</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>1:128</td>
<td>1.6 ± 0.2</td>
<td>16.1 ± 1.4</td>
<td>15.7 ± 1</td>
<td>29.7 ± 2.2</td>
<td>33.4 ± 2.7</td>
</tr>
<tr>
<td>1:256</td>
<td>1.6 ± 0.1</td>
<td>2.1 ± 0.1</td>
<td>17 ± 3.5</td>
<td>19.9 ± 2.2</td>
<td>28.2 ± 2.4</td>
</tr>
<tr>
<td>1:512</td>
<td>1.1 ± 0.1</td>
<td>1.1 ± 0.1</td>
<td>11.1 ± 1.7</td>
<td>12.2 ± 0.8</td>
<td>23 ± 1.8</td>
</tr>
<tr>
<td>1:1024</td>
<td>--</td>
<td>4.5 ± 0.9</td>
<td>0.5 ± 0.2</td>
<td>1.9 ± 0.5</td>
<td></td>
</tr>
<tr>
<td>1:2048</td>
<td>--</td>
<td>--</td>
<td>1.6 ± 0.4</td>
<td>--</td>
<td></td>
</tr>
</tbody>
</table>

* The values shown (Mean ± SD) are measurements of enhanced vascular permeability after intradermal injection of 0.1 ml of the diluted antiseptic. The figures indicate leaked albumin after 3 hours measured as micrograms (µg) of Evans blue dye. Normal values are less than 3 µg. Formocresol causes inflammation when diluted 1000 times; formocresol, cresatin, and camphorated parachlorophenol when diluted 500 times; and camphorated phenol at a dilution of 128 times. Iodine potassium iodide is the least irritating antiseptic. See Spångberg et al.[283] for details.
**Formaldehyde**

Formaldehyde has been used extensively in endodontic therapy despite its high toxicity and mutagenic and carcinogenic potential.\(^{[173]}\) The compound of interest when discussing pulp space disinfection is formocresol. The formaldehyde component of formocresol may vary substantially between 19% and 37%. Tricresol formalin, another formaldehyde preparation, contains 10% tricresol and 90% formaldehyde. Therefore all these preparations have a formaldehyde content well above the 10% normally used for fixation of pathologic specimens. Formaldehyde is volatile and releases antimicrobial vapors if applied on a cotton pellet for pulp chamber disinfection. All these formaldehyde preparations are potent toxins with an antimicrobial effectiveness much lower than their toxicity.\(^{[80]}\)\(^ {[235]}\)\(^ {[285]}\) The formaldehyde in contact with tissue in the pulp and periapical tissues is transported to all parts of the body.\(^{[16]}\)\(^ {[36]}\) Considering the outright toxic and tissue-detructive effects and the mutagenic and carcinogenic potential, no clinical reason exists to use formocresol as an antimicrobial agent for endodontic treatment. The alternatives are better antiseptics with significantly lower toxicity. Clinicians who might still contemplate using formaldehyde in practice are referred to Chapter 11 for a discussion of the legal implications of this unwise decision.

**Halogen**

Chlorine has been used for many years to irrigate the root canals. It also is sometimes used as an intracanal dressing in the form of Chloramine-T.\(^{[78]}\)\(^ {[80]}\) Iodine, in the form of iodine potassium iodide (IKI), is a very effective antiseptic solution with a low tissue toxicity.\(^{[78]}\)\(^ {[80]}\)\(^ {[285]}\) One in vitro study showed that IKI (i.e., IKI 2%) penetrated deeper than 1000 µm of dentin in 5 minutes.\(^{[212]}\) IKI is an effective disinfectant for infected dentin and can kill bacteria in infected dentin in 5 minutes in vitro.\(^{[235]}\) Iodine potassium iodide releases vapors with a strong antimicrobial effect.\(^{[75]}\) The solution can be prepared by mixing 2 g of iodine in 4 g of potassium iodide; this mixture then is dissolved in 94 ml of distilled water. Tincture of iodine (5%) has proved to be one of the few reliable agents for disinfection of rubber dam and tooth surfaces during the preparation of an aseptic endodontic workfield.\(^{[197]}\)

**Calcium Hydroxide**

Hermann\(^{[128]}\) introduced the use of calcium hydroxide in endodontics in 1920. Although its use was well documented for its time, the clinical applications over the next 25 years were not well known.\(^{[129]}\) Calcium hydroxide cannot be categorized as a conventional antiseptic, but it kills bacteria in the root canal space. It has been routinely used by many clinicians over the past 40 years. The value of calcium hydroxide in endodontic treatment of necrotic, infected teeth is now well documented.\(^{[42]}\)\(^ {[267]}\) Calcium hydroxide normally is used as a slurry of calcium hydroxide in a water base. At body temperature, less than 0.2% of the calcium hydroxide is dissolved into Ca\(^+\) and OH\(^-\) ions. Because Ca(OH)\(_2\) needs water to dissolve, water should be used as the vehicle for the calcium hydroxide paste. In contact with air, calcium hydroxide forms calcium carbonate (CaCO\(_3\)). However, this is an extremely slow process of little clinical significance.

Calcium hydroxide paste with a significant amount of calcium carbonate feels granular because the carbonate has a very low solubility. Some have suggested using Cresatin or camphorated parachlorophenol as the mixing vehicle. Mixing with Cresatin results in the formation of calcium cresylate and acetic acid, whereas mixing with camphorated parachlorophenol results in calcium parachlorophenolate. In both cases hydrolysis is inhibited, and the advantageous high pH is not reached.\(^{[15]}\)\(^ {[265]}\)

Calcium hydroxide is a slowly working antiseptic. Direct contact experiments in vitro show that a 24-hour contact period is required for complete killing of enterococci.\(^{[235]}\) In clinical experimentation, 1 week of intracanal dressing has been shown to safely disinfect a root canal system.\(^{[267]}\) A study of 42 patients found that sodium hypochlorite irrigation reduced the bacteria level by only 61.9%, but use of calcium hydroxide in the canals for 1 week resulted in a 92.5% reduction.\(^{[298]}\) These researchers concluded that Ca(OH)\(_2\) should be used in infected cases to more predictably obtain healing.

In addition to killing bacteria, calcium hydroxide has the extraordinary ability to hydrolyze the lipid moiety of bacterial lipopolysaccharides (LPS), thereby inactivating the biologic activity of the lipopolysaccharide and reducing its effect.\(^{[233]}\)\(^ {[234]}\) This is a very desirable effect because dead cell wall material remains after the bacteria have been killed and can continue to stimulate inflammatory responses in the periradicular tissue.
Calcium hydroxide may be mixed with sterile water or saline; this formula is also available commercially from a number of manufacturers in sterile, single-dose packages (e.g., Calasept [J.S. Dental, Ridgefield, CT]; SteriCal [Centrix, Shelton, CT]; and DT Temporary Dressing, [Global Dental Products, North Bellmore, NY]) ([Fig. 8-61]). The mixture should be thick to carry as many calcium hydroxide particles as possible. This slurry is best applied with a lentulo spiral. For maximal effectiveness the root canal must be filled homogeneously to the working length. Saturated calcium hydroxide solution mixed with a detergent is an effective antimicrobial agent suitable for irrigation.[23]

**Bioactive Glass**

Research is underway in the use of bioactive glass as an intracanal medicament. In one study the glass used was composed of 53% SiO₂ (w/w), 23% Na₂O, 20% CaO, and 4% P₂O₅ and was prepared from reagent grade Na₂CO₃, CaHPO₄·2H₂O, CaCO₃, and Belgian sand.[332] When used in root canals, bioactive glass was found to kill bacteria, but the mechanism of action was not pH related and dentin did not seem to alter its effect.[332] Some new obturating materials (e.g., Resilon [Pentron Clinical Technologies, Wallingford, CT]) contain bioactive glass.

**Superoxidized Water**

Superoxidized water is saline that has been electrolyzed to form superoxidized water (hypochlorous acid and free chlorine radicals, supplied as Sterilox [Sterilox Technologies, Radnor, PA]). This solution is nontoxic to biologic tissues yet able to kill microorganisms.[93] A study investigating the cleaning of endoscopes found that the solution killed microbes at a level equivalent to glutaraldehyde and superior to ozonated water and 0.05% chlorhexidine.[306] However, the solution’s effectiveness was reduced by contact with albumin. These researchers concluded that superoxidized water was effective only after the endoscopes had been mechanically cleaned. In addition to its surface disinfection capability,[191] superoxidized water has been shown to have potential as an endodontic irrigating solution. However, additional work is needed to confirm this result.[273]
ROOT CANAL FILLING MATERIALS

Solid Materials

After the pulp space has been appropriately prepared, it must be obturated with a material capable of completely preventing communication between the oral cavity and the periapical tissue wound. Materials used for this purpose should be compatible with healing; this is achieved by attempting to seal the root canal system at both its coronal and apical ends. Apical obturation blocks the exit to the periapical tissues for organisms that have survived in the root canal after cleaning and shaping. Coronal obturation prevents reinfection of the pulp space from the oral environment. Completion of the obturation phase does not signify the end of endodontic therapy. Temporization, core buildups, post and core buildups, final restorations, and good maintenance care are all critical to the long-term success of endodontic treatment. The required physical and biologic properties make the selection of obturation materials critical. The materials commonly used for root canal fillings normally can be divided into a solid phase and a cementing medium (i.e., a sealer).

Gutta-Percha

Gutta-percha, the dried juice of the Taban tree (i.e., *Isonandra percha*), is the most commonly used root canal filling material. It was first introduced to the Royal Asiatic Society of England in 1843 by Sir Jose d’Almeida and was introduced into dentistry in the late 1800s. It occurs naturally as 1,4-polyisoprene and is harder, more brittle, and less elastic than natural rubber. A linear crystalline polymer such as gutta-percha melts at a set temperature, and a random but distinct change in structure results. (See Chapter 10 for further discussion of the physical properties of gutta-percha.)

The crystalline phase has two forms, the alpha phase and the beta phase. The forms differ only in the molecular repeat distance and single-bond form. The alpha form is the material that comes from the natural tree product. The processed, or beta, form is used in gutta-percha for root fillings. When heated, gutta-percha undergoes phase transitions. The transition from beta phase to alpha phase occurs at around 115° F (46° C). An amorphous phase develops at around 130° to 140° F (54° to 60° C). When cooled very slowly (i.e., 1° F per hour), gutta-percha crystallizes to the alpha phase. Normal cooling returns the gutta-percha to the beta phase. Gutta-percha cones soften at a temperature above 147° F (64° C). These cones can easily be dissolved in chloroform and halothane and less well in turpentine.

Modern gutta-percha cones for root fillings contain only about 20% gutta-percha (Box 8–1). The major component is zinc oxide (60% to 75%). The remaining 5% to 10% consists of various resins, waxes, and metal sulfates. The specific content normally is a manufacturing secret. Antiseptic gutta-percha with various antimicrobial agents has been suggested, but no credible information is available concerning the effect of these additives. Gutta-percha cone material that is 1 mm thick has a radiopacity corresponding to 6.44 mm of aluminum.

Box 8-1

<table>
<thead>
<tr>
<th>Composition of Gutta-Percha for Endodontic Use</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gutta-Percha Cones</strong></td>
</tr>
<tr>
<td>Gutta-percha (19% – 22%)</td>
</tr>
<tr>
<td>Zinc oxide (59% – 79%)</td>
</tr>
<tr>
<td>Heavy metal salts (1% – 17%)</td>
</tr>
<tr>
<td>Wax or resin (1% – 4%)</td>
</tr>
</tbody>
</table>

Because gutta-percha cannot be heat sterilized, other decontamination methods must be used. The most practical method is to disinfect the gutta-percha in NaOCl before use. This can be done in 1 minute if the cone
is submerged in a 5% solution of NaOCl. However, after this disinfection it is imperative that the gutta-percha be rinsed in ethyl alcohol to remove crystallized NaOCl before obturation; such crystals impair the obturation seal.

Gutta-percha normally is applied using some form of condensation pressure. However, real compression of gutta-percha is practically impossible. Therefore pressure applied during root canal filling procedures cannot be expected to compress gutta-percha, but it does dislodge gutta-percha points to obtain a more complete fill of the root canal. Gutta-percha may also be plasticized with a solvent or through heating to better fit the pulp space for the obturation. Both methods result in a slight shrinkage of approximately 1% to 2% when the gutta-percha has solidified. Some have suggested that shrinkage in warmed gutta-percha may be prevented if the material is not heated above 113°F (45°C). However, this is practically impossible in vertical warm compaction. Nevertheless, careful control of the temperature during warm compaction is crucial to prevent focal areas of unnecessary high temperatures. The first line of defense is use of devices that provide better temperature control than an open flame. Several such electrically controlled heating devices are available; the Touch ’N Heat and System B units (Analytic Endodontics) are the devices more commonly used for this purpose (Fig. 8–62). Gutta-percha oxidizes with exposure to air and light and becomes brittle. Therefore it should be stored in a cool, dry place for better shelf life. Methods of rejuvenating aged gutta-percha have been suggested.

Gutta-percha cannot be used as the sole filling material because it lacks the adherent properties necessary to seal the root canal space. Several techniques for using heat or solvents to better adapt the gutta-percha to the canal space have been described, but a sealer and cement is always needed for the final seal.

Endodontic gutta-percha is sold as cones in a variety of shapes and tapers (Fig. 8–63). Manufacturers now supply gutta-percha cones in tapers matching the larger taper instruments (#.02, #.04, and #.06). Two types of cones are available, core points used as master cones and auxiliary points used for lateral condensation. An international standard has been accepted for gutta-percha points. Thus the sizing of gutta-percha core points (i.e., master cones) is based on similar size and taper standards as for the endodontic files (ANSI no. 78) (see Table 8–1). The clinician must keep in mind, however, that the tolerance is much less stringent for gutta-percha. An endodontic file must be manufactured with a tolerance of ±0.02 mm, but the gutta-percha must conform to tolerances of only ±0.05 mm. Consequently, with the same size instrument and gutta-percha point, a difference in diameter of 0.07 mm (more than one file size) is possible. This discrepancy can be even greater if the standards are not strictly followed by the manufacturer.

Figure 8-62  System B heating device for vertical compaction and removal of gutta-percha.  (Courtesy SybronEndo, Orange, CA.)
The auxiliary points have a larger taper and a more pointed tip than standard cones. They also are standardized but in a very different system (see Table 8–2). They normally are supplied in sizes such as fine, fine-medium, medium-fine, medium, and medium-large. These gutta-percha cones are usually used as accessory points during lateral condensation. Although core points often are used as master cones for obturation, the auxiliary cone is more suited to this purpose in some applications.

Resilon

Resilon (Pentron Clinical Technologies), a thermoplastic, synthetic, polymer-based root canal filling material, was developed in an attempt to create an adhesive bond between the solid core material and the sealer. It is designed to be used with Epiphany (Pentron Clinical Technologies), a new resin sealer. Resilon can be supplied in the same ISO sizes and shapes (cones and pellets) as gutta-percha. The manufacturer has stated that it can be used with any current root canal obturation technique (lateral condensation, thermoplasticized, carrier, injection). When manufactured in cones, Resilon’s flexibility is similar to that of gutta-percha. Based on polyester polymers, Resilon contains bioactive glass and radiopaque fillers (bismuth oxychloride and barium sulfate) with a filler content of approximately 65%. It can be softened with heat or dissolved with solvents such as chloroform. This characteristic allows the use of current retreatment techniques for nonhealing cases. Because it is a resin-based system, it is compatible with current restorative techniques in which cores and posts are placed with resin bonding agents. [261]

Coated Gutta-Percha

Coated gutta-percha (Ultradent) is under development in an attempt to achieve bonding between the solid core and resin sealer. The uniform layer is placed on the gutta-percha cone by the manufacturer. When the material comes in contact with the resin sealer, a resin bond is formed. The manufacturer claims that this will inhibit leakage between the solid core and the sealer. The technique calls for use of EndoRez sealer (Ultradent) with this new solid core material.

Silver Cones

Pure silver molded into a conical shape has been used for root canal fillings since the 1930s, often for obturation of very narrow canals. [137][305] The use of silver cones for obturation is becoming increasingly rare, however, because it is considered below the standard of care. (Chapter 11 presents more information on this issue.) Because of the stiffness of silver, this technique was easier than using gutta-percha. Stainless steel files have also been used for root canal obturation in clinical situations involving heavily calcified, dilacerated, narrow canals.

Obtaining good obturation with silver is difficult because it cannot be made to conform to the pulp space. Also, most silver cones contain small amounts (e.g., 0.1% to 0.2%) of other trace metals such as copper and nickel. This adds to the corrosion of silver cones (Fig. 8–64), which is a very common complication in clinical cases. [39][124][149][336] Other reasons for the corrosion of silver in situ are the presence of metal restorations and posts that may have been used in teeth in the area. Silver corrosion products are highly toxic and by themselves may cause severe tissue injury. [102][257] Corrosion has been suggested as a reason for the failure of many silver cone root fillings, but despite numerous reports of silver corrosion in situ, it is not clear whether the high failure rate is associated with the corrosion or simply is the result of poor obturation with such rigid material.
Sealers and Cements

Endodontic Sealers

The sealer plays an important role in the root canal filling. It fills all the space the solid core material is unable to fill because of its physical limitations. A good sealer adheres strongly to the dentin and the core material (usually gutta-percha). The sealer also must have cohesive strength to hold the obturation together. Sealers usually are made of a mixture that hardens through a chemical reaction. This reaction normally includes the release of toxic material, which makes the sealer less biocompatible. In general, the sealer is the critical component when the toxicity of materials is assessed.

The sealer must have some degree of radiopacity to be clearly visible on adequately exposed radiographs. Additives used to enhance radiopacity are silver, lead, iodine, barium, and bismuth. Compared with gutta-percha cones, most sealers have a slightly lower radiopacity. A variety of sealers are available, and the clinician must be careful to evaluate all characteristics of a sealer before selecting one.

Zinc Oxide - Eugenol Cements

Many endodontic sealers are simply zinc oxide - eugenol cements that have been modified for endodontic use. The mixing vehicle for these materials is mostly eugenol. The powder contains zinc oxide that has been finely sifted to enhance the flow of the cement. The setting time is adjusted to allow for adequate working time. One millimeter of zinc oxide - eugenol cement has a radiopacity corresponding to 4 to 5 mm of aluminum, which is slightly lower than that of gutta-percha. These cements easily lend themselves to the addition of chemicals; paraformaldehyde is sometimes added for antimicrobial and mummifying effects, germicides for antiseptic action, rosin or Canada balsam for greater dentin adhesion, and occasionally corticosteroids for suppression of inflammatory reactions.

Zinc oxide is a valuable component of the sealer (Table 8-4). It is effective as an antimicrobial agent and has been shown to provide cytoprotection to tissue cells. The incorporation of rosins in sealers initially may have been for the adhesive properties. Rosins (i.e., colophony), which are derived from a variety of conifers, are composed of approximately 90% resin acid. The remaining parts are volatile and nonvolatile compounds, such as terpene alcohol, aldehydes, and hydrocarbons. Resin acids are monobasic carboxylic acids with the basic molecular formula C_{20}H_{30}O_2. Resin acids are amphiphilic, with the carbon group being...
lipophilic, affecting the lipids in the cell membranes. Thus the resin acids have a strong antimicrobial effect that in mammalian cells is expressed as cytotoxicity. The resin acids work similarly to quaternary ammonium compounds by increasing the cell membrane permeability of affected cells. Although toxic, the combination of zinc oxide and resin acids overall may be beneficial. The antimicrobial action of zinc oxide in both gutta-percha cones and many sealers creates a low-level but long-lasting antimicrobial effect. The resin acids are both antimicrobial and cytotoxic, but the combination with zinc oxide exerts a significant level of cytoprotection.

Table 8-4 -- Composition of Some Common Zinc Oxide – Eugenol Endodontic Cements

<table>
<thead>
<tr>
<th></th>
<th>RICKERT’S SEALER</th>
<th>PROCO-SOL</th>
<th>PROCO-SOL (NONSTAINING)</th>
<th>GROSSMAN SEALER’S SEALER</th>
<th>WACH’S PASTE</th>
<th>TUBLI-SEAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powder</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zinc oxide</td>
<td>34 - 41.2</td>
<td>45</td>
<td>40</td>
<td>42</td>
<td>61.3</td>
<td>57.4 - 59</td>
</tr>
<tr>
<td>Silver</td>
<td>25 - 30</td>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oleoresins</td>
<td>16 - 30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>18.5 - 21.3</td>
</tr>
<tr>
<td>Resin (hydrogenated)</td>
<td>36</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Staybelite resin</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dithymoliodide</td>
<td>11 - 12.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnesium oxide USP</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium phosphate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bismuth subcarbonate</td>
<td>15</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bismuth subnitrate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bismuth subiodide</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bismuth trioxide</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7.5</td>
</tr>
<tr>
<td>Barium sulfate</td>
<td>15</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium borate (anhydrous)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heavy magnesium oxide</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.1</td>
</tr>
<tr>
<td>Thymol iodide</td>
<td>3.8 - 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oils and waxes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10 - 10.1</td>
<td></td>
</tr>
</tbody>
</table>

| Liquid |                  |           |                         |                           |              |            |
| Oil of cloves | 78 - 80   |           |                         |                           |              |            |
| Eugenol | 90         | 83.3      | 100                     |                           |              |            |
| Canada balsam | 20 - 22  | 10        |                         |                           |              |            |
| Sweet oil of almond |           | 16.7     |                         |                           |              |            |
| Eucalyptol |           |           |                         |                           | 1.8          |            |
| Beechwood creosote |           |           |                         |                           | 1.8          |            |
| Polymerized resin |           |           |                         |                           |              |            |
| Annidalin |           |           |                         |                           |              |            |

* Proportions of components not disclosed.

Under certain conditions resin acids may react with zinc, forming a resin acid salt (i.e., resinate). This matrix-stabilized zinc resinate is only slightly soluble in water. Therefore zinc oxide – eugenol cements with resin components are less soluble than regular zinc oxide – eugenol cements.
The setting of zinc oxide–eugenol cements is a chemical process combined with physical embedding of zinc oxide in a matrix of zinc eugenolate. The particle size of the zinc oxide, pH, and the presence of water regulate the setting and other additives that might be included in special formulas. The formation of eugenolate constitutes the hardening of the cement; Ca(OH)₂ accelerates this action; therefore, canal systems must be well irrigated when Ca(OH)₂ is removed before obturation. Free eugenol always remains in the mass and acts as an irritant. Some of the more common zinc oxide–eugenol cements are Rickert’s sealer (Kerr Manufacturing Co.), Proco-Sol (Star Dental, Conshohocken, PA), U/P-Grossman’s sealer (Sultan Chemists, Englewood, N.J), Wach’s sealer (Sultan Chemists), Tubli-Seal (Kerr), Endomethasone (Septodont, Saint-Maur, France), and N2 (Agsa, Locarno, Switzerland). Zinc oxide–eugenol cements lose some volume with time because of dissolution in tissues with the release of eugenol and zinc oxide. In one study this volume loss was measured in pure zinc oxide–eugenol cements over 180 days and found to be over 11%. The addition of resin acids to the zinc oxide–eugenol cement significantly reduces this dissolution.

In an earlier time formaldehyde commonly was mixed into endodontic sealers. The most common combinations have been zinc oxide–eugenol cements mixed with formaldehyde (Table 8–5). However, formaldehyde is a dangerous additive to any sealer, because it adds to the already toxic effect of eugenol and prevents or delays healing. The use of endodontic materials containing formaldehyde was briefly popular years ago because formaldehyde necrotizes periradicular tissue, including nerve terminals and immune cells, and therefore sometimes masks the inflammatory processes—unless it impinges on a neurovascular bundle (e.g., the inferior alveolar). Thus despite the necrotic effect of formaldehyde, some patients have few immediate symptoms and the damage is clinically noticeable only years later. Chapter 11 further discusses why potential major liabilities exist for any dentist who unwisely chooses to use formaldehyde or paraformaldehyde during endodontic therapy.)

<table>
<thead>
<tr>
<th>Powder</th>
<th>Endomethasone</th>
<th>N2 (RC-2B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc oxide</td>
<td>+</td>
<td>62–69</td>
</tr>
<tr>
<td>Bismuth subcarbonate</td>
<td>+</td>
<td>5–9</td>
</tr>
<tr>
<td>Bismuth subnitrate</td>
<td>+</td>
<td>2–4</td>
</tr>
<tr>
<td>Barium sulfate</td>
<td>+</td>
<td>2–3</td>
</tr>
<tr>
<td>Dexamethasone</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Hydrocortisone acetate</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Hydrocortisone</td>
<td></td>
<td>1.2</td>
</tr>
<tr>
<td>Prednisolone</td>
<td></td>
<td>0.2</td>
</tr>
<tr>
<td>Tetraiodothymol</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Paraformaldehyde</td>
<td>+</td>
<td>6.5</td>
</tr>
<tr>
<td>Titanium dioxide</td>
<td></td>
<td>2–3</td>
</tr>
<tr>
<td>Phenylmercuric borate</td>
<td></td>
<td>0.16</td>
</tr>
<tr>
<td>Lead tetroxide</td>
<td></td>
<td>11–12</td>
</tr>
<tr>
<td>Liquid</td>
<td></td>
<td>92–100</td>
</tr>
<tr>
<td>Eugenol</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Geraniol</td>
<td></td>
<td>8</td>
</tr>
</tbody>
</table>

* Amounts are not disclosed by the manufacturer.

Chloropercha

Chloropercha (Moyco, Union Broach, York, PA) is another type of sealer that has been used for many years. It is made by mixing white gutta-percha (i.e., alba) with chloroform. This allows a gutta-percha root filling to fit better in the canal. However, chloropercha has no adhesive properties. Another commercial form of...
chloropercha, Kloroperka N-Ø (N-Ø Therapeutics, Oslo), contains resins and Canada balsam and thus has better adhesive properties (Table 8-6). Various forms of chloropercha have a radiodensity (1 mm thick) that corresponds to only 1.2 to 2.7 mm of aluminum, much less than 1 mm of gutta-percha (6.4 mm of aluminum). These sealers appear on radiographs as a vague radiodensity. The general problem with chloropercha products is their shrinkage during the evaporation or disappearance of the chloroform. Some brands, such as Kloroperka N-Ø, have filler particles (e.g., zinc oxide) to reduce the shrinkage. Zinc oxide also increases radiopacity.

Table 8-6 -- Composition of Gutta-Percha Sealers[*]

<table>
<thead>
<tr>
<th></th>
<th>KLOPERKA-NØ</th>
<th>CHLOROPERCHA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powder</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canada balsam</td>
<td>19.6</td>
<td></td>
</tr>
<tr>
<td>Resin</td>
<td>11.8</td>
<td></td>
</tr>
<tr>
<td>Gutta-percha</td>
<td>19.6</td>
<td>9</td>
</tr>
<tr>
<td>Zinc oxide</td>
<td>49</td>
<td></td>
</tr>
<tr>
<td>Liquid</td>
<td>100</td>
<td>91</td>
</tr>
</tbody>
</table>

* Chloropercha is a premixed sealer; Kloroperka N-Ø is a powder-liquid mixture.

Another variation on the chloropercha technique is to use a mixture of 5% to 8% rosins in chloroform. A rosin-chloroform wash of the root canal leaves a very adhesive residue. This residue, combined with dipping of the gutta-percha cone in resin chloroform, provides the sealer in this technique. The technique is difficult, however, because there is no sealer to fill areas where voids exist between the gutta-percha cones. The chloroform technique requires precise manipulations; therefore the clinician must be skilled in various obturation techniques (Fig. 8-65). When the chloroform technique is used correctly, the shrinkage is no greater than when gutta-percha is plasticized by heat.
The use of chloroform has been sharply curtailed in recent years because of its projected toxicity. In endodontics, however, the amounts used normally are insignificant and cause no detectable health hazard. Nevertheless, the clinician must take prudent steps to reduce vaporization during use, because chloroform is highly volatile. When used to soften gutta-percha during revision of old root fillings, the chloroform should be dispensed through a syringe and hypodermic needle. For other uses the exposure time, amount used, and chloroform surface exposed all should be kept to a minimum.

Some chloroform substitutes, such as halothane and turpentine, are in use. Compared with chloroform, halothane is less effective at softening gutta-percha, is similarly hepatotoxic, and has a higher local toxicity (Table 8–7). For these reasons, halothane is not a good substitute. Turpentine is not carcinogenic but is reported to cause allergic reactions easily. It has a high local toxicity and dissolves gutta-percha poorly. Currently, therefore, no good substitute exists for the use of chloroform in endodontic procedures. With careful workplace hygiene, little risk is associated with the occasional use of minuscule amounts of chloroform in endodontics, provided no federal or state laws or regulations are violated.[21][179]

Table 8-7 -- Toxic Effect of Gutta-Percha Solvents on L929 Cells in Vitro

<table>
<thead>
<tr>
<th>TIME</th>
<th>CONTROL</th>
<th>CHLOROFORM</th>
<th>HALOTHANE</th>
<th>TURPENTINE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Evaporation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 8-65 Root filling performed with a resin chloroform dip method. Too much chloroform was used. A, The obturation seemed good at the time of filling. B, At a follow-up 2 weeks later, when the chloroform had evaporated, the gutta-percha mass had lost significant volume and dropped into the periapical tissue.
Calcium Hydroxide Sealers

Recently several calcium hydroxide–based sealers have become commercially available, such as Sealapex (Kerr Manufacturing Co.), CRCS (Hygenic Corp.), and Apexit (Vivadent, Schaan, Liechtenstein). These sealers are promoted as having therapeutic effects because of their calcium hydroxide content (Box 8–2). However, no such convincing results have been shown in scientific trials. To be therapeutically effective, calcium hydroxide must be dissociated into Ca++ and OH-. Therefore an endodontic sealer based on Ca(OH)$_2$ must dissolve to release the calcium hydroxide, and the solid consequently loses content. One major concern is that the calcium hydroxide content may dissolve, leaving obturation voids.\[301\] This would ruin the function of the sealer, because it would disintegrate in the tissue. These sealers also have poor cohesive strength.\[318\] No evidence supports the contention that a calcium hydroxide sealer provides any advantage for root canal obturations or has any of the desirable biologic effects of calcium hydroxide paste. In a study of diffusion of hydroxyl ions into surrounding dentin after root filling with Sealapex and Apexit, no traces were found in teeth filled with Apexit. Some hydroxyl ions could be detected in the dentin close to the root filling with Sealapex.\[288\] In a similar study of calcium and hydroxyl ion release from Sealapex and CRCS, negligible release was noted from CRCS. Sealapex released more ions but disintegrated in the process.\[305\] In vivo studies of Sealapex and CRCS have demonstrated that these sealers easily disintegrate in the tissue,\[271\] and both cause chronic inflammation.\[272\]\[306\]

**Box 8-2**

<table>
<thead>
<tr>
<th>Fresh mix</th>
<th>1 day</th>
<th>7 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sealapex</td>
<td>CRCS</td>
<td>Apexit</td>
</tr>
<tr>
<td>Base</td>
<td>Base</td>
<td>Base</td>
</tr>
<tr>
<td>Calcium hydroxide (25%)</td>
<td>Calcium hydroxide</td>
<td>Calcium hydroxide</td>
</tr>
<tr>
<td>Zinc oxide (6.5%)</td>
<td>Zinc oxide</td>
<td>Zinc oxide</td>
</tr>
<tr>
<td>Catalyst</td>
<td>Catalyst</td>
<td>Catalyst</td>
</tr>
<tr>
<td>Barium sulfate (18.6%)</td>
<td>Barium sulfate</td>
<td>Barium sulfate</td>
</tr>
<tr>
<td>Titanium dioxide (5.1%)</td>
<td>Titanium dioxide</td>
<td>Titanium dioxide</td>
</tr>
<tr>
<td>Zinc stearate (1%)</td>
<td>Zinc stearate</td>
<td>Zinc stearate</td>
</tr>
<tr>
<td>Liquid</td>
<td>Liquid</td>
<td>Liquid</td>
</tr>
<tr>
<td>Calcium hydroxide</td>
<td>Calcium hydroxide</td>
<td>Calcium hydroxide</td>
</tr>
<tr>
<td>Zinc oxide</td>
<td>Zinc oxide</td>
<td>Zinc oxide</td>
</tr>
<tr>
<td>Bismuth dioxide</td>
<td>Bismuth dioxide</td>
<td>Bismuth dioxide</td>
</tr>
<tr>
<td>Barium sulfate</td>
<td>Barium sulfate</td>
<td>Barium sulfate</td>
</tr>
</tbody>
</table>
New sealers are mostly polymers (Table 8). A few of the brands available are AH26 and AH Plus (Caulk/Dentsply), Epiphany (Pentron Clinical Technologies), EndoRez (Ultradent), Endofill (Lee Pharmaceuticals, South El Monte, CA), and Diaket (ESPE, Seefeld, Germany). AH26 is an epoxy resin that initially was developed as a single-filler material. Because of its positive handling characteristics, it has been extensively used as a sealer. It has a good flow, seals well to dentin walls, and allows for sufficient working time. One millimeter of AH26 has a radiopacity corresponding to 6.66 mm of aluminum, making it very similar to gutta-percha. However, this toxicity declines rapidly during setting, and after 24 hours the cement has one of the lowest toxicities of endodontic sealers. The toxicity of AH26 arises from the release of a very small amount of formaldehyde as a result of the chemical setting process. However, the amount of formaldehyde briefly released is thousands of times lower than the long-term release seen with conventional formaldehyde-containing sealers, such as N2. After the initial setting, AH26 has little toxic effect in vitro or in vivo. A new formulation of AH26, AH Plus, is now available. This is a paste and paste-mixing system that assures a better mixture and does not release formaldehyde upon setting. It is more radiopaque and has a shorter setting time (approximately 8 hours), lower solubility, and a better flow compared with AH26. One study demonstrated that AH Plus had a lower short- and long-term toxicity level and was less genotoxic than AH26.

<table>
<thead>
<tr>
<th>Apexit</th>
<th>Base</th>
<th>Activator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium hydroxide (31.9%)</td>
<td>Zinc oxide (5.5%)</td>
<td>Trimethyl hexanedioldisalicylate (25%)</td>
</tr>
<tr>
<td>Calcium oxide (5.6%)</td>
<td>Silicon dioxide (8.1%)</td>
<td>Bismuth carbonate basic (18.2%)</td>
</tr>
<tr>
<td>Zinc stearate (2.3%)</td>
<td>Hydrogenized colophony (31.5%)</td>
<td>Bismuth oxide (18.2%)</td>
</tr>
<tr>
<td>Tricalcium phosphate (4.1%)</td>
<td>Polydimethylsiloxane (2.5%)</td>
<td>Silicon dioxide (15%)</td>
</tr>
</tbody>
</table>

Table 8-8 -- Composition of Resin-Type Endodontic Sealers

<table>
<thead>
<tr>
<th>Powder</th>
<th>Resins</th>
<th>AH26</th>
<th>DIAKET</th>
<th>RIEBLER’S PASTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silver powder</td>
<td>10%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zinc oxide</td>
<td>98%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bismuth oxide</td>
<td>60%</td>
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</table>
Diaket is a polyketone compound containing vinyl polymers that forms an adhesive sealer when mixed with zinc oxide and bismuth phosphate. Small amounts of camphor and phenol interact negatively with the setting process and must be carefully removed before obturation. The material sets quickly in the root canal at body temperature but remains soft longer at room temperature. The volume stability is good and the solubility low.

Epiphany is a dual curable dental resin composite sealer composed of BisGMA, ethoxylated BisGMA, UDMA, and hydrophilic difunctional methacrylates with fillers of calcium hydroxide, barium sulfate, barium glass, and silica. The total filler content of the sealer is approximately 70% by weight. Biocompatibility has been demonstrated both in vitro and in vivo, resulting in approval by the U.S. Food and Drug Administration. Epiphany was designed for use with Resilon instead of gutta-percha. Unlike other resin sealers, this system’s sealer requires a self-etch primer before placement of the resin sealer.

EndoRez is a UDMA resin-based, root canal sealer with hydrophilic properties that allow good penetration into dentinal tubules. In addition to its biocompatibility, it offers good radiopacity. EndoRez is as radiopaque as gutta-percha, which simplifies radiographic interpretation.

Glass Ionomer Cement

Glass ionomer cements have been introduced as endodontic sealers (Ketac-Endo [ESPE]). Glass ionomer cements cause little tissue irritation and have low toxicity in vitro. Little biologic data are available on the use of glass ionomer as an endodontic sealer; therefore the safety and efficacy of these cements have not been established. Questions remain about the quality of the seal achieved with Ketac-Endo because dentin and sealer adhesive failures have been observed. In a recent article, some researchers expressed concern about its solubility compared with other type sealers.

Silicon-Based Sealer

RoekoSeal (Roeko, Langenau, Germany) is a polydimethylsiloxane-based root canal sealer. An in vitro study comparing it with eugenol-based Sealapex or calcium hydroxide - based Kerr’s Pulp Canal Sealer concluded that Roeko seal was less cytotoxic. It has adequate solubility properties. When its resistance to coronal and apical leakage was compared with that of AH26, no significant difference was seen.
both sealers, removal of the smear layer improved the coronal and apical seal. Roeko recently introduced another version of its silicone sealer, called GuttaFlow. It comes in a unidose capsule and is injected after mixing. The silicone is mixed with gutta-percha powder to form what the company calls a “two in one” cold filling system. Additional research is needed on this product.

Sealers Containing Formaldehyde

A large group of endodontic sealers and cements have substantial paraformaldehyde additives. Some of the more common brands are Endomethasone, Riebler’s paste (Amubarut; Wera Karl, Biesingen, Germany), and N2 (Indrag-Agsa, Bologna, Italy. Although these all are essentially the same with regard to toxicity, N2 has drawn the most focus when this phenomenon is discussed. N2 is also known as RC-2B or the Sargenti technique. Historically it has been heavily commercialized. It is difficult to understand how anyone can subscribe to the idea that treating the apical pulp wound with a strong tissue-coagulating toxic material may enhance healing. Furthermore, a dentist who unwisely chooses to use this type of sealer may be accused by an attorney of conscious and reckless disregard for the health, safety, and welfare of the patient. (Chapter 11 presents a fuller discussion of this issue.)

N2 is basically a zinc oxide–eugenol sealer. Its composition has varied extensively over the years. The significant amount of lead oxide[77][319] and smaller amount of organic mercury (Fig. 8–66) that formerly were major toxic components often are missing in recent formulas. However, N2 still contains unacceptable amounts of formaldehyde. It seals well in combination with a core.[40][113] Because it contains 6% to 8% paraformaldehyde (and sometimes hydrocortisone and prednisolone), it loses substantial volume when exposed to fluid.[115] It also absorbs more than 2% of fluid during the first week in situ.[130]

N2 is extremely toxic in experiments in vitro[286] and in animal experiments.[120][165][276][277][278][279][280][281] The tissue reaction normally observed is a coagulation necrosis within a very short time, reaching its maximum in less than 3 days. The coagulated tissue is altered to such an extent that it cannot undergo any repair for months because it is impregnated with formaldehyde. With time the formaldehyde may be washed out of the necrotic tissue[103][104] allowing either bacteria to be established in the necrosis or, if the blood supply is adequate, repair to take place.[478][477][476][279][280][281] In clinical applications this highly undesirable tissue reaction can be seen as localized inflammatory reactions in the periapical tissues and sometimes beyond.[105]

Standards and Properties

Physical Properties

ANSI standard no. 57 outlines various test methods for evaluation of the physical properties of endodontic sealer-filling materials. Sealers are classified into two categories, depending on the intended use: type I materials are intended to be used with core material; type II materials are intended for use with or without core material or sealer. Type I materials are divided into three classes. Class I includes materials in the form of powder and liquid that set through a nonpolymerizing process; class 2 includes materials in the form of two pastes that set through a nonpolymerizing process; class 3 includes polymer and resin systems that set through polymerization. The subclasses for type II materials are the same as for type I materials, except that metal amalgams are also included. ANSI no. 57 describes testing methods for working time, setting time, flow,
film thickness, solubility, and disintegration; it also establishes a specific requirement for radiodensity.[33] Despite these often detailed requirements, significant disagreement exists on the ideal properties of endodontic sealers and fillers. Therefore most of these expectations are guidelines that have not significantly affected the industry.

**Biologic Properties**

ANSI standard no. 41 recommends protocols for biologic evaluation of dental materials. This document outlines recommended test protocols for various dental materials, including certain guidelines for endodontic filling materials. These methods include general toxicity assessments (LD50), cytotoxicity assessments in vitro, sensitization assays, mutagenicity assays, implantation tests, and usage tests. Several test methods are presented for each of these factors, depending on the type of material.

Root canal filling materials generally are toxic, and none fulfills the expectations set forth in ANSI no. 41. However, the methods described in ANSI no. 41 can be used to distinguish more toxic materials from less toxic materials. Less toxic materials produce a less intense or shorter chemical insult to the remaining apical pulp or apical periodontium. If the wound area is free of bacteria when the initial chemical necrosis occurs, tissue repair should occur as the initial irritant declines in intensity. Some tissue irritation may occur as a result of phagocytosis of particles of the material, but an expanding lesion would not develop.[269]

Endodontic sealers other than those that contain paraformaldehyde should not be implicated as the cause of a periradicular bone lesion. However, if the tissue in the apical root area is not sterile, a chemically induced pulp or periapical necrosis may provide an environmental niche suitable for microbial expansion. Thus materials that cause extensive tissue necrosis (either inside the root canal or when extruded as an excess of filling material) are vehicles for the development of failure of endodontic treatment (Fig. 8–67). This supports the idea that treatment should focus on the proper application of asepsis and antisepsis and that materials that are as biocompatible as possible should be used.

**Figure 8-67** Diaket (D) (ESPE, Seefeld, Germany) implanted in the mandible of a guinea pig. The material has necrotized the surrounding bone, which contains sequestered bone and a severe accumulation of all types of inflammatory cells.

Gutta-percha has been extensively investigated as a root canal filling material in animals and has proved biocompatible. Compared with sealers used for root canal obturations, it clearly has the lowest tissue toxicity (Fig. 8–68). In implantation studies ranging up to 6 months’ duration, gutta-percha has been shown to heal in well, with minimal irritation.[3] Similar findings were reported with implantation in humans. After implantation gutta-percha normally is surrounded by a defined capsule rich in cells but without a significant number of inflammatory cells, although some macrophages are present (Fig. 8–69). Results from more
Sensitive assays in vitro support the in vivo results, suggesting that gutta-percha used for root canal fillings has a low toxicity. Gutta-percha in the form of small particles induces an intensive foreign body reaction, with massive accumulation of mononucleated and multinucleated macrophages. This is not surprising, however, because material normally considered inert (e.g., Teflon) causes similar reactions when presented to the tissues as an irregular surface or particles.

Figure 8-68 Gutta-percha implant in the mandible of a guinea pig 12 weeks after implantation. The implant (top) has healed in well, with a thin connective tissue interface (C) forming between the healed bone (B) and the implant (this tissue was lost during histologic preparation). Compare this result with the tissue reaction in Fig. 8–67.

Figure 8-69 Gutta-percha implant in subcutaneous connective tissue of a guinea pig 12 weeks after implantation. The material was
Sealers and cements are the very toxic component of gutta-percha root filling techniques. Therefore the clinician must take great care in selecting materials and must have an understanding of what each material contributes to a disease process. Zinc oxide–eugenol cements have a significant drawback in their release of free eugenol and loss of volume during the hydrolysis that takes place after setting. Several of the polymer materials have a high toxicity during the polymerization phase but may become practically inert when polymerized (Fig. 8–70). Sealers with inclusions of dissolvable components, such as calcium hydroxide, lose these components in the tissue, resulting in compromise of the integrity of the fill.

Figure 8-70  AH26 implant in the mandible of a guinea pig 12 weeks after implantation. Bone has grown up and integrated with the implant. Remnants of the implant, which was lost during histologic preparation, can be seen as a black area at the top of the image. Complete healing was observed without signs of inflammation.

* References [31][32][81][82][134][196][269][276][277][278][279][280] and [282].
DELIVERY SYSTEMS FOR ROOT CANAL FILLING MATERIALS

The search for a more simplified and proficient obturation technique has led to the development of many new hybrid materials. Differences focus on alternative systems for introducing the solid core material into the root canal system while maintaining length control. The newer methods currently in use vary considerably. Most hybrid obturation methods require modification of the outline of the root canal preparation. For optimal results the clinician must consider technique variations before attempting a hybrid obturation method.[323] A comparison of the more commonly practiced obturation methods using an objective and sensitive vacuum dye penetration method failed to show any major difference in the quality of the obturation (Fig. 8–71).[67] However, dye penetration techniques have come into question in recent years. Other evaluation methods, such as dye extraction and fluid filtration techniques, seem to produce more consistent and credible data.[48]

The introduction of new materials, techniques, and delivery systems is challenging basic beliefs and concepts previously thought to be almost sacred. For example, use of a single cone of gutta-percha with sealer historically has been considered unacceptable. However, with the introduction of new technology for cleaning and shaping and the development of innovative sealer delivery systems, a paradigm shift may be occurring toward improved canal preparation to receive more flowable sealers and single insertion of a core material. To validate the long-term success of any of the obturation techniques, clinical studies to support evidence-based best practice must be a goal of endodontic research.

Rigid Systems

ThermaFil Plus (Tulsa Dental Products; Densfil [Caulk/Dentsply]) is an obturation system in which the gutta-percha is preapplied to a carrier that resembles a finger spreader (Fig. 8–72). The gutta-percha obturator is
heated in a special heater (ThermaPrep Plus Oven [Tulsa Dental Products]) (Fig. 8–73) to the appropriate softness, and the obturation is done with the complete device (i.e., gutta-percha core). A sealer must be used for complete obturation. These devices are available with a plastic, stainless steel, or titanium core. If necessary, the plastic core material can be softened with chloroform or heated using a System B for easy removal. These obturators offer an alternative method for obturation with gutta-percha.

**Figure 8-72** ThermaFil obturators. (From Johnson WT: Color atlas of endodontics, St. Louis, 2002, Saunders.)

**Figure 8-73** ThermaPrep Plus heating oven for ThermaFil. (From Johnson WT: Color atlas of endodontics, St. Louis, 2002, Saunders.)

SimpliFill (LightSpeed Technologies) is an obturation system designed to be used with the LightSpeed instrumentation system. The technique is based on a sized plug of gutta-percha or Resilon, 5 mm long, attached to the end of a carrier. After sealer has been placed, the appropriate-size SimpliFill is placed to working length and the carrier is removed, leaving the apical segment obturated and the coronal segment open. Sealer is then injected with a syringe into the coronal segment, and a single cone (gutta-percha or Resilon) or post is inserted. In a study of coronal microbial leakage, an apical plug of SimpliFill in combination with FiberFill (Penton Clinical Technologies, Wallingford, CT) in the coronal segment of canals was found to have significantly less leakage than lateral, vertical, and Obtura II condensation techniques. An in vitro study of cross sections of obturated canals found SimpliFill, when used according to the manufacturer’s instructions, to be equivalent to warm vertical, mechanical lateral, and ThermaFil at 2 and 4 mm from the apex when the percentage of the canal obturated was calculated.

**Injection Techniques**

Several techniques have been described for introducing gutta-percha into the root canal system after the gutta-percha has been plasticized with heat. The Obtura II (Obtura Spartan, Fenton, MO) (Fig. 8–74) currently is the most commonly used injection delivery system for gutta-percha. It dispenses a heavy form of gutta-percha heated to a high temperature. Although the temperature of the gutta-percha in the Obtura II injection gun is as high as 302°F (150°C), the temperature of the extruded material may range from 140°F (60°C) to 280°F (138°C). Intracanal temperatures after delivery, measured with intracanal thermocouples, have ranged from 107.6°F to 192.2°F (42°C to 89°C). Periodontal injuries have been reported after endodontic treatment of teeth in the ferret and the dog. Shrinkage of gutta-percha in these injectable gutta-percha systems does not appear to be different from the shrinkage of normal gutta-percha. When plasticized by heat, gutta-percha has a volume loss of approximately 2% when cooling.
Rotary Techniques

Frictional heat also can be used to soften gutta-percha. This was first suggested with the introduction of the McSpadden compactor instrument. This technique has undergone many variations  and the development of several compaction instruments. The generated heat may exceed safe levels for other heat compaction techniques. One such device, called Quickfil (J.S. Dental), is commercially available. The ability to obturate root canals with this device and friction heating was found to be as good as lateral compaction. Volumetric changes in the gutta-percha after friction heat compaction are similar to other types of gutta-percha condensations using heat.
TEMPORARY CEMENTS

If endodontic therapy cannot be completed in one visit, the pulp space must be closed with temporary cement. This cement must provide a satisfactory seal to prevent bacteria and fluids in the oral cavity from contaminating the pulp space. The cement also must have enough structural strength to withstand the masticatory forces and retain the seal. The most common such cements are IRM (L.D. Caulk, Milford, DE), TERM (L.D. Caulk), and Cavit (ESPE). IRM is a reinforced zinc oxide cement available as a powder or liquid in single-dose mixing capsules. Cavit is a premixed material composed of zinc oxide, calcium sulfate, glycol and polyvinyl acetate, polyvinyl chloride, and triethanolamine. It sets on contact with water. TERM is a filled composite resin that is light activated. Of these, TERM and Cavit provide a better seal than IRM at any thickness of the restorations.[14][123][143] IRM has extensive marginal leakage of fluid, whereas Cavit seems to absorb fluid into the entire body of the restoration. These findings are surprising; however, because of its eugenol content, IRM may provide a bacterial barrier but allow leakage of other liquid substances (Figs. 8–75 and 8–76). Therefore if Cavit or other types of relatively soft temporary cements are used, they must be placed at a thickness of at least 4 to 5 mm. If a more robust temporary restoration is required for longer than 1 week, the soft cement must be covered with a harder cement, such as IRM, glass ionomer cement, or resin.

Figure 8-75  Temporary filling of IRM (white at I). The dye has penetrated the margins and dyed the content of the pulp chamber (P). The dentin (D) has been stained by the dye penetrating the margins.
The interval between sealing the canal system and placing the core buildup is possibly more important than the material used. In a Colleagues for Excellence newsletter, the American Association of Endodontists stated that “restoration … should commence as soon as possible after RCT.” Whenever possible, the bonded core buildup should be placed at the obturation appointment.
RETROGRADE ENDODONTIC TREATMENT

Root-End Preparation

Root-end preparation classically has been done with special miniature handpieces (Fig. 8-77) because of the restriction of available space in the periapical area. In recent years ultrasonic and sonic preparation of the root end has been used extensively. These types of preparation can be done more conservatively than with a bur and still extend deeper into the root canal system. They also require less angulated resection of the root apex. Because of their greater power, the piezoelectrical units have a clear advantage (this type of preparation requires power) (Figs. 8-78 and 8-79). A serious concern was raised with reports of a high incidence of apical cracks in the dentin in the resected area. This cracking was especially pronounced at higher power settings. However, other studies have been unable to find any connection between root-end cracks and ultrasonic preparation. This phenomenon requires further careful assessment, because initial crack lines may propagate more extensive fracture years later.

Figure 8-77  Miniature contra-angle handpiece for root end preparation.

Figure 8-78  Spartan piezoelectrical ultrasonic device with sterilizable handpiece (Obtura Spartan, Fenton, MO). Power and irrigation flow can be adjusted.
Root-End Filling Materials

The choice of root-end filling materials is the subject of some controversy among endodontic surgeons. The classic material in the past was silver amalgam, but based on what is known today, amalgam is no longer an acceptable material for a retroseal. All amalgams, with or without zinc, are unsuitable as retroseals (Figs. 8–80 and 8–81). In vitro, amalgams containing zinc are slightly more toxic than zinc-free amalgams (Table 8–9). Because more biocompatible materials were needed, other materials have been used, such as zinc oxide–eugenol cements (e.g., IRM, Super-EBA), glass ionomer cements, composite resins, and Cavit. The attempt to use Cavit as a retrograde obturation material was unsuccessful. Glass ionomer cements generally have been evaluated and compared with amalgam and gutta-percha with some success. Silver glass ionomer cement (i.e., Ketac-Silver) was evaluated and compared with zinc oxide–eugenol cements and amalgam and was found to be superior in both in vitro and in vivo applications. Mineral trioxide aggregate (MTA) is a root-end repair material that has gained strong acceptance. It is commercially available under the name ProRoot MTA (Dentsply/Tulsa Dental). The material has been suggested for a variety of endodontic procedures such as pulp capping, nonsurgical apical closure, perforation repair, and surgical root-end filling. Because of its high surface pH, it supports tissue repairs similar to those seen with calcium hydroxide. Unlike calcium hydroxide, however, MTA provides a hard-setting, nonresorbable surface with cavity adaptation comparable to Super-EBA. From the available literature, MTA appears to be an excellent material for root-end fillings and perforation repairs. However, the filling material chosen may be just one of several factors that determine treatment success or failure after root-end surgery.
Figure 8-80  Silver amalgam (Dispersalloy), implanted freshly prepared in the mandible of guinea pig, 12 weeks after implantation. Remnants of the amalgam (A), which were removed during histologic preparation, are black. Bone has healed and integrated with the amalgam without the formation of a layer of soft connective tissue.

Figure 8-81  Zinc-free amalgam freshly prepared and implanted in the mandible of a guinea pig, 12 weeks after implantation. Remnants of the amalgam, which were removed during histologic preparation, are black. Bone has healed and integrated with the amalgam without the formation of a layer of soft connective tissue.

Table 8-9  Toxicity of Two Amalgams Used for Root-End Filling

<table>
<thead>
<tr>
<th>Cell Material Contact Time</th>
<th>4 Hours</th>
<th>24 Hours</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>EXPERIMENT</td>
<td>CONTROL</td>
</tr>
<tr>
<td><strong>Kerr Zinc-Free Amalgam</strong></td>
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<tr>
<td><em>In vitro</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fresh</td>
<td>12.1 ± 0.9</td>
<td>7.7 ± 0.4</td>
</tr>
<tr>
<td>Set 1 day</td>
<td>7.7 ± 0.4</td>
<td>7.7 ± 0.4</td>
</tr>
<tr>
<td>Set 7 days</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td><strong>Implanted</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retrieved</td>
<td>9 ± 0.3</td>
<td>9.4 ± 0.5</td>
</tr>
<tr>
<td>Corroded</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Repolished</td>
<td>6.9 ± 0.6</td>
<td>7.5 ± 0.5</td>
</tr>
<tr>
<td>Dispersalloy</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>In vitro</td>
<td>Implantation</td>
</tr>
<tr>
<td>----------------</td>
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<td>-------------------</td>
</tr>
<tr>
<td></td>
<td>Fresh</td>
<td>Implanted</td>
</tr>
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<td>Retrieved</td>
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<td>37.1 ± 1</td>
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</tr>
<tr>
<td></td>
<td>6 ± 0.8</td>
<td>9.4 ± 0.5</td>
</tr>
<tr>
<td>Set 1 day</td>
<td>9.8 ± 0.2</td>
<td>49 ± 7.6</td>
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<tr>
<td></td>
<td>7.4 ± 0.1</td>
<td>44.8 ± 7</td>
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<tr>
<td>Set 7 days</td>
<td>7.4 ± 0.5</td>
<td>7.5 ± 0.5</td>
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<td>6.0 ± 0.8</td>
<td>31.5 ± 1.3</td>
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<tr>
<td></td>
<td>61.8 ± 3</td>
<td>25.7 ± 0.8</td>
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<td></td>
<td>28.9 ± 0.6</td>
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</tr>
<tr>
<td>Implanted</td>
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<tr>
<td></td>
<td></td>
<td>44.8 ± 7</td>
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<td></td>
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<td>26.7 ± 0.8</td>
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<tr>
<td></td>
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<td>Polished</td>
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<td>7.3 ± 0.4</td>
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</tr>
<tr>
<td></td>
<td>31.5 ± 1.3</td>
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</table>

* Cytotoxicity was measured as the release of radiochromium (M ± SD) from L929 cells in vitro. The amalgams were prepared and tested immediately, after 1 day, and after 1 week. Amalgam samples also were prepared and implanted subcutaneously in guinea pigs and left for 3 months; they then were retrieved and tested for cytotoxicity. The samples then were polished and once again tested for cytotoxicity. The zinc-free amalgam showed a slightly lower cytotoxicity than the amalgam containing zinc.
LASERS

Lasers are among the alternative methods used in endodontic treatment. Although this treatment modality is still in its infancy, various laser wavelengths have properties that may be useful when applied to access cavity preparation, cleaning and shaping of root canal systems, and three-dimensional obturation procedures. The use of lasers for endodontics is becoming more reasonable with the development of different wavelengths that remove or alter oral hard dental tissues (enamel, dentin) more predictably. The following is a brief review of the laser systems available today and their ability to affect the outcome of root canal treatment.

Dental lasers currently in use operate in several areas of the electromagnetic spectrum, including the infrared, visible, and ultraviolet ranges. Each laser wavelength in a particular range allows the device to target various tissues and carry out different procedures. For example, carbon dioxide (CO₂) energy is highly absorbed by tissues with a high water content. It therefore may be more effective in removing or altering soft tissue in the oral cavity (e.g., gingiva). Other wavelengths, such as neodimium:yttrium aluminum garnet (Nd:YAG), are absorbed by vascular tissues, such as the dental pulp.

An important part of root canal treatment is giving the root canal system a specific shape while debriding it of organic contents; that is, cleaning and shaping. Early attempts to carry out the cleaning and shaping function were less than successful. Although the Nd:YAG laser used a contact probe that simulated a hand instrument, the probe was composed of a fused silica (glass) and could not be precurved. It also could not be seen radiographically if it separated. In addition, the probe emitted energy at its end rather than through the sides. The result was a preparation that was neither fully clean nor shaped. Other lasers used noncontact probes that emitted the laser beams through a system of mirrors in an articulated arm (wave guide with CO₂); this was effective several millimeters away from the walls of the root canal system. Improvement in the use of these systems may lead to a device that accomplishes all the requirements of a well-cleaned and shaped system and aids in three-dimensional obturation.

The 1.06-µm wavelength Nd:YAG device has been studied extensively. More recent investigations have indicated that this laser is effective when used in infected root canal systems. Dogs’ teeth were infected and then treated at one or two watts (W) with 30 pulses per second (pps) for 1 or 2 seconds. The degree of inflammation radicular at 2, 4, and 8 weeks was significantly less than in the control groups. In a cohort of 38 patients, 44 teeth were treated using a step-back technique. Half the teeth were treated with the Nd:YAG laser (1W, 15 pps, 1 sec) using NaOCl and H₂O₂ irrigants. Tenderness to percussion was less at 1 week and 3 months in the laser-treated groups. When the same wavelength was used to remove debris and assess the amount of carbonization in vitro (light and scanning microscopy), complete debridement was not evident and carbonization was noted. However, the energy densities were very high. An in vivo study indicated that compared with conventional root canal treatment, the system may be effective in one-visit treatment modalities, because no differences were seen between the laser-treated and conventionally treated groups. Removal of filling materials and broken files with the Nd:YAG laser proved effective if temperatures were controlled. A recent study compared the removal of gutta-percha using two solvents with a Nd:YAG system that raised root surface temperatures 4°C. Laser energy alone was found to be effective, whereas solvents did not appreciably improve removal.

When India ink was used to absorb energy and cause an effect, an Nd:YAG laser was found to remove smear layer and reduce apical leakage in extracted, obturated human teeth. Other studies indicated the same results, showing that this laser wavelength was useful for reducing apical leakage in obturated root canal systems.

The permeability of root dentin is an important consideration in root canal treatment, and the laser has been suggested as a means of removing the smear layer and melting and solidifying the walls of the preparation. Comparison of the Nd:YAG device to an erbium:yttrium aluminum garnet (Er:YAG) laser (2.94-µm wavelength) showed that the former had lessened radicular dentin permeability with various irrigation regimens. A method of sterilizing root canal systems has been difficult if not impossible to accomplish. Laser energy may be used to accomplish this important treatment process. An in vitro study using extracted teeth that were inoculated with *Escherichia coli* and *E. faecalis* found that Nd:YAG, Ho:YAG, and Er:YAG...
Lasers eliminated 99% of the organisms without causing unfavorable temperature increases at the settings used in some but not all studies. Others have suggested that the use of a GaAlAs laser in combination with NaOCl/H₂O₂ irrigation may be effective at reducing colony-forming units of bacteria.

Temperature rise is an important consideration in the use of any laser energy. One study used 20 extracted human teeth and an Er:YAG laser at two irradiation intensities with water spray. A temperature increase of less than 6°C was recorded at the apical third and less than 4°C in the midportion of the root, suggesting that the thermal effect on periodontal tissues may be minimal.

Another study found the Er:YAG laser to be effective at reducing intracanal tubule fluid flow. Investigators reported that during root canal system enlargement with a cone-shaped irradiation tip, a preparation was produced that was cleaner than that prepared conventionally. A comparison of apical leakage with the laser and with conventional procedures found that the laser did not affect leakage. Other researchers found that a microprobe cleaned, shaped, and enlarged straight root canals more effectively.

Although no widespread agreement exists on the need to remove the smear layer in root canal preparations, the Er:YAG laser has proved effective at accomplishing this task. An Er:YAG laser was compared with a CO₂ laser for ability to remove the smear layer. A comparison also was made with NaOCl, H₂O₂, and EDTA irrigation regimens. The Er:YAG laser was found to be the most effective of these methods at removing smear layer. A study in modification of root canal dentin found that by varying the electromagnetic wavelength, Er:YAG energy induced different modifications to the root canal surface, which may have some utility in preparation procedures.

Bacterial debridement or sterilization also has been examined. One study found that treatment with an Er:YAG laser showed effective antimicrobial action against E. coli and Staphylococcus aureus. The results were significantly better than those achieved with NaOCl. Others have obtained the same results. More recently, lasers were found to be effective against Candida albicans and four other test organisms. However, 70% of specimens lased 3 mm short of the apex remained infected. When an erbium laser was compared with an alexandrite laser, both were found to be effective against dental bacteria, but the lasing effects were different.

A new laser system is now being marketed; the erbium chromium:YSGG system appears to be effective for agitating a water irrigant such that the liquid cleans and shapes. The effect is believed to be athermal in nature; this certainly would lessen the possibility of an adverse temperature increase that could damage root canal dentin and cause irreversible tissue damage to the periodontal ligament.

Laser energy may prove useful for treating diseases of the root canal system and periradicular regions. However, years of successful endodontic care have demonstrated the value of several already proven methods. The use of laser energy in endodontics must be approached cautiously and thoughtfully and must be grounded in reproducible studies.
SUMMARY

An explosion in knowledge and technology has created an exciting time in the specialty of endodontics. New instruments and materials seem to appear faster than clinicians can learn about the preceding versions. This has created an educational challenge for practitioners, universities, and manufacturers, requiring a greater degree of cooperation among these groups than ever before. Clinicians should use only those instruments and materials shown to be safe and effective in independent studies.
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Chapter 9 - Cleaning and Shaping of the Root Canal System

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FRAMEWORK FOR ROOT CANAL TREATMENT

Clinical endodontics encompasses a number of treatments, but perhaps the most important is treating pulps and root canal systems (with or without periradicular pathosis of pulpal origin) so that patients can retain their natural teeth in function and esthetics. The treatment of traumatic dental injuries and prophylactic treatment of vital pulps to maintain vitality are different from pulpectomies in which root canal instrumentation is required. However, endodontic therapy essentially is directed toward one specific set of aims: to cure or prevent periradicular periodontitis.[295]

Routine orthograde root canal treatment is a predictable and usually highly successful procedure both in relatively straightforward (Fig. 9-1) and more difficult cases (Figs. 9-2 and 9-3). In recent studies and reviews, favorable outcome rates of up to 95% were reported for the treatment of teeth diagnosed with irreversible pulpitis[22][62][90]; favorable outcome rates of up to 85% were reported for necrotic teeth.[61][91][200][207]
Figure 9-1 Effect of routine root canal treatment of a mandibular molar. A, Preoperative radiograph of tooth #19 shows radiolucent lesions adjacent to both mesial and distal root apices. B, Working length radiograph shows two separate root canals in the mesial root and two merging canals in the distal root. C, Posttreatment radiograph after shaping of root canal systems with nickel-titanium rotary files and obturation with thermoplasticized gutta-percha. D, Six-month recall radiograph after restoration of tooth #19 with an adhesively inserted full ceramic crown; some periradicular bone fill can be seen. E, One-year recall radiograph shows evidence of additional periradicular healing. F, Five-year recall radiograph; the tooth not only is periapically sound, but also clinically asymptomatic and fully functional.
Figure 9-2 Root canal treatment in a case of apical and interradicular pathosis. A, Preoperative radiograph of tooth #19 shows an interradicular lesion. B and C, Postoperative radiographs after root canal preparation and obturation. Note the lateral canal in the coronal third of the root canal. D and E, Two-month recall radiograph suggests rapid healing. (Courtesy Dr. H. Walsch.)
To date, many treatment modalities, including nickel-titanium (NiTi) rotary instruments, have not been shown to have a statistically relevant impact on treatment outcomes. This poses a real problem in the age of evidence-based therapy, because a new therapeutic technique should provide a better result than standard procedures in clinical tests. The small number of relevant prospective clinical studies is only partly offset by numerous in vitro experiments. This chapter includes pertinent information from such studies, as well as results from our own experiments, because rotary nickel-titanium instruments have become widely used adjuncts in root canal treatment.

**Pathophysiology of Endodontic Disease**

Many prospective and perioperative factors have been suggested as links to favorable treatment outcomes in endodontic therapy. Such factors include the patient’s age and gender, the position of the tooth in the arch, extension of the root canal filling, and the use of certain interappointment dressings, such as calcium hydroxide Ca(OH)$_2$. The presence of a periapical osseous lesion (i.e., “apical periodontitis”) appears to be a relevant prognostic factor that reduces the likelihood of a favorable outcome for root canal treatment; however, lesion size by itself is not an indication for endodontic surgery (see Chapter 20). Fig. 9–4 shows two cases in which large osseous lesions were treated by orthograde approaches; at recall appointments, the teeth were asymptomatic, and a reduction in lesion size was evident in both cases.
Some may question whether lesions such as the ones in Fig. 9 – 4 are in fact cysts. Several studies have demonstrated that lesion size shows little correlation with the incidence of radicular cysts; only histologic examination can prove whether a radiolucency is in fact a cyst. True cysts are believed to heal only after surgical enucleation, whereas the noncystic majority of apical processes heal predictably by orthograde endodontic treatment without surgery. An orthograde approach, therefore, appears to be beneficial in clinically asymptomatic cases and should include recall appointments at appropriate intervals (see Chapter 24).

If clinical symptoms persist or begin after endodontic therapy, surgery may be performed in addition to orthograde root canal treatment. In the case shown in Fig. 9 – 5, a large lesion that extended into the maxillary sinus and nasal cavity was treated surgically 1 week after orthograde therapy of teeth #7 and #8, which included removal of two instrument fragments. The lesion was completely enucleated during surgery, and a tissue biopsy specimen was submitted for histologic processing; the lesion was diagnosed as a radicular cyst. As expected in this case, the patient reported discomfort after surgery. This supports the preference for a nonsurgical approach whenever possible.
When root canal therapy is part of a comprehensive treatment plan, a favorable outcome for the root canal portion is a prime requirement. Extended bridgework and removable dentures depend on healthy periradicular tissues, just as they depend on healthy marginal and apical periodontal tissues. Fig. 9-6 presents a case in which a removable denture seemed unavoidable at the first examination. After extractions and root canal therapy were performed, small-unit, fixed partial dentures were placed. These reconstructions remain fully functional and allow this patient to benefit from the natural dentition.

Figure 9-5 Possibilities and limitations of orthograde endodontic therapy. In this case, a large lesion in the right maxilla was enucleated and histologically diagnosed as a radicular cyst. A, Preoperative occlusal plane radiograph shows a large periradicular lesion in the right maxilla, as well as two separated instruments in tooth #7 (arrow). B, Postoperative periapical radiograph of tooth #7 and necrotic tooth #8, which were obturated after calcium hydroxide dressings had been placed for two weeks. Obturation was done with laterally compacted gutta-percha and Roth’s 801 sealer. C, Two lentulo spiral fragments removed from tooth #7 (ruler gradation is 0.5 mm). D, Histologic slide shows both respiratory epithelium (arrow) and squamous epithelial lining and inflammatory cells, supporting the diagnosis. (C courtesy Dr. I. Hegyi.)
In summary, orthograde root canal treatment has a high degree of predictability both in normal and complex cases. Some limitations exist, but the potential for a favorable outcome is significant. As indicated previously, the shaping and cleaning performed as part of root canal treatment are directed against microbial challenges to the root canal system. Microbes can breach dental hard-tissue barriers through several avenues, the most common being dental caries (Fig. 9-7).
Dental Anatomy

Pulpal reactions may be observed as soon as the diffusion barrier (the remaining dentin thickness) is sufficiently permeable for bacteria or their toxins to affect the pulp [39] (Fig. 9–7). Under experimental conditions, pulp inflammation can be detected only a few hours after topical application of bacterial components to exposed dentin [28]. In an established lesion, a bacterial ecosystem evolves, with synergisms and antagonisms among the microorganisms (see Chapter 15). These interactions play an important role in the course of the disease, when intraradicular biofilms develop and bacteria invade dentinal tubules [159]. Two key factors initiate and modify inflammatory reactions, such as the development of microabscesses in subodontoblastic regions: the penetration of bacterial components and the release and diffusion of inflammatory mediators.

The stereotypic pulpal defense reaction is hard-tissue deposition (Figs. 9–7 and 9–8) by primary and secondary odontoblasts [65]. Hard tissue is laid down as a response to a stimulus (reactionary or reparative dentinogenesis) and thus takes place within a defined spatial relationship to that stimulus, occurring slightly apical to the lesion.

Figure 9-7 Progression of pulpal disease and the development of periradicular pathosis. A carious lesion leads to contact of toxins and microbes with the coronal pulp, resulting in inflammation and infection. The stereotypic defense reaction of dental pulp then occurs: hard-tissue deposition. This reaction may lead to repair or to additional hard-tissue deposition (e.g., as calcific metamorphosis). The next step may be formation of microabscesses, changes in circulation during inflammation, and ultimately progression of infection into the radicular pulp space. Finally, periradicular osseous lesions may develop if the bacterial challenge persists. (Courtesy Dr. H.-U. Luder and T. Häusler.)
Hard-tissue deposition is a natural event with aging (secondary dentinogenesis), which creates a higher degree of treatment difficulty in older patients. Clinicians note a radiographically detectable decrease in the size of the pulp space that occurs most often in the coronal regions but also can be seen in the more apical areas. This condition is not a contraindication to orthograde endodontic therapy; however, it requires additional attention to clinical procedures such as preenlargement and prebending of hand files (discussed later in the chapter).

The process of calcific metamorphosis is a response to traumatic injury. It is characterized by a reduction in the size of both the radicular and coronal pulp spaces. Conversely, teeth with signs of hard-tissue deposition caused by bacterial attack show an initial reduction of pulp space size coronally, which may involve the pulp chamber and canal orifices (Fig. 9-7). This situation calls for meticulous preparation of an access cavity and preenlargement of canal orifices in a nondestructive manner. Depending on the timing of inoculation and the number of microbes, hard-tissue deposition also may occur more apically.

Reparative dentin may form a diffusion barrier sufficient for the pulp to recover, depending on the severity of the bacterial challenge and the capability of the defense mechanisms. Unfortunately, no consensus exists on the best therapy to allow this recovery to occur.

Further into the disease progress, and if the carious lesion persists, bacteria may be present in sufficient concentrations to induce pulpal inflammation. This is triggered by molecular signals (e.g., cytokines), which are released from cells such as macrophages and neutrophils well before microbes are actually present intrapulpally (see Chapter 13). At this stage, with a diagnosis of reversible pulpitis, endodontic treatment may be avoidable, provided the source of the irritants is removed.

To deliver adequate endodontic therapy, the clinician must understand that apical periodontitis is the endpoint of a disease flow that in most cases originates coronally, either with carious lesions or a traumatized pulp (Fig. 9-7). As stated previously, opportunistic bacteria may invade dental hard tissue, and their byproducts eventually may reach the pulp space (see Chapter 15). Host response factors, such as the recruitment of neutrophil granulocytes and local development of neurogenic inflammation, act against microbial invasion, but this line of defense may succumb to the challenge if the carious defect is not repaired. Then, after microabscesses form, circulation changes occur; coronal and subsequently radicular pulp may become nonperfused and thus necrotic.

At various points in this process, bacterial factors such as lipopolysaccharides and peptidoglycans can reach periapical tissues through apical and accessory foramina. Zones of bone resorption (appearing as radiolucencies) may develop, depending on the balance between microbial virulence factors and host defenses. The development of apical periodontitis is associated with a significantly less encouraging prognosis after orthograde endodontic treatment.

One school of thought emphasizes the importance to successful endodontic therapy of cleaning and filling lateral and accessory canals. Clinical radiographs of artfully done cases support this position; the contribution of accessory canals to lesion development in certain cases seems highly likely.

Figure 9-8 Evidence of coronal hard-tissue deposition. A, Periapical radiograph of tooth #19 shows evidence of reduced coronal and radicular pulp space. B, Intraoral photograph, taken through an operating microscope (×25), of access cavity of the tooth shown in A; note the calcific metamorphosis.
However, this pathogenesis depends on the volume of accessory canals and the amount of bacteria harbored in them. Another subject of controversy is the clinical importance and mechanisms of dentinal tubule infection with bacteria and fungi (Fig. 9–9).

In most cases lesions are associated with the main root canal systems (Figs. 9–1 and 9–3, 9–4, 9–5) and form peripherally around the main foramina. The main canal unquestionably has the highest bacterial load, and important studies link reduction of the viable intracanal bacterial load to favorable outcomes for endodontic therapy. Therefore a primary aim of all endodontic procedures, and most notably of cleaning and shaping, is to remove canal contents, specifically infective microorganisms.

**Clinical Objectives**

A wide spectrum of possible strategies exists for attaining the goal of removing the canal contents and eliminating infection. Lussi et al. introduced a minimally invasive approach to removing canal contents and accomplishing disinfection that did not involve the use of a file (the noninstrumentation technique [NIT]). This system consisted of a pump, a hose, and a special valve that was cemented into the access cavity (Fig. 9–9).
to provide oscillation of irrigation solutions (1% to 3% sodium hypochlorite [NaOCl]) at a reduced pressure. Although several in vitro studies demonstrated that canals can be cleaned and subsequently filled using this system (Fig. 9-10, B and C), preliminary clinical results have not been as convincing (Fig. 9-10, D).

At the opposite end of the spectrum is a treatment technique that essentially removes all intraradicular infection through extraction of the tooth in question (Fig. 9-10, C). Almost invariably, periradicular lesions heal after extraction of the involved tooth.

Clinical endodontic therapy takes place somewhere along this spectrum of treatment strategies. This is reflected in some of the controversies that surround the cleaning and shaping process, such as how large the apical preparation should be and what are the correct diameter, length, and taper.

The foundation of the endodontic treatment plan is an adequate diagnostic process (see Chapter 1), which...
includes obtaining diagnostic radiographs from various angles. Also, the restorability and periodontal status of teeth to be treated endodontically must be determined; in some cases buildups or crown lengthening is required for preendodontic restoration to allow proper isolation, to create pulp chambers that retain irrigants, and to facilitate interappointment temporary restorations. In many cases the existing restoration may have to be removed so that an adequate diagnosis can be made and the immediate cause of endodontic treatment can be assessed.

Once the decision has been made to initiate endodontic treatment, the clinician must integrate his or her knowledge of dental anatomy, immunology, and bioengineering science with clinical information. The intent of this chapter is to assist clinicians with that task and to provide a much-condensed background in radicular anatomy, pulpal pathophysiology, and nickel-titanium metallurgy.

Endodontic therapy has been compared to a chain, and it has rightfully been pointed out that the chain is only as strong as each individual link. For the purposes of this chapter, shaping and cleaning of the root canal system is considered a decisive link, because shaping determines the efficacy of subsequent procedures. It includes mechanical debridement, the creation of space for the delivery of medicaments, and optimized canal geometries for adequate obturation. These tasks are attempted within a complex anatomic framework, as recognized in the early twentieth century by Walter Hess (Fig. 9–11) (see Chapter 7).

Unfortunately, canal preparation results are adversely affected by the highly variable root canal anatomy. This fact is especially true for conventional hand instruments and to a lesser degree for most nickel-titanium rotary instruments. Therefore the radicular anatomy is briefly reviewed as it pertains to cleaning and shaping.

Root canal curvature can be assessed clinically from radiographs, preferably taken from various angles. However, it is well documented that curves in the mesiodistal plane often are greater than those in the more readily accessible buccopalatal plane. In vitro a full account of three-dimensional canal anatomy can be seen with interactive micro-computed tomographic (µCT) reconstructions (Figs. 9–12 and 9–13).

Figure 9-11 Panel of 36 anatomic preparations of maxillary molars from the classic work by Professor Walter Hess of Zurich. Note the overall variability of root canal systems and the decrease of canal dimensions with age. (From Hess W: The anatomy of the root canals of teeth of the permanent dentition, London, 1925, John Bale, Sons & Danielsson.)
The clinician must understand the five commonly encountered canal paths (i.e., canals that merge, curve, recurve, dilacerate, or divide). All five situations are risk factors for file breakage and should be carefully evaluated, as is done for more basic considerations such as the estimated canal length, position of the primary curve, canal diameter, and apical topography.

Early anatomic studies evaluated the position and topography of the apical foramina and the position of the apical constriction. These studies found that the physiologic foramen, or canal terminus, was located up to 1 mm coronal to the anatomic apex, or root tip. This observation has been confirmed by later studies.

Clinically, the landmark detected from radiographs (the radiographic apex) does not necessarily coincide with the anatomic apex because of projection artifacts. Taken together, these observations suggest that shaping to the radiographic apex is likely to produce overinstrumentation past the apical foramen, with possible clinical sequelae of postoperative pain and inoculation of microorganisms into periapical spaces.

Figure 9-12 Micro-computed tomographic scans of dental anatomy (36 µm resolution). A, Clinical view of tooth #9 shows two accessory canals and an apical bifurcation. B, Mesiodistal view of the tooth shown in A. C, Working length radiograph with files placed in both apical canal aspects.

Figure 9-13 Micro-computed tomographic scans of more complicated dental anatomy (36 µm resolution). A, Clinical view of tooth #3 shows a fine mesiobuccal and distobuccal canal system with additional anatomy in all three roots. B, Mesiodistal view of the tooth shown in A.
Foramen diameter was also an issue in both early\textsuperscript{[109]}\textsuperscript{[148]} and more recent studies.\textsuperscript{[41]}\textsuperscript{[81]}\textsuperscript{[176]}\textsuperscript{[273]} The smallest canal diameter, called the \textit{apical constriction}, was located 0.5 to 0.7 mm coronal to the canal terminus.\textsuperscript{[109]}\textsuperscript{[148]}

A wide range of diameters has been reported in that region, from 0.2 to about 1 mm\textsuperscript{[41]}\textsuperscript{[141]}\textsuperscript{[142]}\textsuperscript{[143]}\textsuperscript{[148]}\textsuperscript{[176]}; the concept of a single apical constriction has also been challenged.\textsuperscript{[81]} Moreover, studies have shown that clinicians usually underestimate apical dimensions.\textsuperscript{[315]} Clearly, the apical anatomy presents the clinician with major challenges (Fig. 9–14), such as apically dividing canals, nonround cross sections, and deltalike configurations. In addition, canal cross sections that are wide buccolingually\textsuperscript{[314]} are difficult to instrument with rotary techniques.

\textbf{Figure 9-14} Micro-computed tomographic scan of anatomy of the apical 5 mm of a mesiobuccal root (8 µm resolution). \textbf{A} and \textbf{B}, Three-dimensional reconstruction of outer contour and root canal systems. \textbf{C}, Cross sections 0.5 mm apart.

The clinician must choose the strategies, instruments, and devices to deal with these challenges and to control the preparation shape, length, and width precisely. This allows the practitioner to use endodontic therapy to address acute (Fig. 9–15) and chronic (Fig. 9–16) forms of the disease processes described previously. Recall radiographs taken at appropriate intervals will demonstrate longevity and favorable outcomes (see Figs. 9–1, 9–2, 9–3, 9–4, 9–6, and 9–16) if clinical objectives are maintained (Box 9–1).
Figure 9-15  Sinus tract as a sign of a chronic apical abscess and effect of routine root canal treatment. A, Intraoral photograph of left maxillary region with draining sinus tract (arrow) periapical to tooth #14. B, Preoperative radiograph with gutta-percha point positioned in the sinus tract, pointing toward the distobuccal root of #14. C, Finished root canal fillings after 2 weeks of calcium hydroxide dressing. D, Intraoral photograph of the same region as in A, showing that the sinus tract had closed by the time obturation was performed.
Figure 9-16  Relationship of radicular anatomy and endodontic disease as shown by filled accessory canals. A, Working length radiograph of tooth #13 shows lesions mesially and distally but not apically. B, Posttreatment radiograph shows the accessory anatomy. C, Six-month recall radiograph before placement of the restoration. D, Two-year recall radiograph after resection of the mesiobuccal root of tooth #14 and placement of a fixed partial denture. Excess sealer appears to have been resorbed, forming a distal residual lesion. E, Four-year recall radiograph shows almost complete bone fill. F, Seven-year recall radiograph; tooth #14 is radiologically sound and clinically within normal limits.

Box 9-1

Basic Objectives in Cleaning and Shaping

The primary objectives in cleaning and shaping the root canal system are to:

- Remove infected soft and hard tissue
- Give disinfecting irrigants access to the apical canal space
- Create space for the delivery of medicaments and subsequent obturation
- Retain the integrity of radicular structures
CLEANING AND SHAPING: TECHNICAL ISSUES

Because several technical issues arise with the instruments and devices used for cleaning and shaping, a short review of these products is provided here (also see Chapter 8). A vast array of instruments, both hand-held and engine-driven, is available for root canal preparation. Up to the last decade of the past century, endodontic instruments were manufactured from stainless steel. With the advent of nickel-titanium, instrument designs began to vary in terms of taper, length of cutting blades, and tip design. Files traditionally have been produced according to empiric designs, and most instruments still are devised by individual clinicians rather than developed through an evidence-based approach. Similar to the development of composite resins in restorative dentistry, the development of new files is a fast and market-driven process. With new versions rapidly becoming available, the clinician may find it difficult to pick the file and technique most suitable for an individual case. Practitioners must always bear in mind that all file systems have benefits and weaknesses. Ultimately, clinical experience, handling properties, usage safety, and case outcomes, rather than marketing or the inventor’s name, should decide the fate of a particular design.

Hand and Engine-Driven Instruments

Hand instruments have been in clinical use for almost 100 years, and they still are an integral part of cleaning and shaping procedures. A norm established by the American Dental Association (ADA) and the International Standards Organization (ISO) sets the standards for broaches, K-type files and reamers, Hedström files, and paste carriers; however, the term ISO-normed instruments currently is used mainly for K-files (Fig. 9–17). One important feature of these instruments is a defined increase in diameter of 0.05 mm or 0.1 mm, depending on the instrument size (Fig. 9–18).

Figure 9-17 Schematic drawing of an ISO-normed hand instrument size #35. Instrument tip sizing, taper, and handle colors are regulated by the ISO/ANSI/ADA norm.
**Broaches**

Barbed broaches are produced in a variety of sizes and color codes. They are manufactured by cutting sharp, coronally angulated barbs into metal wire blanks. Broaches are intended to remove vital pulp from root canals, and in cases of mild inflammation, they work well for severing pulp at the constriction level in toto. The use of broaches has declined since the advent of NiTi rotary shaping instruments, but broaching occasionally may be useful for expediting procedures and for removing materials (e.g., cotton pellets) from canals.

**K-Files**

K-files were manufactured by twisting square or triangular metal blanks along their long axis, producing partly horizontal cutting blades (Fig. 9–19). Noncutting tips, also called Batt tips, are created by grinding and smoothing the apical end of the instrument (see Fig. 9–19). Roane and Powell[223] introduced a modified shape, the Flex-R file, which was manufactured fully by grinding so that the transitional angles were smoothed laterally between the tip and the instrument’s working parts. Similar techniques are required to manufacture NiTi K-files[281] such as the NiTi-Flex (Dentsply Maillefer, Ballaigues, Switzerland). NiTi K-files are extremely flexible and are especially useful for apical enlargement in severe apical curves. They can be precurved but only with strong overbending; this subjects the file to excess strain and should be done carefully. Because of their flexibility, the smaller NiTi files (sizes up to #25) are of limited use.

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**Figure 9-18** Increase in tip diameter in absolute figures and in relation to the smaller file size. Note the particularly large increase from size #10 to size #15.
Cross-sectional analysis of a K-file reveals why this design allows careful application of clockwise and counterclockwise rotational and translational working strokes. ISO-normed K- and Hedström files are available in different lengths (21, 25, and 31 mm), but all have a 16 mm long section of cutting flutes. The cross-sectional diameter at the first rake angle of any file is labeled $D_0$. The point 1 mm coronal to $D_0$ is $D_1$, the point 2 mm coronal to $D_0$ is $D_2$, and so on up to $D_{16}$. The $D_{16}$ point is the largest diameter of an ISO-normed instrument. Each file derives its numeric name from the diameter at $D_0$ and is assigned a specific color code (see Fig. 9-17).

Another aspect of ISO files is the standard taper of 0.32 mm over 16 mm of cutting blades, or 0.02 mm increase in diameter per millimeter of length (#.02 taper) (see Fig. 9-17). Thus a size #10 instrument has a diameter of 0.1 mm at $D_0$ and a corresponding diameter of 0.42 mm at $D_{16}$ [$0.1 \text{ mm} + (16 \times 0.02 \text{ mm})$]. For a size #50 instrument, the diameters are 0.5 mm at $D_0$ and 0.82 mm at $D_{16}$.

The tip size increases by 0.05 mm for file sizes #10 to #60; for sizes #60 to #140, the absolute increase is 0.1 mm (see Fig. 9-18). Recalculation of these diameter increments into relative steps (in percentages) reveals dramatic differences: the step from size #10 to #15 is 50%, whereas the increase from size #55 to #60 is less than one fifth of that change (Fig. 9-18).

In very small files (sizes #6 to #10), the problem is partly resolved by several key points: (1) apical dimensions are such that a size #6 file does not significantly remove dentin other than in severely calcified cases; (2) a size #8 file taken 0.5 to 1 mm long, to establish patency (discussed later in the chapter), contacts the desired endpoint of the preparation with a diameter approaching the tip size of a #10 file; (3) similarly, placing a size #10 file just minutely through the foramen eases the way for passive insertion of the subsequent #15 file to full...
The ISO specifications inadvertently complicated the cleaning and shaping of root canal systems. The ISO-normed design is a simplification that has specific disadvantages, and it may explain the clinical observation that enlarging from size #10 to #15 is more difficult than the step from size #55 to #60. The introduction of the Golden Medium files (Dentsply Maillefer), which have tip sizes between the ISO-stipulated diameters, seemed to solve the problem. However, their use is not that important clinically, because the approved machining tolerance of ± 0.02 mm negates the intended advantage. Moreover, although ± 0.02 mm tolerance is stipulated by the ISO norm (see Fig. 9–17), many manufacturers do not adhere to it.

A subsequent modification involved tips with a constant percentage of diameter increments, the Series 29. The first ProFile instruments (Dentsply – Tulsa, Tulsa, OK) followed this design with a nominal diameter increase of 29%. This sizing pattern creates smaller instruments that carry less of a workload. However, the intended advantage is offset by larger diameters, because the 29% increase between successive files is actually greater than the percentage change found in the ISO file series.

Hedström Files

Hedström files are milled from round, stainless steel blanks. They are very efficient for translational strokes, but rotational working movements are strongly discouraged because of the possibility of fracture. Hedström files up to size #25 can be efficiently used to relocate canal orifices and, with adequate filing strokes, to remove overhangs. Similarly, wide oval canals can be instrumented with Hedström files as well as with rotary instruments. On the other hand, overzealous filing can lead to considerable thinning of the radicular wall and strip perforations (Fig. 9–20). As with stainless steel K-files, Hedström files should be single-use instruments.

Gates-Glidden Drills

Gates-Glidden (GG) drills are important instruments that have been used for more than 100 years without noteworthy design changes. These instruments, especially the nickel-titanium FlexoGates model (Dentsply Maillefer), usually work well for preenlargement of coronal canal areas. However, when misused, GG drills can dramatically reduce radicular wall thickness. GG instruments are manufactured in a set and numbered 1 to 6 (with corresponding diameters of 0.5 to 1.5 mm); the number of rings on the shank identifies the specific drill size. GG instruments are available in various lengths and made by several manufacturers. Each instrument has a long, thin shaft with parallel walls and a short cutting head. Because of their design and physical properties, GG drills are side-cutting instruments with safety tips; they can be used to cut dentin as they are withdrawn from the canal (i.e., on the outstroke). Used this way, their cutting action can deliberately be directed away from external root concavities in single-rooted and furcated teeth. GG instruments should be used only in the straight portions of the canal, and they should be used serially and passively.

Two procedural sequences have been proposed: with the step-down technique, the clinician starts with a large drill and progresses to smaller ones; conversely, with the step-back technique, the clinician starts with a small drill and progresses to larger ones. With the step-down approach, the clinician must select a GG
instrument with a diameter that allows introduction into the respective orifice and progression for about 1 mm. The subsequent smaller instruments progress deeper into the canal until the coronal third has been preenlarged. This technique efficiently opens root canal orifices and works best when canals exit the access cavity without severe angulations. Opened orifices simplify subsequent cleaning and shaping procedures and help to establish a smooth glide path from the access cavity into the root canal system.

With the step-back approach, a small GG instrument is introduced into the canal and dentin is removed on the outstroke. This process is repeated with the next larger GG instrument, which is again worked shorter than the preceding smaller one. In this way, the coronal third of the root canal is enlarged and dentin overhangs are removed.

As stated earlier, when used adequately GG instruments are inexpensive, safe, and clinically beneficial tools. High revolutions per minute (rpm), excessive pressure, an incorrect angle of insertion, and the use of GG instruments to aggressively drill into canals have resulted in mishaps, such as strip perforation. Also, GG instruments may fracture when used in curved canal areas because of cyclic fatigue, and the short cutting heads may fracture with high torsional loads. Gates-Glidden drills may be used safely and to their fullest potential at 750 to 1500 rpm. As with nickel-titanium rotary instruments, GG drills work best when used in electric gear reduction handpieces rather than with air motors.

**Nickel-Titanium Rotary Instruments**

Since the early 1990s, several instrument systems manufactured from nickel-titanium have been introduced into endodontic practice. The specific design characteristics vary, such as tip sizing, taper, cross section, helix angle, and pitch (Fig. 9–21). Some of the early systems have been removed from the market or play only minor roles; others, such as LightSpeed (LightSpeed Technologies, San Antonio, TX) and ProFile (Dentsply – Tulsa, Dentsply Maillefer), are still widely used. New designs continually are produced, but the extent to which, if any, clinical outcomes will depend on design characteristics is difficult to forecast.
Most of the instruments described in this section are manufactured by a grinding process, although some are produced by laser etching. Precision at the surface quality is not really at a high level, whereas the tolerances are. Surface quality also is an important detail (see Fig. 9–21), because cracks that arise from superficial defects play a role in instrument fracture. Superficial defects such as metal flash and rollover are common in unused NiTi instruments. Attempts have been made to improve surface quality by electropolishing the surface and by coating it with titanium nitride. The latter process also seems to have a beneficial effect on cutting efficiency.

In essence, two properties of the NiTi alloy are of particular interest in endodontics: superelasticity (Fig. 9–22) and high resistance to cyclic fatigue (discussed later). These two properties allow continuously rotating instruments to be used successfully in curved root canals. Many variables and physical properties influence the clinical performance of NiTi rotaries.
Much of what is known about NiTi instruments, including reasons for instrument fracture and instrument sequences, has been gleaned from clinical practice. In vitro research continues to clarify the relationship between NiTi metallurgy and instrument performance, but already NiTi rotary instruments have become an important adjunct in endodontics.

NiTi rotary instruments have substantially reduced the incidence of several clinical problems, such as blocks, ledges, transportation, and perforation. However, they also have a tendency to fracture more easily than hand instruments. The clinical problems cited above do not by themselves predispose a case to posttreatment disease; rather, they limit the access of disinfecting irrigants to the root canal system, preventing sufficient elimination of microorganisms.

The following sections describe the instruments most widely used in the United States and Europe for root canal preparation. Most basic strategies apply to all NiTi rotary instruments, regardless of the specific design or brand. However, three design groups need to be analyzed separately: group I, the LightSpeed; group II, rotary instruments with #.04 and #.06 tapers, which includes the ProFile and many other models; and group III, rotary instruments with specific design changes, such as the ProTaper (Dentsply Maillefer) and RaCe (FKG, La Chaux-de-Fonds, Switzerland).

**LightSpeed Instruments**

The LightSpeed file, developed by Dr. Steve Senia and Dr. William Wildey in the early 1990s, was introduced as an instrument different from all others because of its long, thin, noncutting shaft (Fig. 9–23) and 0.25 to 2 mm anterior cutting part. A full set consists of 25 instruments in sizes #20 to #100, including half sizes (e.g., 22.5, 27.5).
The recommended working speed for LightSpeed instruments is 1500 to 2000 rpm, and they should be used with minimal torque.\textsuperscript{[249]}

The cross sections of the LightSpeed’s cutting part show three round excavations, the U-shape design common to many earlier NiTi instruments (Figs. 9–23 and 9–24). Because of the relatively thin noncutting shaft, LightSpeed instruments are considerably more flexible than any other instrument on the market. In addition, cyclic fatigue is lower than with all other instruments, allowing the use of higher rpm speeds. All LightSpeed instruments feature a noncutting round tip; tip length increases with instrument size to compensate for decreasing flexibility.
The LightSpeed’s predecessor, the Canal Master-U, had the same general design but was used as a hand instrument. LightSpeed’s manufacturer still recommends some hand use of its instruments, specifically for determining canal diameter. In general, the LightSpeed system requires a specific instrument sequence to produce a tapered shape that facilitates obturation with a gutta-percha cone or with LightSpeed’s proprietary obturation system.

The LightSpeed is a widely researched NiTi rotary instrument, and most reports have found that the system has a low incidence of canal transportation and preparation errors. Loss of working length was minimal in most of these studies.

* References [99][202][205][212][252][253][282][283] and [283].

**ProFile**

The ProFile system was introduced by Dr. Ben Johnson in 1994. In contrast to the LightSpeed, with its thin, flexible shaft, the ProFile has an increased taper compared with conventional hand instruments. The ProFile first was sold as a series of 29 hand instruments in #.02 taper, but it soon became available in #.04 and #.06 conicity (see Fig. 9-24). The tips of the ProFile Series 29 rotary instruments (Dentsply – Tulsa) had a constant proportion of diameter increments (29%). Because of the nonstandardized diameters, obturation was performed with nonstandardized gutta-percha cones, using either lateral compaction or thermoplastic obturation of gutta-percha (see Chapter 10). Later, another ProFile series (Dentsply Maillefer) was developed and marketed in Europe. This version featured tip sizes similar to those of ISO-normed instruments. This set

![Figure 9-24](http://home.mdconsult.com.eproxy1.lib.hku.hk/das/book/body/0/1357/6...)
was believed to better accommodate standardized gutta-percha cones, which are predominantly used in Europe. Subsequently, instruments with even greater tapers and 19 mm lengths were introduced, and recently a #.02 variant was added (see Fig. 9-24).

Cross sections of a ProFile instrument show a U-shape design with radial lands and a parallel central core. Lateral views show a 20-degree helix angle, a constant pitch, and bullet-shaped, noncutting tips. Together with a neutral or slightly negative rake angle, this configuration ensures a reaming or scraping action on dentin rather than cutting. Also, debris is transported coronally and is effectively removed from the root canals.

The recommended rotational speed for ProFile instruments is 150 to 300 rpm, and to ensure a constant rpm level, the preferred means is electrical motors with gear reduction rather than air-driven motors.

ProFile instruments shaped canals without major preparation errors in a number of in vitro investigations. A slight improvement in canal shape was noted when size #.04 and #.06 tapered instruments were used in an alternating fashion. Loss of working length did not exceed 0.5 mm and was not affected by the use of size #.06 instruments.

* References 14, 15, 16, 20, 205, 284 and 285.

GT Files

The Greater Taper file, or GT file (Fig. 9-25), was introduced by Dr. Buchanan in 1994. This instrument also incorporates the U-file design. The GT system was first produced as a set of four hand-operated files and later as engine-driven files. The instruments came in four tapers (#.06, #.08, #.10, and #.12), and the maximum diameter of the working part was 1 mm. This decreased the length of the cutting flutes and increased the taper. The instruments had a variable pitch and an increasing number of flutes in progression to the tip; the apical instrument diameter was 0.2 mm. Instrument tips were noncutting and rounded.
The GT set subsequently was modified to accommodate a wider range of apical sizes. The current set includes instruments of three apical diameters: 0.2, 0.3, and 0.4 mm (Fig. 9–25). The tapers also were modified and now are available in #.04, #.06, #.08 and #.10. In addition, accessory files with a #.12 taper are available in sizes #35, #50, #70, and #90. The maximum diameter in these files is 1.5 mm, similar to that of a #6 GG. The recommended rotational speed for GT files is 350 rpm, and the instrument should be used with minimal apical force to avoid fracture of the tip.

Studies on GT files found that the prepared shape stayed centered and was achieved with few procedural errors. μCT comparisons showed that GT files machined statistically similar canal wall areas compared with ProFile and LightSpeed preparations. These walls were homogeneously machined and smooth.

HERO 642

First-generation rotary systems had neutral or slightly negative rake angles. Second-generation systems were designed with positive rake angles, which gave them greater cutting efficiency. HERO instruments (MicroMega, Besançon, France) are an example of a second-generation system.

Cross sections of a HERO instrument show geometries similar to those of an H-file without radial lands (Fig. 9–26). Tapers of #.02, #.04, and #.06 are available in sizes ranging from #20 to #45. The instruments are relatively flexible (the acronym HERO stands for high elasticity in rotation) but maintain an even distribution of force into the cutting areas. HERO instruments have a progressive flute pitch and a noncutting, passive tip, similar to other NiTi rotary systems. The instruments are coded by handle color.

Table 9-25

<table>
<thead>
<tr>
<th>No. of instruments/set</th>
<th>Tip sizes</th>
<th>Size increments</th>
<th>r.p.m. (recommended)</th>
<th>Lengths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size 20 GT rotary files: 4</td>
<td>20</td>
<td>None, tapers of .04 to .10</td>
<td>150 to 350, minimal axial force, low torque to fracture but higher working torque</td>
<td>18, 21, 25 mm</td>
</tr>
<tr>
<td>Size 30 GT rotary files: 4</td>
<td>30</td>
<td>None, tapers of .04 to .10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size 40 GT rotary files: 4</td>
<td>40</td>
<td>None, tapers of .04 to .10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GT accessory files: 4</td>
<td>35, 50, 70, 90</td>
<td>Varies, taper .12</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Research with HERO files indicates a shaping potential similar to that of the FlexMaster (Dentsply VDW, Munich) and the ProFile, although in one study the HERO induced more changes in cross-sectional anatomy. HERO instruments also were found to cause some aberrations when used in simulated canals with acute curves but were safer than Quantec SC instruments (Analytic Endodontics, Orange, CA).

ProTaper

The ProTaper system is based on a unique concept and comprises just six instruments, three shaping files and three finishing files. These instruments were designed by Dr. Cliff Ruddle, Dr. John West, and Dr. Pierre Machtou. The cross section of the ProTaper shows a modified K-type file with sharp cutting edges and no radial lands (Fig. 9-27); this creates a stable core and sufficient flexibility for the smaller files. The cross section of finishing file F3 is slightly relieved for increased flexibility. The unique design factor is the varying tapers along the instruments’ long axes. The three shaping files have tapers that increase coronally, and the reverse pattern is seen in the three finishing files.

<table>
<thead>
<tr>
<th>No. of instruments/set</th>
<th>Tip sizes</th>
<th>Size increments</th>
<th>r.p.m. (recommended)</th>
<th>Lengths</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>20, 25, 30 with .02, .04, and .06 taper; 35 to 45 with .02 taper</td>
<td>5</td>
<td>300-600, with minimal axial force</td>
<td>21, 25 mm</td>
</tr>
</tbody>
</table>

Shaping files #1 and #2 have tip diameters of 0.185 mm and 0.2 mm, respectively, 14 mm long cutting blades, and partially active tips. The diameters of these files at D14 are 1.2 and 1.1 mm, respectively. The finishing files (F1, F2, and F3) have tip diameters of 0.2, 0.25, and 0.3 mm, respectively, between D0 and D3, and the tapers are 0.07, 0.08, and 0.09, respectively. The finishing files have noncutting tips.

The convex triangular cross section of ProTaper instruments reduces the contact areas between the file and the dentin. The greater cutting efficiency inherent in this design has been safely improved by balancing the pitch and helix angle, preventing the instruments from inadvertently screwing into the canal. The instruments are coded by colored rings on the handles. ProTaper instruments can be used in gear reduction electrical handpieces at 300 rpm in accordance with universally recognized guidelines.

In a study using plastic blocks, the ProTaper created acceptable shapes quicker than GT rotary, ProFile, and Quantec instruments but also created somewhat more aberrations. In a comparison of ProTaper and K3 instruments (SybronEndo, Glendora, CA), Bergmans et al. found few differences, with the exception of some transportation by the ProTaper into the furcation region. A study using μCT showed that the ProTaper created consistent shapes in constricted canals without obvious preparation errors, although wide canals may be insufficiently prepared with this system.

K3

In a sequence of constant development by their inventor, Dr. McSpadden, the Quantec 2000 files were followed by the Quantec SC, the Quantec LX, and the current K3 system (all by SybronEndo). The overall design of the K3 is similar to that of the ProFile and the HERO in that it includes size #.02, #.04, and #.06 instruments. The most obvious difference between the Quantec and K3 models is the K3’s unique cross-sectional design (Fig. 9–28): a slightly positive rake angle for greater cutting efficiency, wide radial lands, and a peripheral blade relief for reduced friction. Unlike the Quantec, a two-flute file, the K3 features a third radial land to help prevent screwing in.
In the lateral aspect the K3 has a variable pitch and variable core diameter, which provide apical strength. This complicated design is relatively difficult to manufacture, resulting in some metal flash (see Fig. 9–28).

Like most other instruments the K3 features a round safety tip, but the file is about 4 mm shorter than other files (although it has the same length of cutting flutes) because of the Axxess handle. The instruments are coded by ring color and number.

Research with the K3 is limited because of its recent introduction, but thus far its shaping ability seems to be similar to that of the ProTaper[30] and superior to that achieved with hand instruments.[238]

**FlexMaster**

The FlexMaster file system currently is not available in the United States. It also features #.02, #.04, and #.06 tapers. The cross sections (Fig. 9–29) have a triangular shape with sharp cutting edges and no radial lands. This makes for a relatively solid instrument core and excellent cutting ability. The overall manufacturing quality is high, with minimal metal flash and rollover.

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**Table: Design specifications**

<table>
<thead>
<tr>
<th>No. of instruments/set</th>
<th>Tip sizes</th>
<th>Size increments</th>
<th>r.p.m. (recommended)</th>
<th>Lengths</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>15-45 with .02 taper; 15-60 with .04 and .06 taper</td>
<td>5</td>
<td>300 to 350, minimal axial force</td>
<td>21, 25, 30 mm</td>
</tr>
</tbody>
</table>

**Figure 9-28** Design features of a K3 instrument. A, Lateral view. (SEM, ×50.) B, Cross section. (SEM, ×200.) C, Lateral view. D, Design specifications.
FlexMaster files have round, passive tips; the tip diameters are 0.15 to 0.7 mm for size #.02 instruments and 0.15 to 0.4 mm for size #.04 and #.06 files (see Fig. 9-29). In addition to the standard set, the Intro file, which has a #.11 taper and a 9 mm cutting part, is available. The instruments are marked with milled rings on the instrument shaft; the manufacturer provides a system box that indicates sequences for narrow, medium-size, and wide canals.

Recent studies indicate that the FlexMaster allows centered preparations in both constricted and wider canals and that it performed on par with other systems. Clinical studies confirmed that the FlexMaster showed superior shaping characteristics compared with K-files. Novice dental students were able to shape plastic blocks successfully with the FlexMaster after a short training period.

RaCe

The RaCe was manufactured since 1999 by FKG and was later distributed in the United States by Brasseler (Savannah, GA). The name, which stands for reamer with alternating cutting edges, describes just one design feature of this instrument (Fig. 9-30). Light microscopic imaging of the file shows twisted areas (a feature of conventional files) alternating with straight areas; this design reduces the tendency to screw into the root canal. Cross sections are triangular or square for #.02 instruments with size #15 and #20 tips. The lengths of cutting parts vary from 9 to 16 mm (see Fig. 9-30).
The surface quality of the RaCe has been improved by electropolishing, and the two largest files (size #35, #.08 taper and size #40, #.10 taper) are also available in stainless steel. The tips are round and noncutting, and the instruments are marked by color-coded handles and milled rings.

Only recently have the results of in vitro experiments comparing RaCe to other contemporary rotary systems become available. Canals in plastic blocks and in extracted teeth were prepared by the RaCe with less transportation from the original curvature than occurred with the ProTaper. The preceding descriptions covered only a limited selection, the most popular and widely used rotary instruments on the market. New files, such as the Sequence by Real World Endo (distributed by Brasseler but manufactured by FKG), are continually added to the armamentarium, and older systems are updated. Thus it is next to impossible to keep track of file designs.

To summarize, most systems include files with tapers greater than the #.02 stipulated by the ISO norm. The LightSpeed is different from all other systems, the ProTaper and RaCe have some unique features, and most other systems have increased tapers. Minor differences exist in tip designs, cross sections, and manufacturing processes, but the clinical effects of these modifications currently are unknown. Even in vitro, tests have only begun to identify the effect of specific designs on shaping capabilities and clinical outcomes. Equally little is known about the physical parameters governing rotary root canal preparation. However, these factors are crucial, because NiTi rotary files have an increased risk of fracture compared with K-files. In a study using plastic blocks, as many as 52 ProFile Series 29 instruments became permanently deformed. Three fractures were reported in a subsequent study on ISO-norm ProFile size #.04 instruments, and three other instruments were distorted. An even higher fracture incidence was shown in a study on rotary instruments used in plastic blocks in a specially designed testing machine. These findings were confirmed...
by two studies in which high fracture incidences were reported for LightSpeed and Quantec rotary instruments used in a clinical setting. Consequently, a benefit versus risk analysis must be done for all rotary NiTi instruments, addressing the reasons and the clinical consequences of instrument fracture.

### Physical and Chemical Properties of NiTi Alloys

During the development of the equiatomic nitinol alloy (55% [by weight] nickel and 45% [by weight] titanium), a shape memory effect was noted; this was attributed to specific thermodynamic properties of the new alloy. The alloy sparked interest in dental research because of its “shape recovery” property after passage through critical temperatures. Some researchers envisioned the manufacture of nondulling rotary instruments from an alloy called 60-nitinol. However, nickel-titanium wire was found to be difficult to bend into clamp retainers.

Subsequently, researchers thought that the superelastic properties of 55-nitinol might prove advantageous in endodontics, and the first hand instruments produced from 55-nitinol were tested (Fig. 9–31). That study found that size #15 NiTi instruments were two to three times more flexible than stainless steel instruments. Nickel-titanium instruments showed superior resistance to angular deflection; they fractured after 2½ full revolutions (900 degrees) compared with 540 degrees for stainless steel instruments (Fig. 9–31, C).

![Stress-strain behavior of nickel-titanium alloy](image)

**Figure 9-31** Stress-strain behavior of nickel-titanium alloy. A, Schematic diagram of linear extension of a NiTi wire. B, Torque to failure test of a size #60, #.04 taper ProFile NiTi instrument. Note the biphasic deformation, indicated by arrows in A and B. C, Comparison of stainless steel and nickel-titanium crystal lattices under load. Hookian elasticity accounts for the elastic behavior (E) of steel, whereas transformation from martensite to austenite and back occurs during the superelastic (SE) behavior of NiTi alloy.
Furthermore, hardly any plastic deformation of cutting flutes was recorded when an instrument was bent up to 90 degrees, and forces required to bend endodontic files to 45 degrees were reduced by 50% with nickel-titanium. In the latter study, the authors speculated that heat, probably during sterilization cycles, could even restore the molecular structure of used NiTi files, resulting in an increased resistance to fracture.

Specific properties of nickel-titanium can be explained by specific crystal structures of the austenite and martensite phases of the alloy. Heating the metal above 212°F (100°C) may lead to a phase transition, and the shape memory property forces the instrument back to a preexisting form. Likewise, linear deforming forces are shunted into a stepwise transition from an austenitic to a martensitic lattice, and this transition, and the shape memory property forces the instrument back to a preexisting form. Likewise, linear deforming forces are shunted into a stepwise transition from an austenitic to a martensitic lattice, and this behavior leads to a recoverable elastic response of up to 7% (Fig. 9 - 31, A).

However, graphs such as those shown in Fig. 9 - 31, B, are generated when larger NiTi instruments are subjected to angular deflection until failure. Such graphs show different results for stainless steel instruments, which produce a relatively steep stress-strain curve with less than 1.3% recoverable deformation. As stated previously, the superelastic behavior of nickel-titanium also dictates the production of NiTi instruments, which must be milled or ground (stainless steel blanks can simply be twisted to produce K-files or reamers). Consequently, NiTi instruments may have characteristic imperfections such as milling marks, metal flashes, or rollover. Some researchers even speculate that fractures in nickel-titanium instruments originate at such surface imperfections. Other studies have suggested that chloride corrosion may lead to micropitting and subsequent fracture in NiTi instruments. However, only immersion in disinfecting solution for extended periods (e.g., overnight) produced corrosion of NiTi instruments and subsequent decreased torsional resistance. Regular cleaning and sterilization procedures do not seem to affect NiTi rotary instruments.

In one study, only limited material loss occurred when NiTi LightSpeed instruments were immersed in 1% and 5% NaOCl for 30 to 60 minutes. Corrosion of NiTi instruments used in the clinical setting, therefore, might not significantly contribute to fracture except when the instruments are immersed in heated NaOCl for longer than 60 minutes.

In general, instruments used in rotary motion break in two distinct modes, torsional and flexural. Torsional fracture occurs when an instrument tip is locked in a canal while the shank continues to rotate, thereby exerting enough torque to fracture the tip. This also may occur when instrument rotation is sufficiently slowed in relation to the cross-sectional diameter. In contrast, flexural fracture occurs when the cyclic load leads to metal fatigue. This problem precludes the manufacture of continuously rotating stainless steel endodontic instruments, because steel develops fatal fatigue after only a few cycles. NiTi instruments can withstand several hundred flexural cycles before they fracture.

Repeated loading and cyclic fatigue tests for endodontic instruments are not described in pertinent norms. Initially, rotary instruments such as Gates-Glidden burs and Peeso reamers were tested with a superimposed bending deflection. In Gates-Glidden burs, a 2 mm deflection of the instrument tip resulted in fatigue life spans ranging from 21,000 revolutions (size #1 burs) to 400 revolutions (size #6 burs). In another study, stainless steel and nickel-titanium hand files were rotated to failure in steel tubes with an acute 90-degree bend and an unspecified radius. Under these conditions, size #40 stainless steel instruments fracture after fewer than 20 rotations, whereas various nickel-titanium files of the same size withstand up to 450 rotations.

Cyclic fatigue was also evaluated for ProFile size #.06 instruments using a similar device. The number of rotations to failure for unused control instruments ranged from 1260 (size #15 files) to 900 (size #40 files). These scores did not change when the instruments were tested under simulated clinical conditions, such as repeated sterilization and contact with 2.5% sodium hypochlorite. Subsequently, control instruments were compared with a group of instruments used in the clinical setting in five molar cases; again, no significant differences were found in resistance to cyclic fatigue.

Haikel et al. used a different testing method involving tempered metal cylinders with radii of 5 mm and 10 mm that produced a 90-degree curve. They reported fatigue fractures for size #15, #.04 taper ProFile instruments after about 2800 cycles with the 10 mm cylinders; in size #40, #.04 taper ProFile instruments, fractures occurred after about 500 cycles with the 5 mm cylinders. In comparison, size #15, #.06 taper ProFile instruments failed also after about 2800 revolutions with the 10 mm cylinders, but failure occurred in size #40.
.06 taper ProFile specimens after only 223 cycles with the 5 mm cylinders.

Rotary nickel-titanium instruments with larger tapers and sizes consistently fractured after fewer rotations, and although the radius of the curves was halved, fatigue-life was reduced by 400%. Haikel et al.\(^{116}\) reported similar results for selected HERO instruments, and their findings were confirmed by other tests on GT rotary instruments. Size #20, .06 taper GT files failed after 530 rotations in a 90-degree curve with a 5 mm radius; size #20, .12 taper GT files failed after 56 rotations under the same conditions.\(^{202}\)

Norms, specifications, tolerances, and other physical parameters have been described for stainless steel hand instruments such as K-files and Hedström files.\(^ {131}\) However, no comparable norms exist for instruments used in continuous rotary motion. Consequently, a number of models have been devised to assess specific properties of nickel-titanium rotary instruments, including torque at failure, resistance against cyclic fatigue, and others (Fig. 9–32). These systems can assess simultaneously torque at failure, working torque axial force, and cyclic fatigue (Fig. 9–33).

**Figure 9-32** Testing platform for analysis of various factors during simulated canal preparation with rotary endodontic instruments. Labeled components are a force transducer (A), a torque sensor (B), a direct-drive motor (C), and an automated feed device (D). For specific tests, a cyclic fatigue phantom or a brass mount compliant with ISO no. 3630–1 (inserts) may be attached.

**Figure 9-33** Physical factors (torque, axial force, and insertion depth) that affect root canal instrumentation documented with a torque-testing platform. A, ProFile size #45, .04 taper used in a mildly curved canal of a single-rooted tooth, step-back after apical...
According to the norms mentioned previously, torque at failure is recorded with the apical 3 mm of the instrument firmly held in the testing device while the instrument’s handle is rotated. A wide variety of rotary nickel-titanium endodontic instruments have been tested in this way. For example, ProFile NiTi rotary files in ISO sizes #25, #30, and #35 (#.04 taper) fractured at 0.78, 1.06, and 1.47 Ncm, respectively.\[275\]

Svec and Powers\[276\] reported similar scores when instruments were forced to fracture in plastic blocks with simulated curved canals. In a different setup, GT rotary instruments (size #20, #.06 taper to size #20, #.12 taper) fractured at 0.51 and 1.2 Ncm, respectively.\[202\] The results of other studies describing torque at failure loads are in general agreement with these findings.\[*\]

Compared with NiTi instruments with tapered flutes, LightSpeed instruments had lower torques to fracture (0.23 to 2 Ncm\[171\]).

When analyzing clinical factors involved in instrument fracture, one must consider both torsional load and cyclic fatigue\[231\] (Fig. 9–34 ). However, these are not separate entities, especially in curved canals\[38\]; working an instrument with high torque may lower resistance to cyclic fatigue.\[34\] Conversely, cyclic prestressing has been shown to reduce the torsional resistance of ProTaper finishing files.\[299\] Also, cyclic fatigue occurs not only in the lateral aspect, when an instrument rotates in a curved canal, but also axially, when an instrument is bound and released by canal irregularities.\[33\]

The torque generated during canal preparation depends on a variety of factors, and an important one is the contact area.\[36\] The size of the surface area contacted by an endodontic instrument is influenced by the instrumentation sequence or by the use of instruments with different tapers.\[244\] A crown-down approach is recommended to reduce torsional loads (and thus the risk of fracture) by preventing a large portion of the tapered rotating instrument from engaging root dentin (known as taper lock).\[36\]\[328\]

The clinician can further modify torque by varying axial pressure, because these two factors are related\[244\] (see Fig. 9–33 ). In fact, a light touch is recommended for all current NiTi instruments to avoid forcing the instrument into taper lock. The same effect might occur in certain anatomic situations, such as when canals...
merge, dilacerate, and divide.

The torsional behavior of nickel-titanium rotary endodontic instruments cannot be described properly without advanced measurement systems and a new set of norms. However, the clinician must be able to interpret correctly the stress-strain curves for all rotary nickel-titanium instruments used in the clinical setting to be able to choose an appropriate working torque and axial force.

* References [37][144][224][131][122][322] and [323].

**Motors and Devices**

Newer motors have been developed for rotary instruments since the simple electric motors of the first generation in the early 1990s (Fig. 9–35, A). Electric motors with gear reduction are more suitable for rotary NiTi systems because they ensure a constant rpm level; however, they also deliver torques much higher than those required to break tips. Some authors believe that torque-controlled motors (Fig. 9–35, B to D), which have been used for several years, increase operational safety. However, others have suggested that torque-control motors may be helpful mainly to inexperienced clinicians. These motors probably do not reduce the risk of fracture caused by cyclic fatigue; also, even if the torque is below the fracture load at D3, a fracture at the smaller diameter (D2) is still possible.


To complicate matters further, an obvious differential exists between torque at failure at D3 and the working torque needed to operate an instrument effectively (Fig. 9–36 and Box 9–2). In many cases the working torque is greater than the torque required to fracture the instrument’s tip. However, the tip will not break if a passive glide path has been verified.
**Box 9-2**

**Instrument Breakage with Torsional Load (MacSpadden Factor)**

For rotary instrument tips, susceptibility to breakage is governed by the quotient of torque needed to fracture divided by working torque. Simply put, the larger the value, the safer the file.

This differential is especially large with files with a taper greater than .06; therefore, these files are rather ineffective in most torque-controlled motors. Most motors allow adjustment of torque for the instrument used, either with a key or a system card that is inserted into the box.

Other factors that may influence the incidence of fracture in motor-driven NiTi rotary instruments are lubrication, specific instrument motion, and speed of rotation. It cannot be overemphasized that nickel-titanium rotary instruments should be used only in canals that have been flooded with irrigant. Although lubricants such as RC-Prep (Premier, Norristown, PA) and Glyde (Dentsply Maillefer) have also been recommended, their benefit has not been proved conclusively.\(^{201}\) In fact, because of chemical interactions between NaOCl and ethylenediamine tetra-acetic acid (EDTA), alternating irrigants and using lubricants that contain EDTA may even be counterproductive. Moreover, no data have been produced linking the use of lubricants to reduction of torque during root canal preparation.

For instrument motion, most manufacturers recommend a pecking, up and down motion. This not only prevents screwing in of the file, it also distributes stresses away from the instrument’s point of maximum flexure, where fatigue failure would likely occur.\(^{199}\)\(^{202}\) Oscillating movements did not significantly enhance the life span of ProFile size .04 or GT rotary instruments rotated around a 5 mm radius cylinder with a 90-degree curve.\(^{199}\)\(^{202}\) Furthermore, large variations were noted in the lengths of the fractured segments,\(^{125}\)\(^{299}\) which suggests that ductile fractures may originate at points of surface imperfections.

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* References [36][37][125][131][199][201][203][224] and [231].

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**Figure 9-36** Diagram comparing fracture loads at D3 (upper section of graph) to torques occurring during preparation of root canals (lower section of graph). Filled columns represent the largest file in each set, and open columns show the scores of the most fragile file (see text and Box 9–3 for details).\(^{123}\)

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K-Files 15-45, Iso 3630-1 (1992)
GT 20/.06/.12, Peters (2001)
Profile 20/.04 60/.04, Peters (2002)
Quantec, Sattapan (2000)
GT 20/.06/.12, Peters (2001)
Profile 20/.04-35/.06, Blum (1999)
Profile 20/.04-60/.04, Peters (2002)
ProTaper S1-F3, Peters (2003)
ProTaper SX-F3, Blum (2003)
Rotational speed may also influence instrument deformation and fracture. Some studies indicated that ProFile instruments with ISO-norm tip diameters failed more often at higher rotational speed\[^{12,19}\] whereas other studies did not find speed to be a factor.\[^{76,137}\]

Clinicians must fully understand the factors that control the forces exerted on continuously rotating NiTi instruments (Box 9–3). To minimize the risk of fracture and prevent taper lock, they should not try to force motor-driven rotary instruments in an apical direction. Similarly, acute apical curves limit the use of instruments with higher tapers because of the risk of cyclic fatigue. The incidence of instrument fracture can be reduced to an absolute minimum if clinicians use data from well-designed torque and stress studies. Adequate procedural strategies, a detailed knowledge of anatomic structures, and specific instrumentation sequences may also improve shaping results.

**Box 9-3**

<table>
<thead>
<tr>
<th>Factors Governing the Potential for Nickel-Titanium Rotary Instrument Fractures</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Clinician’s handling (most important)</td>
</tr>
<tr>
<td>• Combination of torsional load, bending, and axial fatigue</td>
</tr>
<tr>
<td>• Root canal anatomy</td>
</tr>
<tr>
<td>• Manufacturing quality</td>
</tr>
</tbody>
</table>

Specific procedures have been developed for removing fractured instruments from root canals (Fig. 9–37); these are discussed in detail elsewhere in this book (see Chapter 25). Most of those methods require the use of additional equipment, such as a dental operating microscope and ultrasonic units. However, the best way to deal with instrument fracture is prevention. An understanding of the anatomy of the root canal system, together with a clear plan for selecting, sequencing, and using shaping instruments, can certainly help prevent procedural mishaps.
Disinfectants, Dentin Surface Modifiers, and Lubricants

Studies have demonstrated conclusively that mechanical instrumentation cannot sufficiently disinfect root canals, regardless of whether stainless steel or nickel-titanium instruments are used (Fig. 9–38). Irrigation solutions are required to eradicate microorganisms, and over time a variety of chemicals have been promoted for this purpose. The ideal irrigant or combination of irrigants kills bacteria, dissolves necrotic tissue, lubricates the canal, removes the smear layer, and does not irritate healthy tissues. Some formaldehyde-containing materials are no longer recommended for clinical use, but many irrigating solutions and varying concentrations of commonly used materials are described in the literature. Some solutions used in the past were sterile saline, NaOCl, and detergents (e.g., quaternary ammonium compounds, chlorhexidine, citric acids, and EDTA). This section describes current materials and gives some recommendations for their clinical use.

Figure 9-37 Removal of a separated NiTi instrument from a mesiolingual canal of a mandibular molar. A, Fragment located in the middle third of the root. B, Clinical aspect of the fragment after enlargement of the coronal third of the root canal with modified Gates-Glidden drills, visualized with an operating microscope. (×25.) C, Radiograph taken after removal of the fragment; four hand files have been inserted into the canals. D, Final radiograph shows slight widening of the coronal third of the mesiolingual canal and fully sealed canal systems. A full crown was placed immediately after obturation. E, Recall radiograph 5 years after obturation shows sound periradicular tissues. F, Removed fragment and separated file (gradation of ruler is 0.5 mm).
Sodium Hypochlorite

A 0.5% solution of sodium hypochlorite was used effectively during World War I to clean contaminated wounds. Also, NaOCl at varying concentrations has been in use in root canal therapy for many decades. NaOCl is effective against endodontic microorganisms (Table 9-1), including those difficult to eradicate from root canals, such as Enterococcus, Actinomyces, and Candida organisms.

Table 9-1 -- Activity of Various Irrigants against Microorganisms

<table>
<thead>
<tr>
<th>Microorganism</th>
<th>NAOCL</th>
<th>CHX</th>
<th>IKI</th>
<th>MTAD</th>
<th>CA(OH)₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enterococci</td>
<td>3 min at 0.0005% solution in filter paper specimens</td>
<td>24 hours of iodine (2%) exposure in potassium iodide (4%) resulted in complete killing in dentin blocks up to a depth of 700 µm</td>
<td>5 min application resulted in no growth on infected dentin</td>
<td>24 hours to reduce cultured bacteria below detection limit, but activity was inhibited by dentin powder, hydroxyapatite, and serum albumin</td>
<td>7 days to render canals bacteria free but showed little effect on Enterococcus faecalis</td>
</tr>
<tr>
<td></td>
<td>15 min at 0.25% solution in contaminated dentin blocks</td>
<td>7 days of 0.5% dressing resulted in complete killing in dentin blocks up to full depth of 950 µm</td>
<td>1 hour to reduce bacteria under</td>
<td>MTAD was</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30 min at 0.5%</td>
<td>24 hours to reduce</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

Figure 9-38 Remaining potentially infected tissue in fins and isthmus configuration after preparation with rotary instruments. A, Cross section through a mesial root of a mandibular molar, middle to coronal third of the root. Both canals have been shaped; the left one is transported mesially. (× 10.) B, Magnified view of rectangle in A. Note the presence of soft tissue in the isthmus area. (× 63.) (Courtesy Professor H. Messer.)
In root canal treatment, NaOCl solutions are used at concentrations ranging from 0.5% to 5.25%. In infected dentin blocks, a 0.25% solution of NaOCl was sufficient to kill Enterococcus faecalis in 15 minutes; a concentration of 1% NaOCl required 1 hour to kill Candida albicans.[247]

NaOCl dissolves organic material, such as pulp tissue and collagen. Lower concentrations (e.g., 0.5% or 1%) dissolve mainly necrotic tissue.[332] Higher concentrations allow better tissue dissolution but dissolve both necrotic and vital tissue, which is not always a desirable effect. In some cases, full-strength NaOCl (5.25%) may be indicated; however, although higher concentrations may increase antibacterial effects in vitro,[329] enhanced clinical effectiveness has not been demonstrated conclusively for concentrations stronger than 1%.

Commercially available household bleach contains 5.25% NaOCl, has an alkaline pH of 12 to 13, and is hypertonic.[271][332] Some authors recommend dilution of commercially available NaOCl with 1% bicarbonate instead of water to adjust the pH to a lower level.[24][271] Others do not see any reduction of the aggressiveness on fresh tissue by buffering NaOCl and recommend diluting solutions of NaOCl with water to obtain less concentrated irrigation solutions.[332]

NaOCl only minimally removes dentin or smear layer (Fig. 9–39); therefore, some recommend concurrent use of demineralizing agents to enhance cleaning of difficult-to-reach areas, such as dentinal tubules and lateral canals.[50][185]
Chlorhexidine (CHX) is a broad-spectrum antimicrobial agent effective against gram-negative and gram-positive bacteria (see Table 9–1). It has a cationic molecular component that attaches to negatively charged cell membrane areas, causing cell lysis. CHX has been used in periodontal therapy for many years. Its use as an endodontic irrigant is based on its substantivity and long-lasting antimicrobial effect, which arises from binding to hydroxyapatite. However, it has not been shown to have clinical advantages over NaOCl. Some researchers found that CHX had significantly better antibacterial effects than calcium hydroxide Ca(OH)2 when tested on cultures. Effective combinations of CHX and Ca(OH)2 are available and show strong antimicrobial activity against obligate anaerobes, the combination augmenting the antibacterial effect of either medicament on certain species. The addition of CHX or iodine potassium iodide to an intracanal dressing of Ca(OH)2 in vitro did not affect the alkalinity (and hence the efficacy) of the calcium hydroxide suspensions.

**Iodine Potassium Iodide**

Iodine potassium iodide (IKI) is a traditional root canal disinfectant. IKI kills a wide spectrum of microorganisms found in root canals (see Table 9–1) but shows relatively low toxicity in experiments using tissue cultures. Iodine acts as an oxidizing agent by reacting with free sulfhydryl groups of bacterial enzymes, cleaving disulfide bonds. *E. faecalis* often is associated with therapy-resistant periapical infections (see Chapter 15), and combinations of IKI and CHX may be able to kill calcium hydroxide – resistant bacteria more efficiently. A recent study by Sirén et al evaluated the antibacterial activity of a combination of calcium hydroxide with IKI or CHX in infected bovine dentin blocks. Although calcium hydroxide alone was unable to destroy *E. faecalis* inside dentinal tubules, calcium hydroxide mixed with either IKI or CHX effectively disinfected dentin. An obvious disadvantage of iodine is a possible allergic reaction in some patients.
MTAD

New chemicals for irrigating root canals are constantly developed, including solutions based on antibiotics. Use of these irrigants is controversial, however, because of the emergence of increasingly resistant strains of bacteria (e.g., therapy-resistant enterococci), which may be due to overprescription of antibiotics in general. The increased risk of host sensitization by local antibiotics can be circumvented to some degree by using the antibiotic as a dressing. Because exposure to vital tissues is limited, higher microbicidal concentrations may be used.[177] A number of antibiotics, including erythromycin, chloramphenicol, tetracycline, and vancomycin, have been tested successfully against enterococci. In one study, investigators evaluated microbial susceptibility to different antibiotics in vitro; they found that enterococcal isolates were resistant to benzylpenicillin, ampicillin, clindamycin, metronidazole, and tetracycline but sensitive to erythromycin and vancomycin.[23] MTAD (Dentsply - Tulsa), a recently introduced irrigation solution, contains doxycycline, citric acid, and a surface-active detergent (Tween 80).[29] In vitro experiments indicate that MTAD has potential for removing the smear layer,[26][25][28] but clinical benefits have yet to be demonstrated.

Ethylenediamine Tetra-Acetic Acid

EDTA came into use in endodontics in 1957,[185] whereas NaOCl has been in use for more than 70 years.[303] Chelators such as EDTA create a stable calcium complex with dentin mud, smear layers, or calcific deposits along the canal walls. This may help prevent apical blockage (Fig. 9-40) and aid disinfection by improving access of solutions through removal of the smear layer.

![Figure 9-40](http://home.mdconsult.com.eproxy1.lib.hku.hk/das/book/body/0/1357/6...)

Neutral EDTA showed a higher degree of decalcification of dentin surfaces than RC-Prep, although its effect was reduced in apical regions.[30] Similar to MTAD, RC-Prep did not erode the surface dentin layer.[28] The effect of chelators in negotiating narrow, tortuous, calcified canals to establish patency depends both on canal width and on the amount of active substance available as the demineralization process continues until all chelators have formed complexes with calcium.[129] Calcium binding results in the release of protons, and EDTA loses its efficiency in an acidic environment. Thus the action of EDTA is thought to be self-limiting.[246] In one study, demineralization up to a depth of 50 µm into dentin was demonstrated for EDTA solutions; however, reports demonstrated significant erosion after irrigation with EDTA.[289]

A comparison of bacterial growth inhibition showed that the antibacterial effects of EDTA were stronger than citric acid and 0.5% NaOCl but weaker than 2.5% NaOCl and 0.2% chlorhexidine.[257] EDTA had a
significantly better antimicrobial effect than saline solution; it exerts its strongest effect when used synergistically with NaOCl, although no disinfecting effect on colonized dentin could be demonstrated.[123]

Recent reports have indicated that several disinfecting agents such as Ca(OH)$_2$, IKI, and CHX are inhibited in the presence of dentin.[112][211][212] Moreover, chemical analyses indicated that chlorine, the active agent in NaOCl, is inactivated by EDTA.[107][333]

In light of these facts, in addition to the unproven effect of lubricants containing EDTA on rotary instrument torque, use of these solutions probably should be limited to hand instrumentation early in a procedure. Moreover, an EDTA solution preferably is used at the end of a procedure to remove the smear layer.[322][333] This and/or sufficient volume of NaOCl ensures high disinfecting efficacy by enabling NaOCl to penetrate even into deeper dentin layers (Fig. 9–41).

![Figure 9-41 Penetration of irrigants into dentinal tubules after root canal preparation with different dentin pretreatments.](http://home.mdconsult.com.eproxy1.lib.hku.hk/das/book/body/0/1357/6...)

**Calcium Hydroxide**

Ca(OH)$_2$ is very effective at eradicating intraradicular bacteria. Unfortunately, it is not as effective when used short term[262]; therefore, it requires prolonged exposure[19] or higher temperatures for use as an endodontic
Irrigant. Other Irrigants

Electrochemically activated water (also known as oxidative potential water) recently was tested as a potential irrigant. Although this solution is active against bacteria and removes the smear layer, no evaluations of its clinical potential are available, and in vitro research indicates that NaOCl is a superior disinfectant.

Hydrogen peroxide traditionally has been used as an irrigant in conjunction with NaOCl; however, no additional benefit to NaOCl was registered.

Recently some have advocated the use of 0.2% or 0.5% CHX mixed in addition to sodium hypochlorite, either as an irrigant or mixed with Ca(OH)₂ as an interappointment medicament. These combinations can overcome the inhibiting effect of dentin dust on conventional medicaments and can optimize their antimicrobial properties against certain resistant bacteria and yeasts. Increased effectiveness was observed when Ca(OH)₂ was mixed with some common irrigating solutions. Although some authors could not confirm additive effects and even found a reduction in the antimicrobial action of CHX, it appears that Ca(OH)₂ mixed with IKI or CHX may be able to kill calcium hydroxide–resistant bacteria (Box 9–4).

Box 9-4

**Benefits of Using Irrigants in Root Canal Treatment**

- Removal of particulate debris and wetting of the canal walls
- Destruction of microorganisms
- Dissolution of organic debris
- Opening of dentinal tubules by removal of the smear layer
- Disinfection and cleaning of areas inaccessible to endodontic instruments

Lubricants

In root canal treatment, lubricants are mostly used to emulsify and keep in suspension debris produced by mechanical instrumentation. Although irrigation solutions serve as lubricants, special gel-type substances are also marketed. Two of these are the wax-based RC-Prep, which contains EDTA and urea peroxide, and the glycol-based Glyde. Another purported function of lubricants is to facilitate the mechanical action of endodontic hand or rotary files. A study evaluating the effects of lubrication on cutting efficiency found that tap water and 2.5% sodium hypochlorite solutions increased cutting efficiency compared with dry conditions. The authors of this study cited the ability of a lubricant to remove debris as the factor for the increased efficiency. Similarly, in recent experiments a reduction of torque scores was found when canals in normed dentin disks were prepared with ProFile and ProTaper instruments under irrigation; use of a gel-type lubricant resulted in similar torques.

In summary, irrigation is an indispensable step in root canal treatment to ensure disinfection. The tissue-dissolving and disinfecting properties of NaOCl currently make it the irrigant of choice. EDTA should be used at the end of a procedure to remove the smear layer, followed by another flush with NaOCl or an inert solution such as physiologic saline. This minimizes inactivation of NaOCl by chemical interactions.
CLEANING AND SHAPING: CLINICAL ISSUES

Endodontists widely agree that a major biologic aim of endodontic therapy is to eliminate apical periodontitis by disinfection and sealing of root canal systems. However, considerable disagreement exists over the way this goal should be achieved (see Fig. 9–9). Although “cleaning and shaping” accurately describes the mechanical procedures,[227] it should be emphasized that “shaping and cleaning” more correctly reflects the fact that enlarged canals direct and facilitate the cleaning action of irrigants and the removal of infected dentin.

Microorganisms in the pulp cavity and coronal root canal may be readily killed by irrigants early in a procedure; however, bacteria in less accessible canal areas still can elicit apical periodontitis. These bacteria can be eradicated only after root canal preparation.

Biologic Objectives

Some have suggested that canals should be prepared to a uniform and continuous taper[248]; however, this mechanical objective facilitates obturation rather than antimicrobial efficacy. The preparation shape and antimicrobial efficacy are intimately related through the removal of infected dentin and the delivery of irrigants.

Traditionally fluids have been delivered to root canals passively by syringe and needle (Fig. 9–42); active systems such as the NIT are still in an experimental phase.[166] When delivered passively, irrigants have been shown to progress only 1 mm farther than the tip of the needle.[216] However, enlarged apical canals are likely to allow increasingly deeper needle placement (see Fig. 9–42), and this improves debridement and disinfection of canals.[6] Nevertheless, thorough cleaning of the most apical part of any preparation remains difficult,[318] especially in narrow and curved canals.[122][192][219]
Mechanical Objectives

An important mechanical objective of root canal instrumentation is full incorporation of the original canals into the prepared shape, meaning that all root canal surfaces are mechanically prepared (green areas in Fig. 9–43, A and B); however, this goal is not possible with current techniques. [203]
Preparation errors, such as zips and perforations, should be absent. Although these and other procedural problems (Fig. 9–44) per se may not affect the probability of a favorable outcome, they may leave parts of the root canal system inaccessible for disinfection.

Figure 9-43  Example of a desired shape with the original root canal fully incorporated into the prepared outline. A and B, µCT reconstructions in clinical and mesiodistal views of a maxillary molar prepared with a NiTi rotary system. The green area indicates the preoperative shape, and the red area indicates the postoperative shape. Areas of mixed red and green indicate no change (i.e., no removal of radicular dentin). C to E, Cross sections of the coronal, middle, and apical thirds; the preoperative cross sections (green) are encircled by the postoperative outlines (red) in most areas. (A and B from Hübscher W, et al: Int Endod J 36:740–747, 2000.)
Another important mechanical objective is to leave as much radicular dentin as possible so as not to weaken the root structure, thereby preventing vertical fractures. Although no definitive minimal radicular thickness has been established, 0.2 mm is considered critical. Straightening of canal paths can lead to minimal remaining wall thicknesses (Fig. 9-45); this underlines the need for adequate access cavity preparation and optimal enlargement of the coronal third of the root canal.

Figure 9-44  Schematic diagrams showing the most common preparation errors. A, Apical zip. B, Ledge. C, Apical zip with perforation. D, Ledge with perforation.
Two primary mechanical elements are the apical width and the endpoint of the prepared shape in relation to the apical anatomy. Traditional treatment has held that canal preparation and subsequent obturation should terminate at the apical constriction, the narrowest diameter of the canal. This point is believed to coincide with the cementodentinal junction (CDJ) (see Chapter 7). This definition of working length is based on histologic sections and ground specimens. However, the position and anatomy of the CDJ varies considerably from tooth to tooth, from root to root, and from wall to wall in each canal. Moreover, the CDJ cannot be located precisely on radiographs. For this reason, some have advocated terminating the preparation 0.5 to 1 mm short of the radiographic apex in necrotic cases and 1 to 2 mm short in cases involving irreversible pulpitis. In this way, preparation would take place inside the root canal. Follow-up studies seem to support this strategy.

However, working to shorter lengths could lead to the accumulation and retention of debris, which may result in apical blockage (see Fig. 9-40). Such blockage (which consists of collagen fibers, dentin mud, and residual bacteria) inside apical canal areas is a major cause of persistent or recurrent apical periodontitis, \(115\) \(256\) recently labeled posttreatment disease \(93\) (also see Chapter 24). Moreover, because of the creation of apical blockage, working to short lengths may contribute to procedural errors such as apical perforations and fractured instruments.

The electronic apex locator has helped clinicians identify the position of apical foramina more accurately; the development of this instrument made it possible to work more precisely and routinely as close as 0.5 mm to the canal terminus (see Chapter 8).

### Concepts and Strategies

Two factors are closely related to the preparation length: use of a patency file and the apical width. A patency
file is a small K-file (usually a size #10 or #15) that is passively extended just through the apical foramen.

Use of a patency file has been suggested for most rotary techniques. This step is believed to remove accumulated debris and help maintain working length. However, the issue is controversial, and a large number of U.S. dental schools did not teach this concept, at least not until recently. Moreover, Goldberg and Massonet demonstrated that the use of patency files of varying sizes did not prevent preparation errors.

One concern with the patency file was that instead of having a cleaning effect, the file would push contaminated debris through the foramen. However, a recent in vitro study suggested that the risk of inoculation was minimal when canals were filled with sodium hypochlorite. No definitive evidence exists either favoring or disproving the use of a patency file. However, clinical experience suggests that this technique involves relatively little risk and provides some benefit as long as small files are used carefully.

Like the position of the apical constriction, apical diameters are difficult to assess clinically. Some have recommended gauging canal diameters by passing a series of fine files apically until one fits snugly. However, such an approach is likely to result in underestimation of the diameter. This is a crucial point because the initial canal size determines the desired final apical diameter.

An ongoing debate exists between those who prefer smaller apical preparations combined with tapered shapes and those who favor larger apical preparations for better removal of infected dentin and to allow irrigation fluids access to the apical areas. Both sides stress the importance of maintaining the original path of the canal during preparation; otherwise, bacteria infecting the apical third of the root canal may not be reached by a sufficient bactericidal concentration of an antimicrobial agent. Investigators obtained a higher percentage of bacterial elimination in single-root canal systems by using a combination of significant enlargement of the apical third and sodium hypochlorite irrigation. Preparation errors (e.g., zips, canal transportation) can occur with wide preparations when either stainless steel or nickel-titanium instruments are used (see Fig. 9–44).

Thorough disinfection of the apical part of a root canal is essential, because this area is likely to contain intraradicular bacteria. Wider apical preparations remove potentially infected dentin, allowing the delivering needle and subsequently the antimicrobial irrigant to penetrate the root canal more deeply.

A study investigating rotary nickel-titanium files of three tapers (#.06, #08, and #.10) with file tips in sizes #20, #30, and #40 showed that size #20 instruments left significantly more debris in the apical third compared with size #40 instruments. On the other hand, a study in which half the samples were prepared to a size #25 file and the other half to a size #40 file found no statistically significant difference in bacterial growth after instrumentation, with no growth observed after 1 week of treatment with a calcium hydroxide dressing. Another study compared step-down sequences with additional apical enlargement to ISO size #35 or a serial step-back technique with no apical enlargement. NaOCl and EDTA were used as irrigants. No significant difference was detected in colony-forming units with or without apical enlargement. These researchers concluded that dentin removal in the apical third might be unnecessary if a suitable coronal taper is achieved.

Despite the disagreement over the appropriate width of a preparation (Table 9–2), it appears that root canal preparations should be confined to the canal space, should be sufficiently wide, and should incorporate the original root canal cross sections (see Fig. 9–43). This way, routine root canal treatment results in favorable outcomes at various levels of clinicians’ expertise (Fig. 9–46).

<table>
<thead>
<tr>
<th>ROOT CANAL PREPARATION</th>
<th>BENEFITS</th>
<th>DRAWBACKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Narrow apex</td>
<td>Minimal risk of canal transportation, extrusion of irrigants, or extrusion of filling material</td>
<td>Little removal of infected dentin; Questionable rinsing effect in apical areas during irrigation</td>
</tr>
<tr>
<td></td>
<td>Can be combined with tapered preparation to counteract some drawbacks</td>
<td>Possibly compromised disinfection during interappointment medication; Not ideal for lateral condensation</td>
</tr>
<tr>
<td>Wide apex</td>
<td>Removal of infected dentin</td>
<td>Risk of preparation errors and of</td>
</tr>
<tr>
<td></td>
<td>Access of irrigants and medications to</td>
<td></td>
</tr>
</tbody>
</table>

Table 9-2 -- Benefits and Drawbacks of Wide and Narrow Apical Preparations
<table>
<thead>
<tr>
<th>apical third of root canal</th>
<th>extrusion of irrigants and filling material</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not ideal for thermoplastic obturation</td>
</tr>
</tbody>
</table>

**Figure 9-46** Routine cases treated according to the principles discussed in this chapter. Biologic and mechanical aims were maintained at varying levels of expertise. **A,** Asymptomatic tooth #18 with periradicular lesion; endodontic treatment was indicated. **B,** Recall radiograph after 18 months (treatment was performed by fourth-year student at Zurich Dental School). **C,** Preoperative radiograph of tooth #2, which was diagnosed with irreversible pulpitis. **D,** Recall radiograph 2 years later shows sound periradicular tissue; the tooth is clinically symptom free (treatment was performed by an endodontist).
CANAL PREPARATION TECHNIQUES

The traditional cleaning and shaping strategy (the step-back technique) focused on the initial preparation of the apical third of the root canal system, followed by various flaring techniques to facilitate obturation. In an attempt to reach the canal terminus, the clinician first selected a small file, placed an appropriate curve on the instrument, and then tried to work the file to full length. If the terminus could not be reached, the file was removed and, after irrigation, either the same file or a smaller one was inserted. However, more often than not full length could not be reached because of blockage or coronal binding.

Coronal binding is caused by overhangs at the orifice level and also occurs when the canal is less tapered than an instrument, thus binding somewhere coronally. Moreover, a straight root often has a curved canal; buccal and lingual curvatures that cannot be seen on radiographs also need to be detected. Passing a precurved negotiating file through a coronally tight canal will straighten the instrument. Nonflared canals do not allow efficient irrigation, which further predisposes to blockage.

Various instrumentation sequences have been developed for hand and rotary instruments; these are discussed later in the chapter. However, the shape of the access cavity is the prerequisite that must be optimized before any canal preparation can take place (see Chapter 7).

One approach to the preparation of an adequate access cavity (Fig. 9-47) involves the use of a cylindric diamond or fissure bur, a safety-ended drill for additional enlargement, and round burs to remove overhangs on outward strokes. The access cavity shape must allow instruments unimpeded access to the middle third of the root canal system. Ultrasonically powered instruments used under an operating microscope greatly facilitate removal of mesial dentin shelves in mandibular molars (Fig. 9-48, A and B) and other teeth. Preexisting restorations allow for ideal access cavities that serve as reservoirs of irrigants (Fig. 9-48, C).

Figure 9-47 Sequence of instruments used for optimal preparation of an access cavity (e.g., in an incisor). A parallel-sided diamond or steel bur is used to remove overlying enamel in a 90-degree angle toward the enamel surface (1). The bur is then tilted vertically to allow straight-line access to the root canal (arrow). A bur with a noncutting tip (e.g., Endo-Z bur or ball-tipped diamond bur) is then used to refine access (2). Overhangs or pulp horns filled with soft tissue are finally cleared with a round bur used in a brushing or pulling motion (3).
Basic cleaning and shaping strategies for root canal preparation can be categorized as crown-down, step-back, apical widening, and hybrid techniques. In a crown-down approach, the clinician passively inserts a large instrument into the canal up to a depth that allows easy progress. The next smaller instrument then is used to progress deeper into the canal; the third instrument follows, and this process continues until the terminus is reached. Both hand and rotary instruments may be used in a crown-down manner. However, instrument sets with various tip diameters and tapers allow the use of either decreasing tapers or decreasing diameters for apical progress. Debate continues as to which of those strategies is superior for avoiding taper lock; currently no compelling evidence favors either of them.

In the step-back approach, working lengths decrease in a stepwise manner with increasing instrument size. This prevents less flexible instruments from creating ledges in apical curves while producing a taper for ease of obturation.

As discussed previously, the aim of apical widening is to fully prepare apical canal areas for optimal irrigation efficacy and overall antimicrobial activity. Recently, apical enlargement has been broken down into three phases, preenlargement, apical enlargement, and apical finishing.[304]

Most rotary techniques require a crown-down approach to minimize torsional loads[36] and to reduce the risk of instrument fracture. Used sequentially, the crown-down technique can help to enlarge canals further. All basic techniques described so far may be combined into a hybrid technique to eliminate or reduce the

Figure 9-48 Clinical views of an access cavity in a mandibular molar as seen through an operating microscope. (×20.) A, Modification with an ultrasonically activated tip. B, Access cavity after modification. C, Cavity is flooded with 1% sodium hypochlorite.
shortcomings of individual instruments.

Root canal preparation can be broken down into a series of steps that parallel the insertion depths of individual instruments. Anatomic studies and clinical experience suggest that most teeth are 19 to 25 mm long. Most clinical crowns are approximately 10 mm long, and most roots range from 9 to 15 mm in length. Roots, therefore, can be divided into thirds that are 3 to 5 mm long.

Provided adequate tools are used and the access cavity design is appropriate, excessive thinning of radicular structures can be avoided (see Fig. 9-45). Vertical root fractures and perforations are possible outcomes of excessive removal of radicular dentin in zones that have been termed danger zones[12]: overenthusiastic filing, for example, may lead to more procedural errors (see Fig. 9-20). On the other hand, ideal preparation forms without any preparation errors and with circular incorporation of the original canal cross sections may be achieved with suitable techniques (see Fig. 9-43).

Preenlargement of the coronal half to two thirds to allow files unimpeded access gives the clinician better tactile control in directing small, adequately precurved negotiating files into the delicate apical third (Fig. 9-49). Gates-Glidden drills can be used sequentially to enlarge the coronal third of the canal in teeth with straight roots (Fig. 9-50). Both step-back and step-down sequences have been recommended.

![Various prebent, stainless steel hand files for pathfinding and gauging. Compare the curves in the instruments to the ones in a plastic training block (gradation of ruler is 0.5 mm).](image_url)
Besides Gates-Glidden burs, various instruments have been introduced or suggested for coronal preenlargement, such as the ProFile orifice shapers, GT accessory files, the ProTaper Sx, the FlexMaster Intro file, and the size #40, #.10 taper or size #35, #.08 taper RaCe files. These instruments are better suited to and safer for more difficult cases (Fig. 9–51).

**Figure 9-50** Diagram of coronal enlargement in a maxillary anterior tooth. After preparation of the access cavity (Fig. 9–47) and copious irrigation, Gates-Glidden burs are used in a step-down manner to enlarge the orifice and provide straight-line access into the middle third of the canal. Prebent size #10 K-files are used to explore the canal path and dimension.

**Figure 9-51** Diagram of coronal enlargement in a more complicated maxillary posterior tooth. This maxillary molar presents several difficulties, including a narrow mesiobuccal canal that exits the pulp cavity at an angle. A possible approach in a case involving difficult entry into the root canal system is to use a small orifice shaper (OS1) after ensuring a coronal glide path with a K-file. Use of a
sequence of orifice shapers (OS3 to OS1) then allows penetration into the middle third of the root canal. Wider canals can accept a second sequence of orifice shapers. Copious irrigation and securing a glide path with a size #10 K-file are prerequisites for use of NiTi rotary instruments.

Once the coronal portions of a canal have been enlarged, the apical canal areas can be more efficiently prepared. Better clinical results are obtained with optimized access, regardless of the preparation technique used (Fig. 9–52). Only after preenlargement can fine scouting files (also used before rotary files in the coronal areas) provide information about the root canal paths. Preenlarged canals may accommodate hand files, which can be used to gather specific information about the apical third’s cross-sectional diameter and anatomy.

![Figure 9-52](image-url) Clinical example of the importance of straight-line access to the middle third of the root canal. A, Preoperative radiograph of tooth #30, diagnosed with irreversible pulpitis. This tooth serves as a retainer for a metal-free, fixed partial denture. Note the prominent dentin shelves (arrows). B, Working length radiograph with hand instruments inserted into the mesial and distal canals. C, Cone-fit radiograph showing tapered preparations after removal of the dentin shelves. D, Posttreatment radiograph after thermoplastic compaction of gutta-percha. E and F, Follow-up radiographs at 2 and 4 years. The tooth is clinically symptom free, and the periodontal ligament appears to be within normal limits.

**Hand Instrumentation**

General agreement exists that hand files should be used for the balanced force technique. Roane et al. described this technique as a series of rotational movements for Flex-R files, but it can also be used for K-files and other hand instruments, such as GT hand files. Many different explanations have been offered for the obvious and undisputed efficacy of the balanced force approach; however, general agreement...
exists that it provides excellent canal centering ability, superior to other techniques with hand instruments.\cite{16}

The balanced force technique involves three or four steps. The first step (after passive insertion of an instrument into the canal) is a passive clockwise rotation of about 90 degrees to engage dentin (Fig. 9–53). In the second step, the instrument is held in the canal with adequate axial force and rotated counterclockwise to break loose the engaged dentin chips from the canal wall; this produces a characteristic clicking sound. Classically, in the third step the file is removed with a clockwise rotation to be cleaned; however, because files used with the balanced force technique are not prebent, every linear outward stroke essentially is a filing stroke and may lead to some straightening of the canal path. Therefore, in many cases the clinician may advance farther apically rather than withdrawing the file, depending on the grade of difficulty.

NiTi rotary instruments are an invaluable adjunct in the preparation of root canals, although hand instruments may be able to enlarge some canals just as efficiently when used in appropriate sequences (Fig. 9–54). Hand instruments should be used only after coronal preenlargement (e.g., with Gates-Glidden drills). After preenlargement, the access cavity and canals are flooded with irrigant, and a prebent scouting file is advanced into the canal. A lubricant can help prevent apical blockage in this early stage. Once the working length has been established (aided by an electronic apex locator and radiographically verified), apical enlargement to the desired size begins (Fig. 9–55). As stated previously, various apical preparation designs exist, and the choice is driven mostly by the desired obturation technique, whether an apical stop or an apical taper is prepared. Finally, canal taper is increased by decreasing the working length of larger instruments in 1 or 0.5 mm increments, producing #0.05 and #0.10 mm tapers, respectively.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{Figure_9-53}
\caption{Diagram of handle movements during balanced force hand preparation. Step 1: After pressureless insertion of a Flex-R or NiTiFlex K-file, the instrument is rotated clockwise 90 degrees using only light apical pressure. Step 2: The instrument is rotated counterclockwise 180 to 270 degrees; sufficient apical pressure is used to keep the file at the same insertion depth during this step. Dentin shavings are removed with a characteristic clicking sound. Step 3: This step is similar to step 1 and advances the instrument more apically. Step 4: After two or three cycles, the file is loaded with dentin shavings and is removed from the canal with a prolonged clockwise rotation.}
\end{figure}
Figure 9-54 Root canal instrumentation with hand files: Part I. After the orifice has been accessed (see Figs. 9–47 and 9–52) and copious irrigation performed (1), the working length (WL) is determined. A size #10 and/or #15 K-file is advanced to the desired apical preparation endpoint, aided by an electronic apex locator (2). The apical canal areas are then enlarged with K-files (3) used in the balanced force technique (see Fig. 9–53). Frequent, copious irrigation with sodium hypochlorite is mandatory to support antimicrobial therapy. Frequent recapitulation with fine K-files is recommended to prevent blockage (4). Apical enlargement is complete to the desired master apical file (MAF) size (5), which depends on preoperative canal sizes and individual strategy. Typically, size #40 or larger may be reached in anterior teeth, as in this example. File sizes larger than #20 may be used with NiTi instruments (e.g., NiTiFlex).
Copious irrigation and frequent recapitulations with a smaller file to working length may be required, and in some instances clinicians must devise creative strategies using small crown-down and/or step-back sequences.

In many cases hand instrumentation produces adequate shapes, but clinicians often choose NiTi rotary instruments either to enlarge curved canals or to produce wider tapers. Fig. 9–56 illustrates the development of these shapes in the mesial root canals of a mandibular molar, clearly showing that substantial areas of the root canal surface are not instrumented, even when apical size #50 or #.09 tapers are reached (red areas in Fig. 9–56, G and I).

Figure 9-55  Root canal instrumentation with hand files: Part II. Frequent irrigation with sodium hypochlorite (1) is more efficient after the working length (WL) is reached, because irrigation needles may penetrate deeper into the canal. Canal taper is increased to further improve antimicrobial efficiency and to simplify subsequent obturation. Hand instruments are set to decreasing working length in 0.5-mm increments (step-back) from the master apical file (2 to 3). A fine K-file is used to recapitulate to WL during the procedure (4), and the MAF is used as a final recapitulation (5) to ensure that remaining dentin chips have been removed.

Figure 9-56  Stepwise enlargement of mesial root canal systems in an extracted mandibular molar demonstrated with µCT reconstructions. The buccal canal (left) was prepared with a LightSpeed (LS) instrument, and the lingual canal (right) was shaped with a ProTaper (PT) instrument. A, Preoperative view from the mesial aspect. Note the additional middle canal branching from the lingual canal into the coronal third. B, Initial preparation and opening of the orifices, aided by ultrasonically powered instruments. C, First step of root canal preparation, up to LightSpeed size #20 and ProTaper shaping file S1. D, Further enlargement to LS size #30 and PT shaping file S2. E, Apical preparation to LS size #40 and PT finishing file F1. F, Additional enlargement to LS size #50 and PT finishing file F2. G, Superimposed µCT reconstructions comparing the initial canal geometry (in green) with the shape reached after use of the instruments shown in F. H, Final shape after step-back with LS instruments and PT finishing file F3. I, Superimposed µCT reconstructions comparing initial geometry and final shape. Note the slight ledge in the buccal canal after LS preparation and some
straightening in the lingual canal after PT preparation.

**Rotary Instrumentation**

**LightSpeed Instrument**

Since the introduction of LightSpeed instruments, the manufacturer’s guidelines have changed[17]; this section presents the current version[248] (Figs. 9–57 and 9–58).

![Diagram of LightSpeed Instrumentation](http://home.mdconsult.com.eproxy1.lib.hku.hk/das/book/body/0/1357/6...)

**Figure 9-57** Preparation of a maxillary molar with LightSpeed (LS) instruments. After coronal enlargement with a tapered rotary instrument or GG drills (Figs. 9–47 and 9–50) and irrigation with NaOCl (1), the working length is determined with a small K-file, aided by an electronic apex locator. A patent glide path is secured by hand instrumentation up to a loosely fitting size #15 K-file (2). The canal size is gauged by hand-held LS instruments, and the first LS size to bind (FLSB) is selected. Apical instrumentation is then begun with engine-driven LS instruments, starting with the FLSB (4) up to the desired apical size (see text for further explanation).
After coronal preenlargement with the instrument of choice, working lengths are obtained and apical
enlargement is done with at least a loose-fitting size #15 K-file. Apical canal diameters are then gauged by the
insertion of LightSpeed instruments of increasing size until one binds just before reaching the working length.
This instrument, which is then used in the handpiece, is the first LS instrument size to bind before reaching
the working length (the FLSB).

All LightSpeed instruments are used in the following way: a slow, continuous apical movement is used until
the blade binds; after a momentary pause, the blade is advanced to the working length (WL) with intermittent
(“pecking”) motions. The number of pecks required to reach the WL increases as instrument size
increases, because more wall dentin is cut. The instrument size that requires 12 or more pecks (12-peck rule)
to advance from the point of first binding to the WL is the master apical rotary size (MAR).

An instrument one size larger than the MAR then is used to instrument to a length 4 mm short of the working
length. This shapes the canal for subsequent obturation with SimpliFill (LightSpeed Technologies). The
middle third of the canal is instrumented with sequentially larger full-size instruments until a size is reached
that cannot be easily advanced beyond the coronal third. The midroot area usually is prepared with three or
four LightSpeed instruments. Finally, the MAR is used to recapitulate to the working length (see Fig. 9–58).

ProFile

Many different techniques have been advocated for the ProFile, but the general pattern remains a crown-
down approach with varying tapers and tip diameters. The ProFile therefore can be used as an example for
systems with this basic design (e.g., the HERO 642, K3, and FlexMaster). It must be noted that the
manufacturers’ instructions for those systems are somewhat different, and the instructions for GT rotary and
RaCe files vary even more. Therefore the clinician should always read the manufacturers’ instructions for
details on working with those instruments. That being said, it also must be noted that the merits of specific
instructions have not been scientifically elaborated.

As with other instruments, coronal preenlargement is mandatory (see Figs. 9–51 and 9–52). The working
length then is determined as described previously, and an open glide path is secured with K-files up to size
#15 or #20, depending on the canal anatomy. If canal size permits, canal preparation begins with #.06 taper
instruments in descending tip diameters (Fig. 9–59). In more difficult small canals, #.06 tapers are

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**Figure 9-58** Finishing of LightSpeed preparations to allow obturation. With the canal system flooded (1), apical preparation (2) is continued until an LS instrument requires 12 pecks to reach the working length (WL). The next LS instrument (3) then is used to a point 4 mm short of the WL to prepare for LightSpeed’s SimpliFill obturation system. Alternatively, canals may be flared for other root canal filling techniques by preparing with each subsequent instrument 1 mm shorter (5).
followed by .04-tapered instruments, also with descending tip diameters (Fig. 9–60). Apical preparation is performed either with multiple shaping waves, as suggested for GT rotary files,[47] or in a step-back manner. [242] Because of their superior resistance to cyclic fatigue, .02-tapered ProFile instruments are useful for abrupt apical curves. Preparation is complete once a continuous .06 taper with an adequate apical size is achieved. Recapitulation during the preparation with a small hand file is recommended.

Figure 9-59 ProFile instrumentation in a wider canal. In irrigated and flooded canals (1), a crown-down preparation is done with a sequence of .06-tapered ProFile instruments (2). When the apical third is reached, the WL is determined and a glide path is secured (3). Apical preparation is then completed by continuing the crown-down sequence (4) up to the desired apical width at the WL. Several shaping waves may be required (5).
ProTaper

The approach for ProTaper instruments differs from that for most other NiTi rotary files in that no traditional crown-down procedure is performed (Fig. 9–61).

Figure 9–60  Sequence of ProFile instruments used in constricted canals. After irrigation (1) and coronal preenlargement with orifice shapers (see Fig. 9–51), ProFile instruments size #25, #.06 taper; size #20, #.06 taper; and size #24, #.04 taper are used as crown-down instruments (2). After the WL has been determined and a glide path secured (3), apical preparation to the desired size begins (4). For additional taper, larger instruments may be used to a point short of the WL.

ProTaper

The approach for ProTaper instruments differs from that for most other NiTi rotary files in that no traditional crown-down procedure is performed (Fig. 9–61).
Size #10 and #15 hand files are precurved to match the canal curvature and then passively inserted into the coronal two thirds of a root canal as pathfinding files, which confirm the presence of a smooth, reproducible glide path. This step is essential for ProTaper shaping instruments, because they are mostly side-cutting and have fine, fragile tips.

Shaping files S1 and S2 are then passively inserted into the scouted canal spaces, which have been filled with irrigant (preferably sodium hypochlorite). If necessary, the SX file can be used at this stage to relocate orifices or remove obstructing dentin. After each shaping file is used, the canals are reirrigated and a size #10 file is used to recapitulate to break up debris and move it into solution. This process is repeated until the depth of the pathfinding #10 or #15 file is reached.

After irrigation the apical third is fully negotiated and enlarged to at least a size #15 K-file, and the working length is confirmed (see Fig. 9–61). Depending on the canal anatomy, the rest of the apical preparation can be done with engine-driven ProTaper shaping and finishing hand files. As an alternative, handles can be placed on these instruments (Fig. 9–62) so that they can be used for the balanced force technique.

Figure 9–61 Instrumentation of root canals with ProTaper instruments. After irrigation and scouting (1 and 2), the coronal thirds are enlarged with shaping files S1 and S2. Hand files then are used to determine the WL and to secure a glide path. Apical preparation is completed with S1 and S2. Finishing files are used to the desired apical width.

Figure 9–62 Treatment performed with nickel-titanium rotary and hand instruments to eliminate instrument separation while maintaining biologic aims. A, Preoperative radiograph of tooth #15. B, Postoperative radiograph shows a significant curvature in the mesiobuccal canal and additional anatomy in the lingual root. C, Preoperative radiograph of teeth #14 and #15. Both teeth were diagnosed with irreversible pulpitis. D, Postoperative radiograph shows four canals in both of the treated maxillary molars. Note the wide apical preparation, particularly in the curved mesiobuccal canals. (A and B courtesy Dr. T. Clauder; C and D courtesy Dr. H. Walsch.)

ProTapers S1 and S2 are then carried to the full working length, still in a floating, brushing motion. The
working length should be confirmed after irrigation and recapitulation with a K-file, aided by an electronic apex locator and/or radiographs. Because of the progressive taper and more actively cutting flutes higher up in the ProTaper design, interferences in the middle and coronal thirds are removed at this stage.

The preparation is finished with one or more of the ProTaper finishing files, used in a nonbrushing manner; because of their decreasing taper, these files will reach the working length passively. Recapitulation and irrigation conclude the procedures (see Fig. 9–61).

Most cases requiring root canal therapy lend themselves to canal preparation with many different systems; depending on the individual anatomy and the clinician’s strategy, various sequences may be used. Fig. 9–63 presents two cases that involved different problems and therefore were approached differently. Mesiobuccal roots of the maxillary molar can show substantial curvature; rotary instrumentation and/or hybrid techniques allow preservation of the curvature (Fig. 9–63, A) and optimal enlargement (Fig. 9–63, B). Often hand instruments other than ISO-normed files (see Fig. 9–62) are used in these cases to ensure a smooth, tapered shape or to eliminate ledges.

![Image of instruments]

**Figure 9-63** Instruments with increased taper that can be used by hand. **A,** ProTaper instruments with special handles attached to rotary instrument shanks. **B,** GT hand instruments.

**Hybrid Techniques**

For some time some have suggested combining various NiTi preparation systems to address certain shortcomings of current instruments. Although many combinations are possible, the most popular and useful ones involve coronal preenlargement followed by different additional apical preparation sequences. However, clinicians must keep in mind that anatomic variations in each canal must be addressed individually.
with specific instrument sequences. Most important, oval canals extend deep into the apical area, and apical foramina in fact may be oval in most cases. Naturally, a rotating file can produce a round canal at best; therefore, a strategy must be devised for adequately shaping oval canals without overly weakening radicular structure (compare Figs. 9–43 and 9–45). One hybrid approach completely prepared 95% or more of all such canals and resulted in extremely wide apical sizes that may be difficult to achieve with most instrument systems (Box 9–5).

**Box 9-5**

**Benefits of Using a Combination of Instruments for Endodontic Therapy**

- Instruments can be used in a manner that promotes their individual strengths and avoids their weaknesses (most important).
- Hand instruments secure a patent glide path.
- Tapered rotary instruments efficiently enlarge coronal canal areas.
- Less tapered instruments allow additional apical enlargement.

Histologic slides (see Fig. 9–39) and µCT reconstructions (see Figs. 9–43, 9–45, and 9–56) show critical areas that were not mechanically prepared despite the use of various individual rotary techniques. The aim of hybridizing NiTi rotary techniques, therefore, is to increase apical size using a fast and safe clinical procedure.

Various clinicians have used this type of hybrid procedure in their practices (see Figs. 9–2, 9–5, 9–15, and 9–62). The technique involves the use of a variety of instruments: GG drills and K-files for establishing straight-line access; ProTaper instruments for body shaping and apical preenlargement; NiTi K-files or LightSpeed instruments for apical widening; and various instruments for final smoothing.

After a precurved, stainless steel file has confirmed a smooth glide path into the coronal two thirds, irrigation and mechanical preparation with a sequence of ProTaper files open and preenlarge the apical third (Fig. 9–64). Once the working length has been established, the apical third is flooded with sodium hypochlorite and further enlarged with ProTaper finishing files F1 and F2. The F3 ProTaper finishing file is relatively inflexible, and because of its side-cutting action, it should be used with caution in curved canals (Fig. 9–65).
The effectiveness of some hybrid techniques in enlarging canals recently was documented using superimposed root canal cross sections (Fig. 9-66). This approach can help identify insufficiently prepared areas and weakening of the radicular structure.

**Figure 9-64** Hybrid technique: Part I. After irrigation (1) and scouting (2), GG drills (3) and/or ProTaper SX files (4) are used for coronal preenlargement and to secure straight-line access to the middle third. Prebent K-files are then used to explore and determine the working length (5).

**Figure 9-65** Hybrid technique: Part II. In canal systems flooded with irrigant (1), ProTaper shaping instruments S1 and S2 (2) and then finishing instruments F1 and F2 (3) are used to preenlarge the apical third, allowing irrigants access to the canals. Finishing instrument F3 may be used if feasible (4).
Some hybrid systems seem to work better than others, but the deciding factors seem to be the root canal anatomy and an adequate preparation goal.

If canal curvature is more severe, ProTapers may be used as hand instruments (see Fig. 9–63, A). Because the largest ProTaper instrument has a size #30 tip, in many cases additional enlargement is desired. This may be accomplished with LightSpeed or NiTi K-files (Fig. 9–67), which are first used to working length and then in a step-back approach. Finally, the overall shape may be smoothed with either engine-driven or hand-held instruments. Hand-held ProTaper or GT instruments may aid removal of acute apical curvatures or ledges and provide access to apical canal areas for irrigants.

Figure 9–66 Effect of a hybrid technique on root canal anatomy studied in a Bramante model. A1 to A4, Both mesial canals of an extracted mandibular molar have been instrumented. Canal cross sections are shown before instrumentation (B1 to D1). B2 to D2, Cross sections after preenlargement with a ProTaper F3 file (left canal) and a size #45, .02 taper instrument (right canal). The final apical sizes were LightSpeed (LS) #50 and size #50, .02 taper in the left and the right canal, respectively. (Courtesy Dr. S. Kutler, Dr. M. Geralu, and Dr. R. Perez.)
Other Systems

Ultrasonically activated files or alternating file movements with special handpieces may be used to work canal areas that rotary instruments cannot reach. However, to date no evidence shows that canal preparation with ultrasonic instruments is clinically beneficial. Similarly, neither traditional modified handpieces nor a recently introduced system (EndoEZE AET; Ultradent, South Jordan, UT) have been shown to allow preparation of adequate canal shapes.

Ultrasonic devices have been linked to a higher incidence of preparation errors and to reduced radicular wall thickness. Newer analytic systems (e.g., μCT) allow tracking of the amount of dentin removed (Fig. 9–68); however, the amount of potentially infected dentin that should be removed to maximize the chance of a successful outcome is unclear.

Figure 9-67  Hybrid technique: Part III. Under irrigation (1), LightSpeed instruments may be used to enlarge substantially (2 and 3) and to flare the apical section (4). NiTi hand instruments (5) may be used similarly (see text for more detailed explanation).
Figure 9-68  Reconstruction from µCT data (36 µm isotropic resolution) showing the amount of removed dentin by color coding. Maxillary molar shaped with ProTaper, apical size #25 (=F2) in mesiobuccal and distobuccal canals; palatal canal shaped to size #30 (=F3). The bar indicates the removed volume, expressed as the number of voxels. Note the red areas, which indicate dentin removal of more than 500 µm.
CANAL CLEANING TECHNIQUES

Irrigants and other intracanal medicaments are necessary adjuncts that enhance the antimicrobial effect of mechanical cleansing and thus overall clinical efficacy.[50][51][52] Several studies[205][206][277][312][317] have shown that large areas of canal walls, particularly in the apical third but also in ribbon-shaped and oval canals, cannot be cleaned mechanically, meaning that microorganisms present in these untouched areas could survive (see Figs. 9–38, 9–43, and 9–45). Residual bacteria and other microorganisms exist both in these hard-to-reach spaces and in dentinal tubules.[113][197][228] Chemical disinfection is an important cornerstone of a successful outcome, because it reaches bacteria or fungi present in dentinal tubules and in the crevices, fins, and ramifications of a root canal system.[189][306] In one study, investigators prepared root canals, irrigated with saline solution, and sampled before, during, and after instrumentation.[75] They then cultivated and counted colony-forming units. These researchers found that with instrumentation alone, progressive filing reduced the number of bacteria, regardless of whether rotary or stainless steel hand instrumentation was used. However, no technique resulted in bacteria-free canals. Siqueira et al[257] confirmed this finding; they found that instrumentation combined with saline irrigation mechanically removed more than 90% of bacteria in the root canal. Many authors have stressed the importance of using antimicrobial irrigants during chemomechanical preparation to ensure complete disinfection.[258]

Substances that have been used to rinse and chemically clean root canals have different purposes, such as dissolution of soft and hard tissues, antimicrobial effect against bacteria or other microorganisms in the root canal, and inactivation of bacterial lipopolysaccharides. These substances also should be as nontoxic as possible to protect the periradicular tissues. Unfortunately, solutions that are toxic for bacterial cells frequently are toxic for human cells as well; therefore, care must be taken to avoid extrusion of irrigants into periapical regions.[43]

Another critical factor is the volume of irrigant. In a study evaluating the effect of different amounts of fluids, the volume of irrigant was found to affect the cleanliness of the root canal.[32] NaOCl and EDTA administered in larger volumes produced significantly cleaner root canal surfaces than smaller volumes.[32] The choice of an appropriate irrigating needle, therefore, is also important. Although larger gauge needles allow the irrigant to be flushed and replenished more quickly, the wider needle diameter does not allow cleaning of the apical and narrower areas of the root canal system (Fig. 9–69). Excess pressure or wedging of needles into canals during irrigation, with no possibility of backflow of the irrigant, should be avoided under all circumstances[128] to prevent extrusion of the irrigant into periapical spaces. In juvenile teeth with wide apical foramina or when the apical constriction no longer exists, special care must be taken to prevent resorption or overpreparation of the root canal.[20]
Most root canals that have not been instrumented are too narrow to be reached effectively by disinfectants, even when very fine irrigation needles are used (see Figs. 9-42 and 9-69). Therefore effective cleaning of the root canal must include intermittent agitation of the canal content with a small instrument; this prevents debris from accumulating at the apical end of the root canal (see Fig. 9-40). A suction system with a fine-caliber suction tip may be a valuable adjunct for removing solutions and floating debris.

**Disinfection**

Different types of microorganisms, such as bacteria, yeasts, and possibly viruses, can infect the pulp and may lead to apical periodontitis (see Chapters 14 and 24 and Fig. 9-7). These microorganisms must be reduced or eliminated to reestablish periradicular health. When bacterial samples test negative after treatment, the prognosis is improved. During mechanical root canal preparation, endodontic instruments are used to clean and enlarge root canal systems. Rotating instruments have an additional, advantageous “Archimedes screw” effect by which debris is transported in an apicocoronal direction. Even when simple saline was used as an irrigant, a tenfold to 1000-fold reduction of the bacterial load through mechanical instrumentation was demonstrated. However, as noted earlier, instrumentation alone does not produce a bacteria-free root canal. In one study, dentin samples tested positive in most of the teeth after mechanical instrumentation even though bacteria had
been eliminated from the root canals in some cases.[52] Bacteria persisted in seven root canals despite mechanical cleaning and saline irrigation during five consecutive appointments. Moreover, teeth with a high number of bacteria in the initial sample remained infected despite being treated five times.[53] In another study, teeth that caused symptoms tended to have more bacteria than teeth with no clinical symptoms.[190]

Ørstavik and Haapasalo[189] investigated the effect of endodontic irrigants and dressings in standardized bovine dentin specimens that were infected with test bacteria. They found that bacteria were capable of colonizing the canal lumen and dentinal tubules. In the specimens used, *E. faecalis* rapidly infected the whole length of the tubules, whereas *Escherichia coli* penetrated approximately 600 µm. They also found that IKI appeared to be more effective at destroying bacteria than NaOCl, which was more effective than CHX.

Other investigators have explored the effects of sodium hypochlorite (with and without EDTA), chlorhexidine, and hydrogen peroxide in varying concentrations when used in sequence or in combination as endodontic irrigants.[123] They found that chlorhexidine and sodium hypochlorite were similarly effective in eliminating the bacteria tested. Synergistic effects were observed for some of the irrigants (e.g., chlorhexidine and iodine potassium iodide).

Both of the preceding studies used infected dentin specimens; dentin is an important factor in disinfection because certain concentrations of calcium hydroxide solution, sodium hypochlorite, chlorhexidine, and iodine potassium iodide are inactivated or their activity is reduced by dentin powder.[112] (Fig. 9–70).

Some of the more difficult to remove endodontic pathogens, which can cause treatment failure, are enterococci and *Actinomyces* and *Candida* organisms[29][182] (see Chapter 15). Table 9–1 presents the results of a number of studies evaluating the effectiveness of some commonly used antimicrobial agents.

When reading literature about antimicrobial efficacy, clinicians must keep in mind that most disinfecting solutions are inhibited or even inactivated by contact with dentin or dentin powder during root canal preparation.[112][210] Moreover, chemical interactions occur between irrigation solutions; for example, NaOCl can become ineffective if it comes in contact with EDTA.[107] (Fig. 9–70).

Currently, the endodontic irrigation solution with the best proteolytic effect is NaOCl, even though it does not meet all the requirements of an ideal irrigant (Box 9–6). It is readily available, inexpensive, and a widely used irrigation solution. Given sufficient time, NaOCl is a powerful solvent of necrotic pulp tissue and organic debris and has excellent antimicrobial properties. Necrotic tissue and debris are dissolved by the breakdown of proteins into amino acids through free chlorine in NaOCl. Concentrations used clinically range from 0.5% to 5.25%. However, because free chlorine is the important component, the solution must be replenished frequently during preparation to compensate for lower concentrations and to constantly renew the fluid inside...
the root canal. This is even more important when the root canal is narrow and small and files must carry the NaOCl to the apical third during instrumentation (see Fig. 9–42). A 1% solution is effective at dissolving tissue and providing an antimicrobial effect. The use of commercial household bleach in its undiluted form (5.25%) causes substantial necrosis of wound surface areas and may result in serious clinical side effects (Fig. 9–71). It is diluted in 1:1 or 1:3 ratios with water to produce a 2.5% or 1% solution; both are suitable for clinical endodontic use.[269][329][331]

Box 9-6

**Properties of an Ideal Irrigant for Root Canal Treatment**

The irrigant should:

- Be a highly effective disinfectant
- Be nontoxic locally and nonallergenic
- Differentiate between necrotic and vital host tissue
- Retain its effectiveness with dental hard tissue and when mixed with other irrigants

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**Figure 9-71** Toxic effect of NaOCl on periradicular tissues. After root canal treatment of tooth #3, the patient reported pain. A, On a return visit, an abscess was diagnosed and incised. B, Osteonecrosis was evident after 3 weeks.

As stated earlier, irrigation needles should never be wedged into canals during irrigation to avoid extrusion and serious damage to periapical tissues.[43] Higher concentrations of NaOCl are more aggressive toward living tissue and can cause severe injuries when forced into the periapical area (Fig. 9–71).

Such accidents can be prevented by marking the working length on the irrigation needle with a bend or a rubber stop and by passively expressing the solution from the syringe into the canal (see Fig. 9–69). The needle should be continuously moved slightly up and down. It should remain loose in the canal, allowing a backflow of fluid. The goal is to rinse the suspended, concentrated dentinal filings out of the pulp chamber and root canals as new solution is brought down into the most apical areas by the endodontic instrument and the capillary effect.

Patency files should be used carefully and should not be extended farther than the periodontal ligament, because they are possible sources of irrigant extrusion.

In one study, heating increased the antibacterial action of NaOCl.[67] This can be done in several ways; for example, after the solution has been drawn into the irrigating syringe, a syringe warmer can be used (e.g., Syringe Warmer [Vista Dental Products, Racine, WI]) (Fig. 9–72). Heating also enhanced the antibacterial effectiveness of CHX and Ca(OH)2 solutions.[88][89] A 0.5% NaOCl solution heated to 113°F (45°C) dissolved pulp tissue as efficiently as a 5.25% solution used as the positive control (Fig. 9–73). Heating to 140°F (60°C) resulted in almost complete dissolution of tissue. Studies have shown that 1 minute at 116.6°F (47°C) is the cutoff exposure at which osteoblasts can still survive; however, higher temperatures may in fact be sufficient to kill osteoblasts and other host cells.[86][87][88] Also, warming of NaOCl to 122°F (50°C) or 140°F (60°C) increases collagen dissolution and disinfecting potential, but it may also have severely detrimental effects on NiTi instruments, causing corrosion of the metal surface after immersion for 1 hour (Fig. 9–74).
**Figure 9-72** Device for heating syringes filled with irrigation solution (e.g., NaOCl) before use.

**Figure 9-73** Effect of heating on the ability of 0.5% NaOCl to dissolve pulp tissue. NaOCl heated to 113°F (45°C) dissolved pulp tissue as well as the positive control (5.25% NaOCl) did. When the NaOCl was heated to 140°F (60°C), almost complete dissolution of tissue resulted. *(From Sirtes and Zehnder, unpublished data. 334)*
An increase in the temperature of the irrigant may be a reason to include ultrasonic devices in canal irrigation; these devices also increase the tissue-dissolving capabilities of sodium hypochlorite. In one study, the peak irrigant temperature during use of an ultrasonic device reached 113°F (45°C) near the file tip but remained at 89.6°F (32°C) on the outer root surface of teeth prepared to a size #45. Another reason for using ultrasonic devices might be enhancement of canal cleanliness. However, some authors have reported no beneficial effect with ultrasonics, neither in debriding root canal walls nor in reducing bacterial counts. A recent study corroborated these mixed findings; in this study, smear layer removal with and without ultrasonics after canal preparation with LightSpeed and ProFile rotary instruments did not differ significantly.

**Smear Layer Management**

EDTA is a decalcifying, chelating agent used as a gel or a 17% buffered solution during instrumentation of root canals. It acts as a chelator with calcium ions and removes the dentinal debris produced on the root canal walls during preparation. It thus opens dentinal tubules, allowing better penetration of disinfectants. Whenever the wall of a root canal is instrumented, whether by hand or rotating instruments, the parts of a dentin wall touched by an instrument are covered by a surface layer called the **smear layer**. The smear layer, which consists of dentin shavings, cell debris, and pulp remnants, can be described as itself having two separate layers: a loose superficial deposit and an attached stratum that extends into the dentinal tubules, forming occluding plugs.
For some time clinicians and researchers paid little attention to the smear layer, partly because it was a thin superficial layer (1 to 5 µm) that might be present or not, depending on the type of instrument and the sharpness of its cutting blades. Also, because acids and chelating agents dissolve the smear layer, it was removed and escaped attention in routinely processed specimens (Fig. 9-75). Smear layers are not seen in unprepared canal areas, which may have calcospherites, buttonlike structures that are abundant on intracanal surfaces.

Some authors have reported that an overlying smear layer delays but does not eliminate the effect of medicaments. Others contend that a smear layer may adversely affect disinfection and may also increase microleakage after canal obturation. Although organic substrate in a smear layer may serve as a nutrition source for some species of bacteria, some have suggested that, conversely, a smear layer can act as a beneficial barrier, preventing microorganisms from entering the dentinal tubules when a root canal is colonized by bacteria between appointments. The decalcifying effect of EDTA is self-limiting; therefore the solution must be replaced at intervals. EDTA can help open very narrow root canals and can decalcify to a depth of approximately 50 µm. Because the smear layer consists of organic and inorganic components, alternating use of NaOCl and EDTA is most effective.

Liquid disinfectants were effective against E. faecalis in dentinal tubules up to depths of 400 µm. Microbiologic
analyses of split root halves showed that early removal of the smear layer resulted in significantly higher bacteria counts. In contrast, other researchers have acknowledged that the smear layer, while acting as a barrier, might block irrigation solutions from entering the dentinal tubules. Moreover, some bacteria (e.g., *Bacteroides gingivalis* and *Treponema denticola*) have the potential to dissolve smear layer proteins, thereby producing gaps, which could promote both coronal and apical microleakage and bacterial multiplication.

Fig. 9–76 shows root canal cross sections with very little debris; irrigating solutions can penetrate the dentinal tubules in this example. Some reported that the presence of the smear layer had no significant effect on apical leakage in dye penetration test. Others described an improved seal after removal of the smear layer. The latter study, which used a coronal leakage model, found a significantly decreased incidence of bacterial penetration (30% versus 70%) when the canals were irrigated with 17% EDTA and 5.25% NaOCl before obturation. In obturated root canals, a remaining smear layer led to bacterial leakage in 60% of the samples versus no leakage when the smear layer was removed. Other authors had similar results after smear layer removal with EDTA solution alone. Another investigation described many lateral canals in the apical thirds of the root canals systems cleaned with a barbed broach wrapped with MTAD-soaked cotton and showed less erosion than when EDTA was used. Other studies have found that a stronger bond was present when the smear layer was removed, and a statistically significant reduction of microleakage was measured. However, another investigation reported increased apical microleakage of the filled root canal after removal of the smear layer.

![Figure 9-76](http://home.mdconsult.com.eproxy1.lib.hku.hk/das/book/body/0/1357/6...)

Figure 9-76  Example of canals with minimal smear layer. A, Middle third after irrigation with 17% EDTA and 2.5% NaOCl. B, Apical third with some particulate debris. 

As shown in Fig. 9–41, dye staining is improved when the dentinal tubules are opened and the smear layer
is removed with EDTA, at least in the two more coronal levels. Although the effect of the smear layer on leakage has been widely studied, its removal from root canal walls remains controversial. The apparently conflicting results of studies could stem from differences in the various microleakage test models and from different obturation and irrigation techniques. The problem of coronal leakage has received much attention as a major factor in determining the success or failure in root canal therapy.

In general, it seems beneficial to remove the smear layer in the later phases of endodontic therapy rather than during the early phases.

Research continues on ways to improve the effectiveness of irrigation. For example, tensides were added to irrigants more than 20 years ago to reduce their surface tension, thereby improving wetability. The rationale for this increased wetability was to improve the penetration of irrigants into the dentinal tubules (this concept is still pursued with MTAD today). One irrigating “cocktail” investigated was a mixture of 5% NaOCl and 17% EDTA with the tensioactive chemical Triton X-100; this solution was used with ProFile instruments. The study reported that apical smear layer scores were significantly lower compared with those of control groups when the tensioactive agent was used throughout the preparation process.

In two in vitro studies, the noninstrumentation technique, which relies on activated irrigation solutions rather than mechanical preparation, produced excellent canal cleanliness. However, preliminary clinical studies identified a need for improvement before this system can be used routinely to clean root canals.

For the time being, root canals must be mechanically enlarged. Larger apical preparations enhance the efficacy of irrigation, and the additional use of ultrasonic energy during cleaning and shaping may also increase the efficacy of endodontic irrigants. Ultrasons used passively in canals with sufficiently large apical preparations may reach and better clean any uninstrumented canal areas. One investigation studied the debriding ability of 2.5% NaOCl in canal recesses. In 10 of 11 cases, these researchers found significantly cleaner histologic sections after ultrasonically activated irrigation. In the ultrasonically treated group, the bacteria count was reduced by 99.8%. However, hand filing alone reduced the bacteria count by 99.3%; therefore the improvement from ultrasonic therapy was limited. With ultrasonics, root canals are debrided by shear stresses produced between the irrigant and the canal wall, with subsequent cell disruption.

Acoustic streaming of the irrigation fluid through ultrasonic treatment has been suggested as a method of improving cleanliness. However, this effect occurs mainly in the most coronal levels; the apical areas were least affected by activated irrigation. Because the amplitude of the oscillation is greatest at the instrument’s tip, attenuation and constraint most significantly affect the apical part, where the diameter of the canal is smallest.

One investigator reported that the most effective regimen with ultrasonic energy was to activate every dose of irrigant placed in the canal. With this approach, roughly 18 minutes of irrigation is required per canal. Other investigators used an irrigation time of 1 minute each for EDTA and NaOCl, which seems clinically more practical. These authors stated that the use of ultrasonic energy for irrigant activation did not improve debridement compared with control groups. However, bacterial species show varying degrees of susceptibility to ultrasonication.

Because of the conflicting evidence concerning the effectiveness of ultrasonics in root canal therapy, other methods of disinfecting and debriding canals properly must be studied. Such research might include better ways to deliver irrigants and disinfecting solutions.
SUMMARY

Cleaning and shaping are important, interdependent steps in root canal treatment. Cleaning, as demonstrated by an intracanal surface free of smear layer, can be done only after root canals have been sufficiently enlarged to accommodate adequate irrigation needles. Canal preparation is optimized when mechanical aims are fulfilled and enlargement is acceptable; such aims include avoiding both significant preparation errors and weakening of the radicular structure, which can result in fractures.

Taken together and performed to a high standard, the procedures described in this chapter lay the foundation for biologic success in both straightforward (Fig. 9-77) and more complicated (Fig. 9-78) clinical cases. Recall radiographs confirm favorable outcomes, or biologic success (i.e., the prevention or healing of periradicular periodontitis) over the years. Similarly, adherence to the principles discussed leads to predictable outcomes for root canal treatments.

Figure 9-77  Clinical cases treated according to the principles detailed in this chapter. A, Preoperative radiograph of tooth #30 with a periradicular lesion. B, Postobturation radiograph. C, Two-year follow-up radiograph shows osseous healing. D, Immediate postobturation radiograph of tooth #29 shows both a periapical and a lateral osseous lesion. E and F, One-year and three-year follow-up radiographs show progressing osseous healing. Note the imperfect obturation of tooth #30.
Figure 9-78 Complicated clinical cases treated with hybrid techniques. A, Preoperative radiograph of tooth #16 indicates laceration and significant curvature of all roots. B, Postoperative radiograph shows multiple planes of curvature. C, Preoperative radiograph of tooth #19, which was diagnosed with irreversible pulpitis. D, Angulated postoperative radiograph shows three canals in the mesiobuccal root canal system, all of which were prepared to apical size #50. (A and B courtesy Dr. T. Clauder; C and D courtesy Dr. H. Walsch.)
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Chapter 10 - Obturation of the Cleaned and Shaped Root Canal System

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CORONAL SEAL

Success in endodontic treatment was originally based on the triad of debridement, sterilization, and obturation with all aspects equally important. Currently, successful root canal treatment is based on more broad principles. These include diagnosis and treatment planning, knowledge of anatomy and morphology, and the traditional concepts of debridement, sterilization, and obturation.

In an early radiographic study of success and failure, Ingle[126] indicated that 58% of treatment failures were due to incomplete obturation. Unfortunately, teeth that are poorly obturated are often poorly prepared. Procedural errors such as loss of length, canal transportation, perforations, loss of coronal seal, and vertical root fracture may have occurred and have been shown to adversely affect the apical seal.[285]

Since Ingle’s classic study, great emphasis has been placed on developing materials and techniques for obturating the radicular space. Various experimental methods have been used to assess microleakage following obturation, including radioisotopes,[69] dyes,[131] bacteria,[49] proteins,[173] and endotoxins.[49] These methodologies have employed a variety of in vitro conditions and experimental periods that often produce conflicting results. Fortunately clinical success rates following endodontic treatment are high despite the varied conditions, materials, and techniques employed. Circumstantial evidence indicates that the cleaning and shaping procedures provide an aseptic environment, and with this elimination of the etiology for pathosis the method of obturation becomes less critical.

The process of cleaning and shaping determines both the degree of disinfection and the ability to obturate the radicular space. Obturation is therefore a reflection of the cleaning and shaping and is evaluated on the basis of length, taper, density, level of gutta-percha removal, and the coronal seal (adequate provisional restoration) (Fig. 10-1). It is not possible to fully assess the seal established during obturation with a radiograph, and it is important to remember that no material or technique prevents leakage.[3][105] Indeed, obtaining an impervious seal may not be feasible because of the porous tubular structure of dentin.[2]
The primary etiology of pulpal and periradicular pathosis is bacterial. Pulpal remnants, necrotic tissue, bacteria, and bacterial byproducts remaining in the inaccessible areas of a cleaned and shaped canal system could initiate or perpetuate a lesion because the host defense mechanisms are unable to remove them. Evidence suggests that root canal systems cannot be completely cleaned and disinfected. Obturation of the radicular space is necessary to eliminate leakage. Obturation prevents coronal leakage and bacterial contamination, seals the apex from the periapical tissue fluids, and seals the remaining irritants in the canal.

Coronal leakage has also been demonstrated to contribute to treatment failure.

Maintaining a coronal seal and placing of a definitive restoration should be considered an essential component of successful endodontic treatment. Investigators suggest that it is more prudent to use a permanent restorative material to prevent leakage. One study found that good postendodontic restorations resulted in significantly more successful cases when compared with good endodontics (80% versus 75.7%) and poor restorations resulted in significantly more periradicular inflammation cases when compared with poor endodontics (30.2% versus 48.6%). The success rate for good restoration and good endodontics was 91% compared with a success rate of 18% with the poor endodontic treatment and a poor restoration. Another study found technically good endodontics produced the highest success rates. In
combination with technically good restorations the success rate was 81%. With poor restorations the success rate was 71%. Technically poor endodontics combined with either good restorations or poor restorations had significantly lower success rates 56% and 57%, respectively. The radiographic quality of the endodontic treatment was significantly more important than the technical quality of the coronal restoration when the periapical status of endodontically treated teeth was evaluated. One investigator[11] recently noted that the prognosis for endodontically treated posterior teeth restored with crowns was enhanced sixfold. Thus the ability to deliver high-quality endodontic and restorative treatment is a major factor in good clinical outcomes.

Using histologic and microbiologic techniques, investigators evaluated 39 teeth that were without proper restorations for at least 3 months and exposed to caries and the oral environment.[20] Thirty-four specimens were without radiographic discernible periradicular pathosis. Lesions were detected on five roots. Stainable bacteria were found in abundance at the orifice and in dentinal tubules but were absent midroot and apically in 37 roots. Inflammatory cell infiltrates were absent or sparse in 32 teeth while 7 teeth exhibited distinct inflammation. Despite pathosis involving five roots the results indicated that well-obtubated root canals are resistant to bacterial penetration when exposed to the oral environment. Findings in this study were consistent with an observational study that found coronal leakage was not a significant factor in root canal failure using matched pairs of teeth for analysis.[20]

Three-dimensional obturation of the radicular space is essential to long-term success. The canal system should be sealed apically, coronally, and laterally. Various methods have been advocated for obturation. Unfortunately all materials and techniques result in leakage[29] Although a poorly obturated canal and leakage are correlated, radiographic evaluation of obturation does not correlate well with leakage.[10][14] An adequate radiographic appearance of the obturation may not correlate with an adequate seal (Fig. 10–2). Variation in radiographic interpretation by the clinician, the overlying osseous structures, and the lack of uniformity in the obturation materials are significant variables.[26][72][73][14]

In a recent prospective study the Toronto group[83] evaluated success and failure of endodontic treatment at 4 to 6 years after completion of treatment. Teeth were treated by using flared preparation and vertical compaction of warm gutta-percha or step-back preparation and lateral compaction. Differences were noted with the adequacy of the fill and the treatment technique. Adequate length had a higher success rate (87%) when compared with inadequate length (77%). The flared preparation and vertical compaction had a higher success rate (90%) when compared with step-back preparation and lateral compaction (80%). This study also confirmed previous studies[24][25] indicating preexisting apical pathosis as a factor reducing a favorable prognosis and highlighted the obturation technique as a factor influencing success and failure.[24]

![Figure 10-2 A](image1.png) B, Angled view reveals voids.

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HISTORIC PERSPECTIVES

The achievement of a “hermetic seal” is often cited as a major goal of root canal treatment. According to accepted dictionary definitions, the word hermetic means sealed against the escape or entry of air—or made airtight by fusion or sealing. However, root canal seals are commonly evaluated for fluid leakage—a parameter used to praise or condemn obturation materials and techniques. This occurs both apically and coronally. Somehow the term hermetic has crept into endodontic nomenclature in a manner probably quite similar to the invention of an airtight seal. A god of wisdom, learning, and magic in ancient Egypt, Thoth, better known as Hermes Trismegistus (Hermes thrice greatest), is credited with this invention. His significant contribution to civilization allowed the preservation of oils, spices, aromatics, grains, and other necessities in previously porous, earthenware vessels. A simple wax seal of the vessel walls helped to create the “hermetic seal.” Endodontically speaking, the term hermetic is inappropriate; instead, terms such as fluid-tight, fluid-impervious, or bacteria-tight seals are more contemporary.

In 1924 Hatton indicated, “Perhaps there is no technical operation in dentistry or surgery where so much depends on the conscientious adherence to high ideals as that of pulp canal filling.” The essence of this statement had been significantly influenced by years of trial and error in both the techniques and materials used to obturate the prepared root canal system. Much of the frustration and challenge that emanated from this concern, however, was due to the lack of development in root canal preparation techniques coupled with indictments of the “focal infection” craze of that era.

Before 1800, root canal filling, when done, was limited to gold. Subsequent obturations with various metals, oxychloride of zinc, paraffin, and amalgam resulted in varying degrees of success and satisfaction. In 1847 Hill developed the first gutta-percha root canal filling material known as “Hill’s stopping.” The preparation, which consisted principally of bleached gutta-percha and carbonate of lime and quartz, was patented in 1848 and introduced to the dental profession. In 1867 Bowman made claim (before the St. Louis Dental Society) of the first use of gutta-percha for canal filling in an extracted first molar.

References to the use of gutta-percha for root canal obturation before the turn of the twentieth century were few and vague. In 1883 Perry claimed that he had been using a pointed gold wire wrapped with some soft gutta-percha (the roots of the present-day core carrier technique?). He also began using gutta-percha rolled into points and packed into the canal. The points were prepared by cutting base plate gutta-percha into slender strips, warming them with a lamp, laying them on his operating case, and rolling them with another flat surface (a contemporary technique used to custom roll a large cone?). Perry then used shellac warmed over a lamp and rolled the cones into a point of desired size, based on canal shape and length. Before placing the final gutta-percha point, he saturated the tooth cavity with alcohol; capillary attraction let the alcohol run into the canal, softening the shellac so that the gutta-percha could be packed (the forerunner of a chemical-softening technique?).

In 1887 the S.S. White Company began to manufacture gutta-percha points. In 1893 Rollins introduced a new type of gutta-percha to which he added vermilion. Because vermilion is pure oxide of mercury and therefore dangerous in the quantities suggested by Rollins, many people criticized this technique.

With the introduction of radiographs into the assessment of root canal obturations, it became painfully obvious that the canal was not cylindric, as earlier imagined, and that additional filling material was necessary to fill the observed voids. At first, hard-setting dental cements were used, but these proved unsatisfactory. It was also thought that the cement used should possess strong antiseptic action, hence the development of many phenolic- or formalin-type of paste cements. The softening and dissolution of the gutta-percha to serve as the cementing agent, through the use of rosins, was introduced by Callahan in 1914. Subsequently a multitude of various pastes, sealers, and cements were created in an attempt to discover the best possible sealing agent for use with gutta-percha.

Over the past 70 to 80 years the dental community has seen attempts to improve on the nature of root canal obturation with these cements and with variations in the delivery of gutta-percha to the prepared canal system. During this era the impetus for these developments was based heavily on the continued belief in the concept of focal infection, elective localization, the hollow-tube theory, and the concept that the primary cause...
for failure of root canal treatment was the apical percolation of fluids, and (potentially) microorganisms, into a poorly obturated root canal system. From this chronologic perspective of technical and scientific thought this chapter clarifies and codifies contemporary concepts in the obturation of the cleaned and shaped root canal system.
TIMING OF OBTURATION

Factors influencing the appropriate time to obturate a tooth are the patient’s signs and symptoms, the pulp and periradicular status, the degree of difficulty, and patient management.

Vital Pulp Tissue

Currently the consensus is that one-step treatment procedures are acceptable in cases where the patient exhibits a vital pulp. Removal of the normal or inflamed pulp tissue and performance of the procedure under aseptic conditions should result in a successful outcome because of the absence of bacterial contamination. Obturation at the initial visit also precludes contamination as a result of leakage during the period between patient visits.

Elective root canal treatment for restorative reasons can be completed in one visit providing the pulp is vital and time permits. Obturation of patients whose condition is urgent or emergent depends on the preoperative diagnosis. When pain occurs as the result of irreversible pulpitis, obturation can occur at the initial visit since removal of the vital tissue will generally resolve the patient’s pain.

Necrotic Pulp Tissue

Patients who present with pulp necrosis with or without asymptomatic periapical pathosis (chronic apical periodontitis, chronic apical abscess, condensing osteitis) may be treated in one visit based on what is known today. When patients present with acute symptoms caused by pulp necrosis and acute periradicular abscess, obturation is generally delayed until the patient is asymptomatic. However, more than 10 years ago, investigators demonstrated that cases with soft-tissue swelling could be completed in one visit with appropriate endodontic treatment, incision for drainage, and a regimen of antibiotics. Management of these patients, however, may be more difficult should problems persist or become worse after the completion of treatment.

During the 1970s there was concern about the timing of obturation. Performing endodontic treatment in one step was controversial. Conventional wisdom was that patients would have a higher incidence of postoperative pain; however, studies demonstrated that the incidence of pain was not increased in patients who were treated in one appointment versus those treated in multiple appointments.

In contrast to teeth with vital pulp tissue, teeth exhibiting pulp necrosis frequently exhibit bacterial contamination and may require a different approach to treatment. Sjogren et al raised questions regarding the long-term prognosis of teeth exhibiting necrotic pulp tissue and apical periodontitis treated in a single visit. In their clinical study the authors thoroughly instrumented only 55 infected teeth with apical pathosis teeth using only 0.5% sodium hypochlorite (NaOCl). Before obturation, cultures were obtained using advanced anaerobic bacteriologic techniques. Following cleaning and shaping, bacteria could be detected in 22 teeth. Complete healing occurred in 94% of cases that yielded a negative culture while the success rate of treatment of teeth with positive cultures before obturation had a statistically significant lower rate of success at 68%.

Other investigators overinstrumented and overfilled teeth 45 minutes following extraction. Following the procedures, teeth exhibiting vital pulps and no periradicular disease were without bacteria. Teeth exhibiting periapical pathosis before extraction demonstrated a high percentage of bacteria at the root apices. The organisms were found to remain firmly attached to resorptive lacunae, indicating the instrumentation/obturation procedures were unable to eliminate the organisms.

However, other investigators were unable to confirm Sjogren’s results, in a study of 39 patients with periapical lesions exhibiting both positive and negative canal cultures at the time of obturation. Twenty-one teeth were treated in one visit and 18 in two visits with an interappointment dressing of calcium hydroxide. Periapical healing was observed over a period up to 4.5 years with complete radiographic healing occurring in 81% of the cases in the one-visit group and in 71% of the cases in the two-visit group.
In a prospective clinical study, investigators evaluated the effect of calcium hydroxide as an interappointment dressing on the periapical healing of lesions associated with necrotic pulps in 73 patients. Thirty-six teeth were endodontically treated in one visit. Thirty-one teeth were treated in two visits with calcium hydroxide as an intracanal medicament. Periapical healing increased with the length of the observation period. In both treatment groups the success rate exceeded 90%, and no statistically significant difference existed between the two groups.\[272\]

Controlled laboratory studies support the use of calcium hydroxide as an antimicrobial agent before obturation of teeth with pulp necrosis. Two studies \[136\][137\] evaluated periapical healing of infected root canals in dogs. After inducing periapical pathosis the teeth were treated with immediate obturation or with calcium hydroxide for 1 week before obturation. Results of the radiographic examination at 6 months indicated complete healing was similar for the one-step (35.3%) and calcium hydroxide (36.8%) groups. The calcium hydroxide group had fewer failed cases (15.8% versus 41.2%) and more improved cases (47.4% versus 23.5%) when compared with the one-step group.\[137\] In histologic evaluations the calcium hydroxide group had significantly less inflammation than the one-step group.\[136\] One study also evaluated periapical healing of infected teeth in dogs following immediate obturation or with prior calcium hydroxide treatment for 7 or 14 days. Results indicated both calcium hydroxide groups were superior to the one-step group with the 14-day calcium hydroxide group being superior to the 7-day group.\[130\]

In general, obturation can be performed following cleaning and shaping procedures in cases when the canal can be dried and the patient is not experiencing swelling. An exception is the presence or persistence of exudation from the canal. Obturation of a canal that cannot be dried is contraindicated.

Complete cleaning and shaping should be accomplished and calcium hydroxide placed as an antimicrobial and temporary obturant in necrotic cases that cannot be treated in one visit\[242\] because investigators noted that bacteria in instrumented, unfilled canals can multiply and reach their pretreatment numbers in 2 to 4 days.\[44\]

Procedural concerns also dictate the time of obturation. Difficult cases may require more time for preparation and can be managed more uneventfully in multiple appointments. Patients may require multiple short appointments because of medical conditions, their psychologic state of mind, and fatigue.

* References \[90\][178\][182\][185\][207\][245\]
LENGTH OF OBTURATION

One of the controversies in endodontics that remains unresolved is the apical limit of root canal treatment and obturation. Early studies identified the dentinocemental junction as the apical limit for obturation. However, this histologic landmark cannot be determined clinically, and it has been found to be irregular within the canal. The dentinocemental junction may be several millimeters higher on the mesial canal wall when compared with the distal wall. In addition, the dentinocemental junction does not coincide with the narrowest portion of the canal or apical constriction. The reader is referred to Chapter 7 for more information on this anatomy.

Traditionally the apical point of termination has been 1 mm from the radiographic apex. Kuttler noted the apical anatomy consists of the major diameter of the foramen and the minor diameter of the constriction, with the apical constriction identified as the narrowest portion of the canal. The average distance from the foramen to the constriction was found to be 0.5 mm with the foramen varying in distance from the apex up to 2.5 mm. Kuttler also noted that the foramen to constriction distance increases with age because of cementum deposition. Supporting this finding, other investigators found the location of the foramen was not at the apex. Deviations occurred in 92% of the roots and averaged 0.6 mm. Still another investigator noted in 92% of examined teeth that the apical constriction was between 0.5 and 1 mm from the apex. One study noted the average apex to constriction distance was 0.9 mm and that 95% of the constrictions were between 0.5 and 1 mm; this study also noted that the classic apical anatomy described by Kuttler was present in only 46% of the teeth. Other variations identified were the tapering constriction, the multiconstriction, and the parallel constriction. Other investigators examined 230 roots of permanent teeth stereomicroscopically and with radiographs. Results of this study indicated a deviation of the foramen from the apex in 76% of the roots with microscopy and 57% with radiography; the mean distance was 1 mm.

A later study found no foramina coincided with the long axis of the root with the distance ranging from 0.2 to 3.8 mm. Root resorption is an additional factor in length determination. Resorption is more common with necrosis and apical bone resorption, and this can result in loss of the constriction. Based on these findings it appears that canals filled to the radiographic apex are actually overextended.
A recent study by the Toronto group[82] on the prognosis of re-treatment identified perforation, preoperative periradicular disease, and adequate length of the root canal filling as factors significantly influencing success and failure. The authors speculated that canals filled more than 2 mm short harbored necrotic tissue, bacteria, and irritants that when re-treated could be cleaned and sealed. The success rate for negotiating the apical unfilled canal was 74%.

Controversy also exists with regard to the role accessory canals play in success and failure (Fig. 10–6). For example, one scanning electron microscopy (SEM) study of apical anatomy of each tooth group except third molars noted no pattern for foraminal openings[102]; the number of accessory canals ranged from one to sixteen. While lateral canals can be associated with pathosis a recent study indicates that accessory canals are common but play little role in periradicular pathosis (Fig. 10–7).[15]
Further, other studies demonstrated that it is not possible to completely debride the canal space regardless of the technique or irrigant.\cite{154,271} Wein and Buchanan\cite{274} noted that these structures are only demonstrated. Often, smaller apical accessory canals remain unfilled or partially filled.\cite{268} Accessory/lateral canals are often obturated by chance and only serendipitously identified on the postoperative radiograph (Fig. 10–8).

Investigators compared obturation of lateral canals using six obturation techniques in resin blocks.\cite{71} All techniques were able to obturate lateral canals with sealer. Warm vertical compaction, carrier-based thermoplastic gutta-percha, continuous wave of compaction, and vertically compacted high temperature gutta-percha filled lateral canals with gutta-percha significantly better than lateral compaction or warm lateral compaction. The use of sealer enhanced the ability of the gutta-percha to obturate the lateral canals.\cite{71}

The importance of length control in obturation relates to extrusion of materials. Studies indicate that extrusion decreases the prognosis for complete regeneration.\cite{1} One study evaluated the quality of root canal treatment in an American population.\cite{41} Periapical disease was evident in 4.1% of all teeth and 31.3% of root-filled teeth, and the study noted that a periapical pathosis was found with 43% of the teeth with overfills. In another study of 1000 cases, investigators found that overfilling resulted in a failure rate of 37%. This was four times greater than cases filled short.\cite{251} A third study found in necrotic cases, better success was achieved when the procedures terminated at or within 2 mm of the radiographic apex.\cite{292} Obturation shorter than 2 mm from the apex or past the apex resulted in a success rate 20% lower. For vital cases, termination between 2 and 3 mm was acceptable. Other investigators found teeth obturated less than 2 mm from the apex had a higher success rate when compared with cases obturated more than 2 mm from the apex.\cite{193}

Based on biologic and clinical principles, instrumentation and obturation should not extend beyond the apical foramen. This was demonstrated in one study that histologically evaluated 41 human root – filled teeth from 36 patients.\cite{206} In six cases exhibiting overfills histologic examination revealed severe inflammation.

Whereas the guideline of 1 mm from the radiographic apex remains rational, the point of apical termination of the preparation and obturation remains empiric. The need to compact the gutta-percha and sealer against the apical dentin matrix (constriction of the canal) is essential for success. The decision of where the apical constriction of the canal lies is based on the clinician’s basic knowledge of apical anatomy, tactile sensation,
radiographic interpretation, apex locators, apical bleeding, and the patient’s response.

* References [24][25][26][27][28][29]

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PREPARATION FOR OBTURATION

During the cleaning and shaping process, organic pulpal materials and inorganic dentinal debris accumulate on the canal wall, producing an amorphous irregular smear layer (Fig. 10-9) as shown in a study that noted the smear layer is superficial with a thickness of 1 to 5 µm and this superficial debris can be packed into the dentinal tubules at varying distances.

In cases of necrosis this layer may also be contaminated with bacteria and their byproducts. For example, one study found bacteria can extend into the dentinal tubules of necrotic teeth 10 to 150 µm. Another study noted that capillary action and fluid dynamics play a role in packing debris into the tubules; and yet another investigation noted a mean penetration of 479 µm following a 28-day incubation period.

The smear layer is not a complete barrier to bacteria but may act as a physical barrier, decreasing bacterial penetration into tubules. This was illustrated by a study that demonstrated removal of the smear layer permitted colonization of the dentinal tubules at a significantly higher rate when compared with leaving the smear layer in place.

The smear layer may also interfere with adhesion and penetration of sealers into dentinal tubules. Evidence indicates that sealer penetration into dentinal tubules does not occur when the smear layer is present. For example, one study found removal of the smear layer permitted Roth 811 (Roth International, Ltd., Chicago, IL), CRCS (Coltene/Whaledent, Inc., Cuyahoga Falls, OH), and Sealapex to penetrate between 35 and 80 µm, whereas the presence of the smear layer obstructed tubular penetration of all sealers. Further, other studies found that that smear layer removal increased bond strength and reduced microleakage in teeth obturated with AH-26 (Dentsply/Maillefer, Ballaigues, Switzerland).

A different investigation found the combination of smear layer removal, AH-26 as the sealer, and vertical compaction of gutta-percha had a cumulative effect in reducing leakage.

There does not appear to be a consensus on removing the smear layer before obturation. The advantages and disadvantages of the smear layer remain controversial; however, evidence is growing to support removing the smear layer before obturation. The organic debris present in the smear layer might constitute substrate for bacterial growth, and it has been suggested that the smear layer prohibits sealer contact with the canal wall and permits leakage. Bacterial penetration in the presence of a smear layer in canals obturated with thermoplasticized gutta-percha and sealer has been shown to be significantly higher than with smear layer removal before obturation. An additional consideration is the presence of viable bacteria that remain in the dentinal tubules and use the smear layer for sustained growth and activity. Removal of the smear layer introduces the possibility of reinfecting the dentinal tubules if the leakage occurs. However, one study demonstrated bacteria present before obturation are not viable following obturation.

The smear layer may also interfere with the action of irrigants used as disinfectants.
layer is not removed, it may slowly disintegrate and dissolve around leaking obturation materials, or it may be 
removed by bacterial byproducts such as acids and enzymes.\textsuperscript{[430]}

The smear layer may interfere with the adhesion and penetration of root canal sealers. It also may prevent 
gutta-percha penetration during thermoplastic techniques.\textsuperscript{[106]} Significant tubular penetration of gutta-percha 
and sealers has been shown with thermoplasticized obturations\textsuperscript{[106]} and with dentin-bonded composite resins.\textsuperscript{[157]} Removal of the smear layer also enhances the adhesion of sealers to dentin and tubular penetration.\textsuperscript{[157]}

One investigation examined the penetration depth of three different root canal sealers into the dentinal tubules with and without the smear layer. Scanning electron microscopy of extracted single-rooted human teeth obturated with lateral compaction of gutta-percha using AH Plus (Dentsply/Maillefer), Apexit, and Roth 811 demonstrated that the smear layer prohibited the sealers from penetrating dentinal tubules. Smear layer removal allowed the penetration of all sealers to occur to a varying depth.\textsuperscript{[147]} A recent study found removal of the smear layer reduced both coronal and apical leakage regardless of the sealer tested.\textsuperscript{[56]}

An additional method of removing the smear layer involves sonic and ultrasonic instruments. In early studies of ultrasonic instrumentation, investigators noted the technique was effective in removing the smear layer.\textsuperscript{[59]} Another investigator also demonstrated smear layer removal with ultrasonication and NaOCl.\textsuperscript{[48]} A more recent study compared the cleaning efficacy of short-term sonic and ultrasonic passive irrigation with 5.25% NaOCl after hand instrumentation in the apical 3 to 6 mm of maxillary molar root canals.\textsuperscript{[419]} Passive sonic or ultrasonic irrigation for 30 seconds resulted in significantly cleaner canals than hand filing alone, and ultrasonic irrigation produced significantly cleaner canals than irrigation. However, other studies found ultrasonication and NaOCl to be ineffective in removing the smear layer.\textsuperscript{[18]}

A new method for removing the smear layer employs the use of a mixture of a tetracycline isomer, an acid, and a detergent (MTAD) (BioPure, Tulsa/Dentsply, Tulsa, OK) as a final rinse to remove the smear layer.\textsuperscript{[258]} MTAD removed most of the smear layer; however, some organic components of the smear layer remained on the surface of the root canal walls. The effectiveness of MTAD to completely remove the smear layer was enhanced when low concentrations of NaOCl were used as an intracanal irrigant before the use of MTAD as the final rinse. Further studies demonstrated MTAD was superior to NaOCl in antimicrobial action.\textsuperscript{[233,234]} A more recent study showed MTAD was effective in killing Enterococcus faecalis at 200× dilution, which was more potent than NaOCl because it ceased being active when diluted 32×; EDTA had no antimicrobial activity.\textsuperscript{[259]} One investigator found MTAD to be less toxic than eugenol, 3% H\textsubscript{2}O\textsubscript{2}, Ca(OH)\textsubscript{2} paste, 5.25% NaOCl, Peridex, and EDTA.\textsuperscript{[237]} Other investigators found no significant difference in flexural strength and modulus of elasticity in dentin bars exposed to MTAD, indicating no alteration in the physical properties of the dentin, and noted that teeth treated with the MTAD protocol for clinical use (20 minutes of 1.3% NaOCl/5 minutes of MTAD) may not need any additional dentin conditioning before the application of bonding agents.\textsuperscript{[165]}

Following the completion of cleaning and shaping procedures, removal of the smear layer is generally accomplished by irrigating the canal with 17% disodium EDTA and 5.25% NaOCl (\textbf{Fig. 10 - 10}).\textsuperscript{[19]} Chelators remove the inorganic components, leaving the organic tissue elements intact. NaOCl is necessary for removal of the remaining organic components. Fifty percent citric acid has also been shown to be an effective method for removing the smear layer,\textsuperscript{[17,112]} as has tetracycline.\textsuperscript{[13,113]}

http://home.mdconsult.com.eproxy1.lib.hku.hk/das/book/body/0/1357/7...
Chelating agents were introduced to endodontic treatment by Nygaard-Ostby in 1957 for treatment of calcified narrow root canals. EDTA is the chelating solution customarily used in endodontic treatment. It is available in both liquid and paste forms with common concentrations between 15% and 17%. Frequently a detergent is added to the liquid to decrease surface tension, to increase the cleaning ability, and to enhance the bactericidal action of the solution. The effectiveness of EDTA is related to time of application, the pH, and the concentration.

Demineralization results in increased dentin permeability because of the removal of the smear layer and plugs and enlargement of the tubules. It appears the tubular enlargement is due to selective removal of the peritubular dentin. The action of chelators and acids appears to be more effective in the coronal and middle thirds of the root and is reduced apically. This reduced activity may be a reflection of canal size. This is a clinical concern because of the more irregular structure of dentin in the apical third. A recent investigation demonstrated marked variations in the apical portion of the root including accessory root canals, areas of resorption and repaired resorptions, pulp stones, irregular or absent primary tubules, irregular secondary dentin, and cementum-like tissue lining the apical root canal wall. The variable structure of the apical region of human teeth presents challenges during endodontic obturation techniques requiring adhesives since this may influence the dentin bonding ability in the apical regions.

EDTA appears to be biocompatible when used clinically; however, irreversible decalcification of periapical bone and neuroimmunologic disturbances have been noted. Extrusion of both NaOCl and EDTA in clinical treatment should be avoided.

The recommended time for removal of the smear layer is 1 to 5 minutes. The small particles of the smear layer are primarily inorganic with a high surface/mass ratio that facilitates removal by acids and chelators. Investigators have found that a 1-minute exposure to 10 ml of EDTA was adequate to remove the smear layer and that a 10-minute exposure caused excessive removal of both peritubular and intratubular dentin.

The use of EDTA in combination with NaOCl is recommended and may enhance the cleaning and antimicrobial effects of these solutions when compared with using them alone.


THE IDEAL ROOT CANAL FILLING

Various endodontic materials have been advocated for obturation of the radicular space. Most techniques employ a core material and sealer. Regardless of the core material a sealer is essential to every technique and provides the fluid-tight seal.

The American Association of Endodontists’ Guide to Clinical Endodontics outlines contemporary endodontic treatment. Nonsurgical root canal treatment of permanent teeth involves the use of biologically acceptable chemical and mechanical treatment of the root canal system to promote healing and repair of the periradicular tissues. The process is accomplished under aseptic conditions with rubber dam isolation. With regard to obturation, the guide states, “Root canal sealers are used in conjunction with a biologically acceptable semi-solid or solid obturating material to establish an adequate seal of the root canal system.” In this area the guidelines indicate “Paraformaldehyde containing paste or obturating materials have been shown to be unsafe. Root canal obturation with paraformaldehyde containing materials is below the standard of care for endodontic treatment” (Fig. 10–11). Chapter 11 gives further information on this issue.

Figure 10-11 A periapical radiograph of a mandibular left second premolar and first molar demonstrating Sargenti paste root canal treatment. In addition to the toxic material, the technique often accompanies inadequate cleaning and shaping procedures.

Assessment of nonsurgical treatment is primarily based on the postoperative radiographic examination. The radiographic criteria for evaluating obturation include the following categories: length, taper, density, gutta-percha and sealer removal to the facial cementoenamel junction in anterior teeth and to the canal orifice in posterior teeth, and an adequate provisional restoration is placed (Fig. 10–12).
Quality assurance is accomplished through a careful evaluation of treatment procedures. Only with this approach can deficiencies be identified and corrected. Although the anatomy and morphology of the radicular space vary tremendously, the obturated root canal should reflect the original canal shape. Procedural errors in preparation, such as loss of length, ledging, apical transportation, apical perforation, stripping perforation, and separated instruments, may not be correctable. Errors in obturation, such as length, voids, inadequate removal of obturation materials, and temporization, may be correctable.

Radiographic interpretation may vary among clinicians because of differences in radiopacity in root canal sealer/cements, constituents in specific brands of gutta-percha, interpretation of voids in vivo versus in vitro, the overlying bony anatomy, radiographic angulation, and the limited two-dimensional view of the obturated canal or canals.

An often overlooked aspect in the assessment of root canal obturation is the density of the apical portion of the fill. The apical third of the canal may be filled with a sea of root canal cement and a single master cone or poorly compacted mass of previously softened gutta-percha. Radiographically, the apical third of the canal appears less radiodense. An ill-defined outline to the canal wall is evident, along with obvious gaps or voids in the filling material or its adaptation to the confines of the canal. Because of the use of highly radiopaque root canal sealers/cements, the apical portion may only be filled with sealer, giving the clinician the false impression of a dense, three-dimensional obturation with gutta-percha.

Figure 10-12  A, Postoperative radiograph of a maxillary right first molar demonstrating adequate length, density, and taper. B, Postoperative radiograph of a mandibular right first molar with an adequate obturation.
Root canal sealers vary in radiopacity. Some contain silver particles or significant amounts of barium sulfate to enhance their radiopacity. Although these components may enhance visualization of anatomic structures such as lateral canals, it is important to realize they do not increase the sealing ability of the sealer. They may also give the impression a canal is well obturated when voids are masked by the density of the sealer. It is erroneous to claim that obturations with highly radiopaque sealers are better than those made with less radiopaque materials. This type of comparison and claim to superiority are both unfounded and unwarranted. The radiographic appearance or aesthetic appearance of the obturated canal system should be secondary to meticulous cleaning and shaping. Although assessment of the root canal obturation is based on radiographic findings, root canal sealers do not have to be highly radiopaque to be effective.
TYPES OF SEALERS

Root canal sealers are necessary to seal the space between the dentinal wall and the obturating core interface. Sealers also fill voids and irregularities in the root canal, lateral and accessory canals, and spaces between gutta-percha points used in lateral condensation. Sealers also serve as lubricants during the obturation process. Grossman[97] outlined the properties of an ideal sealer (Box 10-1). Currently no sealer satisfies all the criteria.

Box 10-1

Properties of an Ideal Sealer

- Exhibits tackiness when mixed to provide good adhesion between it and the canal wall when set
- Establishes a hermetic seal
- Radiopacity so that it can be seen on the radiograph
- Very fine powder so it can mix easily with the liquid
- No shrinkage on setting
- No staining of tooth structure
- Bacteriostatic, or at least does not encourage bacterial growth
- Exhibits a slow set
- Insoluble in tissue fluids
- Tissue tolerant; that is, nonirritating to periradicular tissue
- Soluble in a common solvent if it is necessary to remove the root canal filling

Sealers should be biocompatible and well tolerated by the periradicular tissues.[248] All sealers exhibit toxicity when freshly mixed; however, their toxicity is greatly reduced on setting. [153] Sealers are resorbable when exposed to tissues and tissue fluids.[12] Tissue healing and repair generally appear unaffected by most sealers, provided there are no adverse breakdown products of the sealer over time.[31][35][36][37][38] Breakdown products from the sealers may have an adverse effect on the proliferative capability of periradicular cell populations. [153] As a result, sealers should not be placed routinely in the periradicular tissues as part of the obturation technique. [153] Although an osteogenic response has been observed,[119][246][253][262] the ability of these sealers to sustain a high pH over time has been questioned.[148]

The most popular sealers are zinc oxide–eugenol formulations, calcium hydroxide sealers, glass ionomers, and resins. Regardless of the sealer selected, all exhibit toxicity until they set. For this reason, extrusion of sealers into the periradicular tissues should be avoided (Fig. 10-13).
Zinc oxide–eugenol sealers have a history of successful use over an extended period of time. Zinc oxide–eugenol sealers will resorb if extruded into the periradicular tissues.\cite{12} They exhibit a slow setting time,\cite{5} shrinkage on setting, and solubility,\cite{13}\cite{8} and they can stain tooth structure.\cite{6}\cite{20} An advantage to this sealer group is antimicrobial activity.\cite{4}\cite{13}\cite{115}\cite{174}

An early zinc oxide–eugenol sealer was introduced by Rickert and Dixon.\cite{203} This powder/liquid sealer contained silver particles for radiopacity. Although it was possible to demonstrate the presence of lateral and accessory canals the sealer had the distinct disadvantage of staining tooth structure if not completely removed. Procosl (Procosl, Inc., Philadelphia, PA) is a modification of Rickert’s formula in which the silver particles have been removed. Grossman\cite{98} modified the formulation and introduced a nonstaining formula in 1958 (Box 10–2). This is the formulation in Roth’s Sealer (Roth International). Tubliseal (SybronEndo, Orange, CA) is a catalyst/base zinc oxide–eugenol sealer that is convenient to mix but has a faster setting time when compared with the liquid/powder sealers. Wach’s Sealer (Balas Dental, Chicago, IL) contains Canada balsam, which gives the material a sticky or tacky property that softens the gutta-percha into a more homogeneous mass when used with lateral compaction.

**Box 10-2**

**Formula for Zinc Oxide–Eugenol Root Canal Sealer**

<table>
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<th>Powder</th>
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\textbf{Figure 10-13} A, Extrusion of sealer evident on the postoperative radiograph of a maxillary first molar. The separated lentulo spiral in the mesiobuccal root indicates a possible method of sealer placement. B, Maxillary occlusal film demonstrates that the sealer is located in the maxillary sinus. Correction using nonsurgical techniques is not possible. C, Maxillary right first molar with extrusion of the sealer and gutta-percha.
Calcium hydroxide sealers were developed for therapeutic activity. It was thought that these sealers would exhibit an antimicrobial activity and have osteogenic-cementogenic potential. Unfortunately these actions have not been demonstrated. Solubility is required for release of calcium hydroxide and sustained activity. This is inconsistent with the purpose of a sealer. CRCS Calciobiotic Root Canal Sealer is a zinc oxide–eugenol sealer with calcium hydroxide as one ingredient SealApex (SybronEndo) is a catalyst/base system. The base contains zinc oxide, calcium hydroxide, butyl benzene, sulfonamide, and zinc stearate. The catalyst contains barium sulfate and titanium dioxide as radiopacifiers in addition to resin, isobutyl salicylate, and aerosol R 972.

Glass Ionomer Sealers

The glass ionomers have been advocated for use in obturation because of their dentin-bonding properties. Ketac-Endo (3M/Espe, Minneapolis, MN) enables adhesion between the material and the canal wall. A disadvantage to glass ionomers involves removal if re-treatment is required. This sealer has minimal antimicrobial activity.

Resin

Resin sealers have a long history of use, provide adhesion, and do not contain eugenol. AH-26 is a slow-setting epoxy resin that was found to release formaldehyde when setting. AH Plus is a modified formulation of AH-26 in which formaldehyde is not released. The sealing abilities of AH-26 and AH Plus appear comparable.

Medicated Sealers

Sealers containing paraformaldehyde are contraindicated in endodontic treatment. Although the lead and mercury components may have been removed from these zinc oxide–eugenol formulations over time, the severely toxic paraformaldehyde content has remained a constant. These sealers are not approved
by the U.S. Food and Drug Administration[9] and are unacceptable under any circumstances in clinical treatment because of the severe and permanent toxic effects on periradicular tissues.[23] A paste containing 6.5% paraformaldehyde as well as lead and mercury was advocated for use by Sargenti[213][214][215] and originally marketed as N-2. Removal of the heavy metals resulted in a new formulation: RC2B. Other paraformaldehyde sealers include Endomethasone, SPAD, and Reibler’s Paste. The toxic in vivo effects of these materials on the pulp and periapical tissues have been demonstrated over time.[67][180]

Figure 10-15 Patient treated with Sargenti paste in her mandibular left second premolar and first molar. A, Preoperative radiograph exhibits an osteolytic response associated with the premolar and the proliferative response associated with the molar. B, Postoperative radiograph of the teeth. C, One year follow-up radiograph exhibiting osseous regeneration apical to the second premolar and appropriate restorative treatment.

In addition to the toxic nature of the material, clinicians employing the material place it with a lentulo spiral. Overextension has resulted in osteomyelitis and paresthesia.[61][145] One clinician reported irreversible neurotoxicity, manifested as dysesthesia, in cases overfilled with paraformaldehyde pastes.[145]
SEALER PLACEMENT

Various methods of sealer placement have been advocated, including the master cone, lentulo spirals, files and reamers, and ultrasonics. Investigators compared sealer placement using a file rotated counterclockwise, the lentulo spiral (Fig. 10-16), an ultrasonic file, and coating the master gutta-percha cone. Placement did not differ with the various techniques; however, the investigators noted the most variation in sealer coating was in the apical area. Another study compared sealer placement with a K-type file, the lentulo spiral, and using the master cone in curved canals. Results demonstrated no significant differences in the techniques after obturation; no technique covered more than 62.5% of the canal wall surface. Other investigators found ultrasonics produced the best sealer distribution when used circumferentially. These findings were supported by another study that found ultrasonic placement superior to manual techniques.

The method of obturation does not seem to affect the sealer distribution on the canal wall in the apical portion of the canal; however, lateral compaction results in better distribution in the mid-coronal areas when compared with warm vertical compaction. Recent evidence indicates the method of obturation affects the sealer penetration into tubules. This was exemplified by a study that found thermoplastic techniques produced deeper sealer penetration into tubules. Removal of the smear layer enhances sealer penetration into the dentinal tubules.
Although a variety of core materials have been used in conjunction with a sealer/cement, the most common method of obturation involves gutta-percha as a core material. Regardless of the obturating technique, emphasis should be placed on the process of cleaning and shaping the canal. The materials and techniques described do not routinely provide for an impervious seal of the canal system; all materials leak to some extent.\[2\] The choice of obturation techniques depends on the unique circumstances each case provides.

The properties of an ideal obturation material were outlined by Grossman\[97\] (Box 10–3). Historically, a variety of materials have been employed to obturate the root canal space. Solids, semisolid materials, and pastes have been employed. A common solid material was the silver cone.

Box 10-3

<table>
<thead>
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<th>Properties of an Ideal Obturation Material</th>
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<tr>
<td>• Easily manipulated and provides ample working time</td>
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<tr>
<td>• Dimensionally stable with no shrinkage once inserted</td>
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<td>• Seals the canal laterally and apically, conforming to its complex internal anatomy</td>
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<tr>
<td>• Nonirritating to the periapical tissues</td>
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<tr>
<td>• Impervious to moisture and nonporous</td>
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<tr>
<td>• Unaffected by tissue fluids—no corrosion or oxidization</td>
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<tr>
<td>• Inhibits bacterial growth</td>
</tr>
<tr>
<td>• Radiopaque and easily discernible on radiographs</td>
</tr>
<tr>
<td>• Does not discolor tooth structure</td>
</tr>
<tr>
<td>• Sterile</td>
</tr>
<tr>
<td>• Easily removed from the canal if necessary</td>
</tr>
</tbody>
</table>

Silver Cones

Jasper\[129\] introduced cones made of silver, which he claimed produced the same success rate as gutta-percha and were easier to use. The rigidity provided by the silver cones made them easy to place and permitted length control; however, their inability to fill the irregularly shaped root canal system permitted leakage (Fig. 10–17). When silver points contact tissue fluids or saliva they corrode.\[133\] The corrosion products have been found to be cytotoxic\[226\] and produce pathosis or impeded periapical healing.
With the introduction of the rigid silver cones it became possible to easily place them to length. This resulted in clinicians often failing to properly clean and shape the canal before obturation. Treatment failures were the result of the leakage and the failure to remove the irritants from the root canal system. The use of silver cones is considered to be below the standard of care in contemporary endodontic practice. For further information on this issue, the reader is referred to Chapter 11.

**Gutta-Percha**

Gutta-percha is the most popular core material used for obturation. It is the trans isomer of polyisoprene and exists in two crystalline forms (alpha and beta). In the unheated beta phase the material is a solid mass that is compactable. When heated the material changes to the alpha phase and becomes pliable and tacky and can be made to flow when pressure is applied. A disadvantage to the alpha phase is the material shrinks on setting.

Gutta-percha cones consist of approximately 20% gutta-percha, 65% zinc oxide, 10% radiopacifiers, and 5% plasticizers. Unlike rubber, room temperature gutta-percha cannot be compressed or made to flow. Compaction results in transmission of forces to the material and the canal wall equally and may result in root fracture. Gutta-percha can be made to flow if it is modified by either heat or solvents such as chloroform. This permits adaptation to the irregularities of the canal walls.

![Figure 10-17 Silver cones were advocated for ease of placement and length control. A, Radiograph of a facial maxillary right central incisor obturated with a silver cone. B, Tissue discoloration indicating corrosion and leakage. C, Lingual view indicates coronal leakage. D, Corroded silver cone removed from the tooth. E, Postoperative radiograph of the tooth.](image)

With the introduction of the rigid silver cones it became possible to easily place them to length. This resulted in clinicians often failing to properly clean and shape the canal before obturation. Treatment failures were the result of the leakage and the failure to remove the irritants from the root canal system. The use of silver cones is considered to be below the standard of care in contemporary endodontic practice. For further information on this issue, the reader is referred to Chapter 11.
The alpha form gutta-percha melts when heated above 65°C. When cooled extremely slowly, the alpha form will recrystallize. Routine cooling results in the recrystallization of the beta form. Although the mechanical properties for the two forms are the same, when alpha phase gutta-percha is heated and cooled it undergoes less shrinkage, making it more dimensionally stable for thermoplasticized techniques. The use of alpha phase gutta-percha for obturation has increased as thermoplastic techniques have become more common.

Gutta-percha cones are available in conventional and standardized sizes. The conventional nomenclature refers to the dimensions of the tip and body (Fig. 10–18). A fine-medium cone has a fine tip with a medium body. Standardized cones are designed to match the taper of stainless steel and nickel titanium instruments (Figs. 10–19 and 10–20). Unfortunately uniformity in manufacturing is not present, and the actual cone size varies.

**Figure 10-18** Conventional gutta-percha cones: extra fine, fine fine, fine, medium fine, fine medium, medium, large, and extra large.
Although the points cannot be heat sterilized, a recent study found gutta-percha points should be sterilized before use by placing the cones in 5.25% NaOCl for 1 minute. This study also found 2% gluteraldehyde, 2% chlorohexidine, and 70% ethyl alcohol were not effective in killing the *Bacillus subtilis* spores.\(^{[24]}\)

**Figure 10-19**  
A. Standardized cone sizes #15 to #40.  
B. Standardized cones #.06, taper sizes #15 to #40.  
C. Standardized cones Protaper S1, S2, S3.

**Figure 10-20**  
Size #30 standardized gutta-percha points exhibiting #.02, #.04, and #.06 tapers.
Resilon

Recently, resin-based obturation systems, Epiphany (Pentron Clinical Technologies, Wallingford, CT) and Real Seal (SybronEndo), were introduced as an alternative to gutta-percha. Resilon™ is a high-performance industrial polyurethane that has been adapted for dental use.

![Resilon System](image)

The system resembles gutta-percha and can be placed using lateral compaction, warm vertical compaction, or thermoplastic injection. It consists of a resin core material (Resilon) composed of polyester, difunctional methacrylate resin, bioactive glass, and radiopaque fillers and a resin sealer. Resilon is nontoxic, nonmutagenic, and biocompatible. The core material is available in conventional and standardized cones and pellets for use in the Obtura II (Obtura Spartan, Fenton, MO).

Following cleaning and shaping procedures an appropriate cone is fit and a radiograph obtained to verify the apical position. Since NaOCl may affect the bond strength of the primer, EDTA should be the last irrigant used before rinsing the canal with sterile water, saline, or chlorhexidine. After drying the canal a self-etch primer (sulfonic acid-terminated functional monomer, HEMA, water, and polymerization initiator) is used to condition the canal walls and prepare them for bonding to the resin sealant (resin matrix of BisGMA, ethoxylated BisGMA, UDMA, and hydrophilic difunctional methacrylates and fillers [70%] of calcium hydroxide, barium sulfate, barium glass, bismuth oxychloride, and silica). Two or three drops are placed in the...
canal using a pipette, a syringe, or a paper point that wicks the material to the apex. The excess primer is removed, the resin sealer is dispensed onto a mixing slab, and the viscosity is adjusted using the thinning resin. The sealer is applied using a paper point, Resilon point, or lentulo spiral. The canal is then obturated using lateral compaction, warm vertical compaction, or thermoplastic injection. The sealer takes approximately 25 minutes to set, so it is recommended that the coronal surface of the material be light cured for 40 seconds.

When using System B the temperature setting should be 150 °C at a power of 10. With the Obtura II thermoplasticized injection system the temperature settings vary depending on the needle tip employed. For the 25-gauge needle a 160 °C setting is selected, for the 23-gauge needle a 140 °C setting is utilized, and for the 20-gauge tip the setting that is recommended is 120 °C to 130 °C.

The Resilon core bonds to the resin sealer, which attaches to the etched root surface forming a “monoblock.” This results in a gutta-percha – sealer interface and a tooth-sealer interface (Fig. 10-23). This bonding of Resilon appears to provide a better coronal seal and may strengthen the root.

![Figure 10-23](scanning-electron-microscopy SEM view of Resilon tags extending into the dentinal tubules.]

Investigators evaluated coronal leakage of Resilon using *S. mutans* and *E. faecalis* in roots that are filled using lateral and vertical compaction techniques with gutta-percha and AH-26 or Resilon and Epiphany sealer.[236] Resilon showed significantly less coronal leakage when compared with gutta-percha. In another study, investigators used a dog model to assess the ability of Resilon or gutta-percha and AH-26 in preventing apical periodontitis in teeth inoculated with microorganisms. Results indicated periapical inflammation in 18 of 22 roots (82%) obturated with gutta-percha and AH-26 while the Resilon group exhibited periapical inflammation in 4 of 21 roots (19%).[237] Still another study demonstrated that teeth filled with Resilon were more resistant to fracture than roots filled with gutta-percha and AH-26 sealer.[257]

**Custom Cones**

When the apical foramen is open or a canal is large a custom cone may need to be developed (Fig. 10-24). This permits the adaptation of the cone to the canal walls, reduces the potential for extrusion of the core material, and may improve the seal.[21][140] The technique involves selection of a master cone and fitting the cone 2 to 4 mm short of the prepared length with frictional resistance. The cone is grasped with a locking cotton pliers or hemostat so that it can be placed into the canal in the same spatial relationship each time. The cone is removed and the tip softened in chloroform, eucalyptol, or halothane for 1 or 2 seconds. Only the outer superficial portion of the cone is softened. The central core of the cone should remain semirigid. The cone is then placed into the canal and gently tamped to length. The process can be repeated until an adequate impression of the canal is obtained at the prepared length. A radiograph is obtained to verify the proper fit and position. An alternative to solvents is softening with heat.[143]
Large canals necessitate fabricating a large master cone before canal adaptation. This can be accomplished by heating several large gutta-percha cones and rolling the mass between two glass slabs until an appropriate size is obtained (Fig. 10-25). A spatula may also be used to shape the cone.

Figure 10-24  Apical root resorption often results in an open apex requiring fabrication of a custom cone. A, Preoperative radiograph of the maxillary left central incisor with pulp necrosis and chronic apical periodontitis. Apical root resorption is present. B, In fabricating a custom master cone a gutta-percha point is fit several millimeters short before softening in solvent and tamping to place. C, Softening the apical 2 to 3 mm in chloroform that has been placed in a tuberculin syringe. D, The completed custom cone represents an impression of the apical portion of the canal. E, The postoperative radiograph with post space prepared. F, A 1-year follow-up radiograph demonstrating osseous regeneration.

Figure 10-25  For large canals several gutta-percha points can be heated and rolled together using a spatula or two glass slabs.
METHODS OF OBTURATION

Lateral Compaction

Lateral compaction is a common method for obturation (Fig. 10–26). The technique can be used in most clinical situations and provides for length control during compaction. A disadvantage is the technique may not fill canal irregularities as well as warm vertical compaction. The procedure can be accomplished with any of the acceptable sealers.
Following canal preparation a standardized cone is selected that has a diameter consistent with the largest file used in the canal at the working length. Standardized cones generally have less taper when compared with conventional cones and will permit deeper spreader penetration. An alternative is to adapt an appropriately tapered conventional cone by cutting small increments from the tip. This "master cone" is measured and grasped with a forceps so the distance from the cone tip to the forceps is equal to the prepared length. A reference point on the cone can be made by pinching the cone. The cone is placed in the canal, and if an appropriate size is selected, there will be resistance to displacement or "tug back." If the cone is loose it can be adapted by removing 1 mm increments from the tip. If the master cone fails to go to the prepared length a smaller cone can be selected. When the cone extends beyond the prepared length a larger cone must be adapted or the existing cone shortened until there is resistance to displacement at the corrected working length.

The master cone placement is confirmed with a radiograph. The canal is irrigated and dried with paper points. Sealer is applied to the canal walls, and a spreader is selected that matches the taper of the canal. Appropriate accessory points are also selected. The correlation between spreader size and conventional
cones is variable, and in small curved canals there does not appear to be a difference in the quality of obturation with conventional cones when compared with standardized cones.

Finger spreaders provide better tactile sensation and are less likely to induce fractures in the root when compared with the more traditional D-11T hand spreader. Spreader made from nickel titanium are available and provide increased flexibility, reduce stress, and provide deeper penetration when compared with stainless steel instruments. The spreader should fit within 1 to 2 mm of the prepared length, and when introduced into the canal with the master cone in place, it should be within 2 mm from the working length. There appears to be a correlation between establishing a seal and spreader penetration.

After placement the spreader is removed by rotating it back and forth as it is withdrawn. An accessory cone is placed in the space vacated by the instrument. The process is repeated until the spreader no longer goes beyond the coronal one third of the canal. The excess gutta-percha is removed with heat and the coronal mass compacted with an appropriate plugger. This process is repeated, compacting the cones until the spreader will no longer penetrate the coronal one third of the canal. Only light pressure is required because the gutta-percha is not compressible, and because as little as 1.5 kg of pressure is capable of fracturing the root (Fig. 10–27). For example, investigators noted that removal of dentin was a significant factor in root fracture.

A disadvantage to lateral compaction is that the process does not produce a homogeneous mass. The accessory and master cones are laminated and remain separate. It is hoped that the space between each of the cones is filled with sealer.

The excess gutta-percha in the chamber is then seared off and vertically compacted with a heated plugger at the orifice or approximately 1 mm below the orifice in posterior teeth. Warm vertical compaction of the coronal gutta-percha enhances the seal. In anterior teeth the desired level is the cementoenamel junction on the facial surface.

An alternative to lateral compaction with finger spreaders is ultrasonics. For example, one study found the technique produced an adequate obturation and a 93% clinical success rate.

Another study used ultrasonic-energized files in a warm lateral compaction technique and found the amount of gutta-percha by weight increased by 33% with two applications of ultrasonics when compared with lateral compaction. Unfortunately, investigators found the mean internal temperature rise was 29°C at the 6 mm level with external heat generation exceeding the safe limit of 10°C.

**Warm Vertical Compaction**
Schilder\textsuperscript{[228]} introduced warm vertical compaction as a method of filling the radicular space in three dimensions. Preparation requirements for the technique include preparing a canal with continuously tapering funnel and keeping the apical foramen as small as possible.

Armamentarium includes a variety of pluggers and a heat source. Schilder pluggers come in a variety of sizes (#8 = 0.4 mm, #8½ = 0.5 mm, etc. for sizes #9, #9½, #10, #10½, #11, #11½, #12) with increasing diameter. The instruments are marked at 5 mm intervals. Various ISO standardized instruments are also available (\textbf{Fig. 10–28}).

The technique involves fitting a master cone short of the corrected working length (0.5 to 2 mm) with resistance to displacement (\textbf{Fig. 10–29}). This ensures the cone diameter is larger than the prepared canal. Conventional cones that closely replicate the canal taper are best because they permit the development of hydraulic pressure during compaction. Following the adaptation of the master cone it is removed and sealer applied. The cone is placed in the canal and the coronal portion removed. Heat is applied with a heated spreader or plugger that removes portions of the coronal gutta-percha and softens the remaining material in the canal. The Touch ‘n Heat (SybronEndo) (\textbf{Fig. 10–30}) is an alternative to applying heat with a flame-heated instrument because it permits temperature control. A plugger is inserted into the canal and the gutta-percha condensed, forcing the plasticized material apically. The process is repeated until the apical portion has been filled. The coronal canal space is back-filled using small pieces of gutta-percha. The sectional method consists of placing 3 to 4 mm sections of gutta-percha approximating the size of the canal into the
root, applying heat, and compacting the mass with a plugger.

One study measured temperature changes in the canal with warm vertical compaction. The maximal temperatures were noted coronally and decreased apically. The authors noted at 8 mm from the apex the maximal temperature in the canal was 118°C. At 0 to 2 mm from the apex the maximal temperature
decreased to 44°C.[30] Another study compared root surface temperatures for warm vertical obturation using the System B heat source, the Touch’n Heat device, and a flame-heated carrier in maxillary and mandibular incisors and premolars 2 mm below the cementoenamel junction. System B and the Touch’n Heat produced a surface temperature rise that was less than 10°C for all maxillary and incisors and premolar teeth. The Touch’n Heat produced a greater than 10°C rise in mandibular incisors. The flame-heated carrier produced temperature changes greater than 10°C in all experimental teeth. Since the critical level of root surface heat required to produce irreversible bone damage is believed to be greater than 10°C the findings suggest that warm vertical compaction with the System B should not damage supporting periodontal structures; however, caution should be exercised with the Touch’n Heat and flame-heated carriers.[156]

The potential for vertical root fracture is also present with warm vertical compaction. The forces developed appear to be equal to lateral compaction.[28] Investigators compared warm vertical compaction and lateral compaction depicted by Endogrammes as a function of time. Results indicated the forces developed with the two techniques were not significantly different. In a follow-up study, mean values for the wedging with warm vertical compaction were 0.65 +/- 0.07 kg, whereas lateral compaction was 0.8 +/- 0.1 kg.[29]

Warm thermoplastic techniques have the advantage of producing movement of the plasticized gutta-percha, filling irregularities and accessory canals better than lateral compaction.[71][286] This is illustrated in a study that found a correlation between the quality of adaptation and the depth of heat application and canal size. Heat application close to the apical extent of the preparation produced the best results, and adaptation was better in small canals when compared with wide canals.[285] However, plasticized techniques result in more extrusion of materials.[152] There appear to be no consistent differences in the techniques in sealing the canal space.[286]

Advantages to the warm vertical compaction include filling of canal irregularities and accessory canals. Disadvantages are slight risk of vertical root fracture because of compaction forces, less length control than lateral compaction, and the potential for extrusion of material into the periradicular tissues. Warm vertical compaction is difficult in curved canals where the rigid pluggers are unable to penetrate to the necessary depth. To compensate for the rigid carriers to penetrate within 4 to 5 mm from the apex, the canals must be enlarged and more tapered in comparison with the lateral compaction technique. Excessive removal of tooth structure weakens the root.

**Continuous Wave Compaction Technique**

A variation of warm vertical compaction is the continuous wave compaction technique.[40] The increasing use of nickel-titanium rotary preparation techniques and the fabrication of standardized cones for files of greater taper have resulted in more clinicians using thermoplasticized techniques. The manufacturing of cones to mimic the tapered preparation permits the application of greater hydraulic force during compaction when appropriately tapered pluggers are used. The continuous wave compaction technique employs an electric heat carrier, System B unit, and #.06, #.08, #.10, and #.12 tapered stainless steel pluggers each with a tip diameter of 0.5 mm (Fig. 10–31). The #.06 tapered plunger approximates the fine conventional gutta-percha cone, the #.08 plunger the fine-medium cone, the #.10 plunger the medium cone, and the #.12 plunger the medium-large cone. Pluggers are consistent with the GT Profile instruments, and Autofit gutta-percha cones are also available.
The electric heat source permits a variable temperature setting. The recommended temperature setting for the System B unit is 200°C. One study evaluated internal and external temperature changes with the System B unit with varied tips and temperature settings of 200°C, 250°C, and 300°C. At 6 mm the System B unit set at 300°C with the fine-medium plugger produced the highest mean internal temperature (74°C). The authors noted the external temperature setting never exceeded the critical 10°C rise with any temperature setting or tip configuration.\cite{252} This was confirmed in another study that measured temperature changes 2 mm apical to the cementoenamel junction and at 1.5 mm from the apex. Results indicate temperature changes apically were negligible. The mean change near the cementoenamel junction was 4.1°C.\cite{267}

Another study found obturation temperature elevations produced during obturation with System B were significantly less ($P < 0.001$) than with the warm vertical compaction. An elevation of external root surface temperature by more than 10°C was noted with vertical compaction.\cite{238} Investigators measured the root surface temperatures while using the System B heat source at various temperature settings from 250°C to 600°C. Results indicated that the highest temperature occurred 5 mm from the apex, and only this site exceeded the 10°C rise. Based on this study a temperature setting of 250°C or greater may be potentially hazardous.\cite{85} For example, investigators using a thermocouple and simultaneous infrared analysis of temperatures found the root surface temperature averaged 13.9°C whereas the infrared technology indicated a 28.4°C rise at the same sites.\cite{172}

After fitting an appropriate master cone a plugger is prefitted to fit within 5 to 7 mm of the canal length (Fig. 10–32). The point of plugger binding is noted since once the instrument reaches this point the hydraulic forces on the gutta-percha will decrease and forces on the root increase. There appears to be a correlation between the depth of the heated plugger to the working length and the quality of obturation and filling of canal irregularities.\cite{29,133,288} Increasing the temperature settings does not seem to increase the effectiveness of obturation.\cite{133}
The System B unit is set to 200°C in the touch mode. The plugger is inserted into the canal orifice and activated to remove the excess coronal material. Compaction is initiated by placing the cold plugger against the gutta-percha in the canal orifice. Firm pressure is applied along with heat that is applied by activating the device. The plugger is moved rapidly (1 to 2 seconds) to within 3 mm of the binding point (Fig. 10–33). The heat is inactivated while firm pressure is maintained on the plugger for 5 to 10 seconds. After the gutta-percha mass has cooled a 1-second application of heat separates the plugger, and it is removed. The pluggers are designed to heat from the tip to their shank, which decreases the potential for dislodging the compacted mass and prevents a second application of heat to the material. Confirmation that the apical mass is still present in the canal can be established with hand pluggers. Two hand instruments are manufactured with tip diameters of 0.4 and 0.9 mm and 0.7 and 1.4 mm.

In ovoid canals where the canal configuration may prevent the generation of hydraulic forces an accessory cone can be placed alongside the master cone before compaction. With type II canals the master cones are placed in both canals before compaction. A hand plugger is used to stabilize the cone in one canal while the other is being obturated.

Filling the space left by the plugger can be accomplished using a thermoplastic injection technique (Obtura II or Ultrafil 3D [Colene/Whaledent, Inc.]) (Fig. 10–34) or by fitting an accessory cone into the space with sealer, heating it, and compacting with short applications of heat and vertical pressure.
Warm Lateral Compaction

Lateral compaction of gutta-percha provides for length control, which is an advantage over thermoplastic techniques. The Endotec II provides the clinician with the ability to employ length control with a warm gutta-percha technique (Fig. 10–35). Investigators demonstrated that the Endotec II produced a fusion of the gutta-percha into a solid homogeneous mass.[127] One study evaluated three thermoplasticized filling techniques and lateral compaction using a bacterial metabolite model and found the Endotec superior to lateral compaction alone, lateral hermocompaction, and Ultrafil 3D.[143] Investigators found warm lateral compaction with the Endotec increased the weight of the gutta-percha mass by 14.63% when compared with traditional lateral compaction.[161] Another study found a 24% increase in weight with warm lateral compaction using the System B device.[179] Other investigators compared the stress generated with lateral compaction and warm lateral compaction with the Endotec and found the warm lateral compaction technique created less stress during obturation.[168] Another investigator evaluated the effects of warm lateral and warm vertical compaction on the periodontal tissues.[50] Neither technique produced heat-related damage.

The technique involves adapting a master cone in the same manner as with lateral compaction. An appropriate-size Endotec II tip is selected. The Endotec II tips are available in various tapers and tip diameters. The sizes consist of #.02/30, #.05/30, #.02/40, #.04/40, #.04/70, #.06/70, and #.06/100. The device is activated and the tip inserted beside the master cone to within 2 to 4 mm of the apex using light pressure. The tip is rotated for 5 to 8 seconds and removed cold. An unheated spreader can be placed in the channel created to ensure adaptation and an accessory cone placed. The process is continued until the canal is filled.

Thermoplastic Injection Techniques

Heating of gutta-percha outside the tooth and injecting the material into the canal is an additional variation of the thermoplastic techniques (Fig. 10–36). The Obtura II (Fig. 10–37) and Ultrafil 3D (Fig. 10–38) systems are examples. The Obtura II system heats the gutta-percha to 160°C, whereas the Ultrafil 3D system employs a low-temperature gutta-percha that is heated to 70°C.
Figure 10-36  Thermoplastic techniques are often used in cases with significant canal irregularities. A. A preoperative radiograph of a maxillary central incisor exhibiting internal resorption. B. Postoperative radiograph demonstrates a dense obturation of the resorptive defect with gutta-percha.
Figure 10-37  Obtura II unit with silver tips, gutta-percha plugs, and cleaning solution.  (Courtesy Obtura Spartan, Fenton, MO.)
Obtura II

The Obtura II system consists of a hand-held “gun” that contains a chamber surrounded by a heating element into which pellets of gutta-percha are loaded. Silver needles (varying gauges of 20, 23, and 25) are attached to deliver the thermoplasticized material to the canal. The control unit allows the operator to adjust the temperature and thus the viscosity of the gutta-percha. At 6 mm from the apex a study found that the highest internal temperature with the Obtura II was 27°C.\(^\text{[252]}\)

Canal preparation is similar for other obturation techniques. The apical terminus should be as small as possible to prevent extrusion of gutta-percha. The technique requires the use of sealer, and once the canal is dried, the canal walls are coated with sealer using the last file used to length or a paper point. Gutta-percha is preheated in the gun, and the needle is positioned in the canal so that it reaches within 3 to 5 mm of the apical preparation. Gutta-percha is then gradually, passively injected by squeezing the trigger of the “gun.” The needle backs out of the canal as the apical portion is filled. Pluggers dipped in alcohol are used to compact the gutta-percha. A segmental technique may also be used, in which 3 to 4 mm segments of gutta-percha are sequentially injected and compacted. In either case, compaction should continue until the gutta-percha cools and solidifies to compensate for the contraction that takes place on cooling.

The difficulties with this system include lack of length control. Both overextension and underextension are common findings. To overcome this drawback, a hybrid technique may be used, in which the clinician begins filling the canal using the lateral compaction technique. When the master cone and several accessory cones have been placed so that the mass is firmly lodged in the apical portion of the canal, a hot plugger is introduced, searing the points off approximately 4 to 5 mm from the apex. Light vertical compaction is applied to restore the integrity of the apical plug of gutta-percha. The remainder of the canal is then filled with thermoplasticized gutta-percha injected as described.

Investigators studied the success rate of cases of 236 teeth obturated with the Obtura system at 3, 6, and 12 months. Results indicated 96% of the cases were successful, with the highest success rate being in teeth filled flush with the apex (97%) when compared with overextensions (93%) and filling short (93%).\(^\text{[254]}\) Another study compared lateral compaction with Thermafil and Obtura II in root canal models and found that the Obtura II produced the best adaptation to the canal walls.\(^\text{[277]}\) Other investigators found that continuous wave obturation with the Obtura II backfill initially produced a better bacterial seal when compared with lateral compaction using bilaterally matched teeth and an anaerobic bacterial leakage model.\(^\text{[128]}\)

Ultrafil 3D

Ultrafil 3D is a thermoplastic gutta-percha injection technique involving gutta-percha cannulas, a heating unit, and an injection syringe. The system employs three types of gutta-percha cannulas. The Regular Set is a low-viscosity material that requires 30 minutes to set. The Firm Set is also a low-viscosity material but differs in that it sets in 4 minutes. The manufacturer recommends compaction following the initial set with both materials. Endoset has a higher viscosity and does not flow as well. It is recommended for techniques employing compaction and sets in 2 minutes. The heater is preset at 90°C and does not require adjustment.

Each cannula has a 22-gauge stainless steel needle that measures 21 mm in length. The needles can be precurved. Cannulas can be disinfected but are not designed for heat sterilization procedures. Heating time varies, but for a cold unit it takes 10 to 15 minutes. In a warm heater the recommended time is 3 minutes. After removing the cannula from the heater the needle should be placed on the hot part of the heater for several seconds. The gutta-percha remains able to flow for 45 to 60 seconds depending on the viscosity.

Carrier-Based Gutta-Percha

Thermafil

Thermafil (Dentsply – Tulsa Dental, Tulsa, OK) was introduced as a gutta-percha obturation material with a solid core. Originally manufactured with a metal core and a coating of gutta-percha, the carrier was heated over an open flame. The technique was popular since the central core provided a rigid mechanism to facilitate
the placement of the gutta-percha. Advantages were ease of placement and pliable properties of gutta-percha. Disadvantages were that the metallic core made placement of a post challenging and re-treatment procedures were difficult. In addition, the gutta-percha was often stripped from the carrier, leaving the carrier as the obturating material in the apical area of the canal.

Recent changes in the carrier systems include the development of a plastic core coated with alpha phase gutta-percha (Fig. 10-39) and a heating device that controls the temperature (Fig. 10-40). Obturators are designed to correspond to the ISO standardized file sizes, variable tapered nickel titanium rotary files, and the GT Profile nickel titanium rotary files (Fig. 10-41). Size verifiers are available to aid in selection of the appropriate carrier and should fit passively at the corrected working length.
As with all techniques a sealer is required. Grossman formulation sealers and resin sealers consistent with AH-26 and AH Plus are acceptable; however, Tubiseal and Wach’s Paste are not recommended.

Removal of the smear is strongly recommended (see Chapter 9) and has been shown to enhance the seal with Thermafil. After drying the canal a light coat of sealer is applied and a carrier is marked, set to the predetermined length. This is accomplished by using the millimeter calibration markings on the carrier shaft. Markings are made at 18, 19, 20, 22, 24, 27, and 29 mm. Gutta-percha on the shaft that may be obscuring the calibration rings can be removed with a surgical blade or knife. The carrier is disinfected with 5.25% NaOCl for 1 minute and rinsed in 70% alcohol.

The carrier is then placed in the heating device. When the carrier is heated to the appropriate temperature the clinician has approximately 10 seconds to retrieve it and insert it into the canal. This is accomplished without rotation or twisting. Evidence suggests the insertion rate affects the obturation. The fill length and obturation of irregularities increase with increasing insertion rates. A rapid insertion rate enhances obturation.

The position of the carrier is verified radiographically. The gutta-percha is allowed 2 to 4 minutes to cool before resecting the carrier, which can be several millimeters above the canal orifice. This is accomplished by applying stabilizing pressure to the carrier and cutting the device with an inverted cone, round bur, or a specially designed Prepi (Dentsply – Tulsa Dental) bur. Heated instruments are not recommended for this process because this may result in displacement.
Vertical compaction of the coronal gutta-percha can be accomplished. When necessary, gutta-percha can be added, heat softened, and compacted. An advantage to this technique is the movement of gutta-percha into lateral and accessory canals (Fig. 10-43) [284]; however, extrusion of material beyond the apical extent of the preparation is a disadvantage.

ProPost drills (Dentsply – Tulsa Dental) are recommended if post space is required for restoration of the tooth. The unique eccentric cutting tip keeps the instrument centered in the canal while friction softens and removes the gutta-percha and plastic carrier.

When re-treatment is necessary the plastic carrier has a groove along its length to provide an access point for placement of a file. Chloroform and hand files can be used to remove the gutta-percha surrounding the carrier. Rotary #.04 and #.06 nickel titanium files may also be used to remove the obturation materials.

The plastic carriers are composed of two nontoxic materials. Sizes #20 to #40 are manufactured from a liquid crystal plastic. Sizes #40 to #90 are composed of polysulfone polymer. Both have similar physical characteristics with the polysulfone carriers being susceptible to dissolution in chloroform.

**Successfil**

Successfil (Coltene/Whaledent, Inc.) is a carrier-based system associated with Ultrafil 3D (Fig. 10-44); however, the gutta-percha used in this technique comes in a syringe. Carriers (titanium or radiopaque plastic) are inserted into the syringe to the measured length of the canal. The gutta-percha is expressed on the carrier with the amount and shape determined by the rate of withdrawal from the syringe. Sealer is lightly coated on the canal walls, and the carrier with gutta-percha is placed in the canal to the prepared length. The gutta-percha can be compacted around the carrier with various pluggers depending on the canal morphology. This is followed by the severing of the carrier slightly above the orifice with a bur.

![Figure 10-43](http://home.mdconsult.com.eprxyl.lib.hku.hk/das/book/body/0/1357/7...)

**Figure 10-43** Apical obturation of accessory canals with the Thermafil technique. *(Courtesy Dentsply – Tulsa Dental, Tulsa, OK.)*
SimpliFill (Lightspeed Technology Inc., San Antonio, TX) is manufactured for use following canal preparation with Lightspeed instruments (Fig. 10–45). The carrier has an apical plug with 5 mm of gutta-percha. The technique involves fitting a carrier that is consistent with the Master Apical Rotary File to within 1 to 3 mm of the prepared length (Fig. 10–46). The apical gutta-percha plug can be modified by clipping the end in 1 mm increments to obtain an appropriate fit if the plug is too small. Once the cone is fit it is withdrawn and sealer applied to the canal walls. The SimpliFill carrier is slowly advanced to the prepared length. This may require firm pressure. With the plug at the corrected working length the handle is quickly rotated a minimum of four complete terms in a counterclockwise direction. The coronal space can then be filled with gutta-percha, using lateral compaction or warm vertical compaction. When using lateral compaction it is recommended that the first cone be the same size as the SimpliFill carrier. This sectional technique is efficient, and leakage potential is similar to other common techniques. [212]

Figure 10-44  Successfill is an additional carrier system. (Courtesy Coltene/Whaledent.)

Figure 10-45  SimpliFill carrier and Lightspeed file.
Thermomechanical Compaction

McSpadden introduced an instrument with flutes similar to a Hedstrom file but in reverse. When activated in a slow speed handpiece the instrument would generate friction, soften the gutta-percha, and move it apically. Rotary compactors similar in design have been developed and advocated. To increase flexibility the instrument is available in nickel-titanium.

The technique requires fitting a master cone short of the prepared length and applying sealer. A compactor is selected based on the size of the canal and inserted alongside the gutta-percha cone 3 to 4 mm from the prepared length. The handpiece is activated and the gutta-percha is heated by the friction of the rotating bur. The pliable mass is compacted apically and laterally as the device is withdrawn from the canal.

Advantages include simplicity of armamentarium, the ability to fill canal irregularities, and time. Disadvantages are extrusion of material, instrument fracture, gouging of the canal walls, the inability to use the technique in curved canals, and heat generation.

Solvent Techniques

Gutta-percha can be plasticized by solvents such as chloroform, eucalyptol, and xylol. Disadvantages to the solvent techniques include shrinkage caused by evaporation, voids, the inability to control the obturating material, and irritation to periradicular tissues. The Callahan and Johnston technique involved dissolving gutta-percha in chloroform and placing the mixture into the canal with a syringe. A gutta-percha cone was then softened and placed into the canal; the mass hardened as the solvent evaporated. Unfortunately shrinkage occurred with the evaporation process. The techniques using solvents have been abandoned and replaced with materials and methods that do not exhibit shrinkage.

Pastes

Pastes fulfill some of the criteria outlined by Grossman and can adapt to the complex internal canal anatomy; however, the flow characteristic can result in extrusion or incomplete obturation. The inability to control the material is a distinct disadvantage, and when extrusion occurs it can only be corrected with surgical intervention. Pastes are sometimes used as a substitute for complete cleaning and shaping procedures, and the addition of paraformaldehyde results in severe toxicity.

Immediate Obturation

Apical barriers may be necessary in cases with immature apical development, cases with external apical root resorption, and cases where instrumentation extends beyond the confines of the root. Dentin chips, calcium

Figure 10-46 SimpliFill fit to 1 to 3 mm from the prepared length.
hydroxide, demineralized dentin, lyophilized bone, tricalcium phosphate, hydroxyapatite, and collagen have been advocated for placement as a barrier in canals exhibiting an open apex. The barriers are designed to permit obturation without extrusion of materials into the periradicular tissues but are often incomplete and do not seal the canal.\[211\]

Dentin chips appear to confine materials to the canal space during instrumentation/obturation and may encourage development of a biologic seal.\[79\][211] Enhanced healing, minimal inflammation, and apical cementum deposition have been noted histologically.\[189\] A concern with this technique is contamination of the dentin with bacteria because investigators found infected dentin adversely affected healing.\[121\]

Calcium hydroxide has also been extensively used as a common apical barrier. Calcium hydroxide has been shown to induce an apical barrier in apexification procedures. Calcifications similar to dentin plugs have been noted at the apical foramen.\[139\][199\] Calcium hydroxide has the advantage of being free of bacterial contamination and may provide a better, although imperfect, apical seal.\[275\]

Immature teeth exhibiting pulp necrosis or teeth with apical resorption traditionally were treated with calcium hydroxide to establish an apical barrier before obturation. A recent study demonstrated teeth treated with calcium hydroxide for prolonged periods are more susceptible to fracture.\[8\] Immediate obturation is an alternative to apexification. An apical barrier material should confine obturation materials to the canal space and enhance healing by inducing cementum and bone formation.\[118\][188\][199\] Recently, one investigator used mineral trioxide aggregate (MTA) (Pro Root, Dentsply – Tulsa Dental) as an apical barrier material before obturation (Fig. 10–47).\[235\]

![Figure 10-47](http://home.mdconsult.com.eproxy1.lib.hku.hk/das/book/body/0/1357/75) Mineral trioxide aggregate is available as ProRoot™. This material is advocated for use in apexification, repair of root perforations, repair of root resorption, root-end fillings, and pulp capping. (Courtesy Dentsply-Tulsa Dental, Tulsa, OK.)

Following the cleaning and shaping procedures the canal is dried and MTA placed. The material is compacted into the apical portion of the root to form a barrier. After the material sets, gutta-percha can then be compacted without extrusion (Fig. 10–48). Other investigators found hand compaction of MTA provided better adaptation to the canal walls with fewer voids when compared with ultrasonic placement.\[79\] Another investigation found that ultrasonic placement of a 4 mm apical plug of MTA improved the seal and that placement of a composite resin as the obturation material enhanced the seal and strengthened the root.\[155\]

MTA is sterile, biocompatible, and capable of inducing hard tissue formation. The technique has been shown to be clinically successful and can be accomplished quickly, eliminating the need for numerous visits and possible recontamination during the months required for apexification.

Figure 10-48 Immediate obturation employs a barrier technique to prevent extrusion when the apex is open. This case involves a maxillary left central incisor with pulp necrosis caused by trauma. A, Preoperative radiograph demonstrates a large canal with an open apex. B, Working length is established and the canal prepared. C, Mineral trioxide plug is placed. D, The canal is obturated with gutta-percha.
CORONAL SEAL

No matter which technique is used to obturate the canals, coronal microleakage can occur through seemingly well-obturated canals within a short time, potentially causing infection of the periapical area. Leakage studies indicate that the coronal seal can be enhanced by the application of restorative materials over the canal orifice. 

Cavit (Premier Dental Products, Plymouth Meeting, PA) has traditionally been advocated as an acceptable material. One study demonstrated that placement of 3.5 mm of Cavit or Super-EBA cement (Bosworth, Skokie, IL) decreased bacterial leakage 85% and 65%, respectively, when compared with the unsealed controls, which all leaked at 45 days. Another study demonstrated in a dog model that MTA placed in the orifice decreased inflammation in teeth inoculated with bacteria.

Another method to protect the canals in case of failure of the coronal restoration is to cover the floor of the pulp chamber with a lining of a bonded material after the excess gutta-percha and sealer have been cleaned from the canal. This results in a hybrid layer formation with microtags of resin in the tubules. The resin-modified glass ionomer cement is placed approximately 1 mm thick over the floor of the pulp chamber and polymerized with a curing light for 30 seconds. Investigators found that this procedure resulted in none of the experimental canals showing bacterial leakage at 60 days.
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Chapter 11  -  Endodontic Records and Legal Responsibilities

Edwin J. Zinman

ENDODONTIC RECORD EXCELLENCE

Importance

Endodontic therapy records serve as an important map to document and guide the dentist’s journey down the correct diagnostic and treatment path. Documentation is essential to attaining endodontic excellence.

The dental record must contain sufficient information to identify the patient, support the diagnosis, justify the treatment, and document the course and result of treatment. Records also are fundamental means of communication among health care professionals designed to protect the patient’s welfare.

Content

Endodontic treatment records should include the following information:

1. Name of patient
2. Date of visit
3. Medical (periodically updated) and dental history
4. Allergies and adverse drug reactions
5. Chief complaints
6. Radiographs of diagnostic quality
7. Clinical examination findings
8. Differential and final diagnoses
9. Treatment plan
10. Prognosis
11. Referral, including patient refusals (if any)
12. Communications with any other health care providers
13. Progress notes (including complications)
14. Completion notes
15. Canceled or missed appointments and stated reasons
16. Emergency treatment
17. Patient concerns and dissatisfactions
18. Planned follow-ups
19. Drug and laboratory prescriptions
20. Patient noncompliance
21. Consent forms
22. Accounting
23. Recall notifications
24. Name or initials of entry author

Function

Dental records should document the following information:

1. Course of therapy by recorded diagnosis, informed consent, treatment, and prognosis
2. Communications among the treating dentist and other health care providers, consultants, subsequent
A patient information form provides essential data for patient identification and office communication. The patient’s name, home, business, and e-mail addresses; and telephone and fax numbers are needed to contact the patient for scheduling purposes and to inquire about postoperative sequelae. Location information about the patient’s spouse, relative, or a close friend who can be notified in an emergency is also suggested. In the event the patient is a minor, the responsible parent or guardian should provide the information. Questions about dental insurance and financial responsibility are included on the form to avoid any later misunderstandings and to help fulfill federal requirements of the Truth in Lending Law, applicable if four or more installment payments are arranged (whether or not there are interest or late-payment charges). Patient information should be updated periodically (Fig. 11-1).

**Patient Information Form**

A patient information form provides essential data for patient identification and office communication. The patient’s name, home, business, and e-mail addresses; and telephone and fax numbers are needed to contact the patient for scheduling purposes and to inquire about postoperative sequelae. Location information about the patient’s spouse, relative, or a close friend who can be notified in an emergency is also suggested. In the event the patient is a minor, the responsible parent or guardian should provide the information. Questions about dental insurance and financial responsibility are included on the form to avoid any later misunderstandings and to help fulfill federal requirements of the Truth in Lending Law, applicable if four or more installment payments are arranged (whether or not there are interest or late-payment charges). Patient information should be updated periodically (Fig. 11-1).

**Medical Health History**

![Patient Information Form](image)

**Figure 11-1** Patient information form.
Past and present health status should be thoroughly reviewed by the dentist before proceeding with treatment so that dental treatment can be safely initiated. Health questionnaires open avenues for discussion about problems of major organ systems and important biochemical mechanisms, such as blood coagulation, allergy, immunocompromised status, and disease susceptibility. The dentist may request that the patient be examined by a physician or undergo a laboratory testing under medical supervision to determine whether a suspected medical problem may require attention before endodontic therapy proceeds or if drug sensitivity or allergy mandates treatment modifications. Current medications, medical therapy, and the name and location of the treating physician to be contacted in the event of emergency are essential.

Medical histories must be updated periodically (or at least annually or sooner as the need arises). The patient should be asked to review the previous and current medical history (Fig. 11-2). If no changes are necessary, the patient should date and sign the history form. If any changes are needed, the patient should identify each updated medical change and date and sign the form where indicated for medical update information. Periodically the patient should provide an entirely new updated form, rather than changing data on the old form. Earlier medical histories should be retained in the chart for future reference. If physician communication for treatment occurs, the clinician should record such contacts. In addition, the clinician should verify physician approvals for treatment by fax with verification of receipt or letter or preferably both, with copies retained in the chart.

**Figure 11-2** Medical history form.

Updating the medical history requires the practitioner to be apprised of changes in the patient’s medical condition and any new medications that the patient is taking. A patient untrained in medical science may not
appreciate the fact that new medication may suggest new diseases or changes in existing disease status. For instance, certain regurgitating valvular heart diseases may require antibiotic prophylaxis. New medications may also cause a synergistic effect with other medications that the patient is using or another treating clinician is prescribing.

Clinicians who pass the buck by claiming, “Oh it was my secretary or my assistant. I could do nothing about it,” are nonetheless legally liable for their staff’s actions or inactions. A clinician exclusively relying on staff members to obtain medical histories in a waiting room full of patients is making a mistake because the accuracy of the histories must first be checked and then followed up by the clinician. Training and monitoring staff are duties that clinicians cannot afford to ignore. President Harry Truman’s sage advice, “The buck stops here,” applies to treating clinicians who overdelegate to nondentist staff members who lack the requisite dental education for adequate medical history follow-up.

Dental History

The dental history should include past dental difficulties, name and address of current or most recent treating clinician, chief complaint (including duration and intensity of any pain), relevant prior dental treatment, and attitude regarding teeth retention. Positive responses suggest further patient consultation and consideration for obtaining records (by written release) for elucidation from the patient’s previous clinician. After receiving positive responses, the clinician may also wish to obtain prior radiographs for current comparison and notes of any progressive changes (Fig. 11–3).

**TELL US ABOUT YOUR DENTAL SYMPTOMS**

<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Are you feeling any pain at this time? If not, please go to Question 5.</td>
<td>Yes ____ No ____</td>
</tr>
<tr>
<td>2. If yes, where is the pain located?</td>
<td>Yes ____ No ____</td>
</tr>
<tr>
<td>3. When did you first notice any symptoms?</td>
<td></td>
</tr>
<tr>
<td>4. Did symptoms occur suddenly or gradually?</td>
<td></td>
</tr>
<tr>
<td>5. Please check the intensity, frequency, and quality of the discomfort, which most closely describes your pain:</td>
<td></td>
</tr>
<tr>
<td><strong>INTENSITY</strong></td>
<td><strong>FREQUENCY</strong></td>
</tr>
<tr>
<td>(On a scale of 1 to 10)</td>
<td></td>
</tr>
<tr>
<td>1  2  3  4  5  6  7  8  9  10</td>
<td>Constant</td>
</tr>
<tr>
<td>1  2  3  4  5  6  7  8  9  10</td>
<td>Intermittent</td>
</tr>
<tr>
<td>1  2  3  4  5  6  7  8  9  10</td>
<td>Momentary</td>
</tr>
<tr>
<td>1  2  3  4  5  6  7  8  9  10</td>
<td>Occasional</td>
</tr>
<tr>
<td>6. Is there anything you can do to relieve the pain?</td>
<td>Yes ____ No ____</td>
</tr>
<tr>
<td>7. Is there anything that provokes pain or that you do to cause the pain to increase?</td>
<td>Yes ____ No ____</td>
</tr>
<tr>
<td>8. When eating or drinking, is your tooth sensitive to:</td>
<td>Heat ___ Cold ___ Sweets ___</td>
</tr>
<tr>
<td>9. Does your tooth hurt when you bite down or chew?</td>
<td>Yes ____ No ____</td>
</tr>
<tr>
<td>10. Does it hurt if you press the gum tissue around this tooth?</td>
<td>Yes ____ No ____</td>
</tr>
<tr>
<td>11. Does a change in posture (lying down or bending over) cause your tooth to hurt?</td>
<td>Yes ____ No ____</td>
</tr>
<tr>
<td>12. Do you grind or clench your teeth?</td>
<td>Yes ____ No ____</td>
</tr>
<tr>
<td>13. Has a restoration (filling or crown) been placed on this tooth recently?</td>
<td>Yes ____ No ____</td>
</tr>
<tr>
<td>14. Prior to this appointment, was root canal therapy been started on this tooth?</td>
<td>Yes ____ No ____</td>
</tr>
<tr>
<td>15. Any recent or past trauma or injury to this tooth?</td>
<td>Yes ____ No ____</td>
</tr>
<tr>
<td>16. Is there anything else we should know about your teeth, gums or sinus that would assist us in our diagnosis or treatment?</td>
<td></td>
</tr>
</tbody>
</table>

Signature of Patient (or Parent) __________________________ Date __________
Diagnostic and Progress Records

Diagnostic and progress records often combine fill-in and check-off types of forms. Fill-in or essay-type forms allow greater latitude of response to a question, resulting in a more detailed description. However, one drawback to these forms is that they are open to oversights unless a clinician is very conscientious in following up with further clinical information.

Using only an essay-type health history is insufficient. Often a patient may not appreciate the significance of important symptoms. A check-off format is efficient and more practical. Forms with questions that reveal pertinent data alert the clinician to medical or dental conditions that warrant further consideration or consultation. Moreover, such records can document any missing medical information that the patient failed to provide orally. At the end of the check-off portion of the medical history, an essay question allows the patient to provide any omitted pertinent medical information or elaborate on check-marked items.

Electronic Records

Electronic records represent current methodology for recording patient information (see Chapter 26 for details). Several safeguards are essential for their use. First, patient confidentiality and security must be protected. Consider using AES encryption with at least 1024 bit key. Be certain that only the clinician and authorized staff view patient data in conformance with the Health Insurance Portability and Accountability Act (HIPAA) security standards, effective April 2005. Second, data backup of patient records including digital radiographs and account ledgers should be stored off-site and on-line for retrieval. The entire hard drive containing all computer files should be periodically backed up for additional protection. Multiple copies of the data should be stored in more than one geographic location, and fault protection such as RAID should be installed to prevent data loss.

Radiographs

Radiographs are essential for diagnosis and also serve as additional documentation of the patient’s pretreatment condition. A panographic radiograph is not diagnostically accurate for endodontics and therefore should be used only as a screening device (see Chapter 5). Diagnostic quality periapical plain-film or digital radiographs are essential aids for diagnosis, for working films (e.g., measuring the length of root canals, fitting gutta-percha cones), to verify the final fill, and for follow-up comparisons at recall examinations. Therefore the clinician should retake any radiographs that lack diagnostic quality and retain all radiographs.

Digital radiography is recommended because it increases endodontic efficiency. No developing time is needed. Thus procedural radiographs can be viewed instantly and approved or retaken with little time in between (no downtime is required to wait for a film to exit the film processor). Newer digital x-rays with improved sensor technology use high-resolution CCD (charged coupling device) chips rather than CMOS (complementary metal-oxide semiconductor) technology, and provide close-up zooming with improved image quality as described in Chapter 26.

Evaluation and Differential Diagnosis

Diagnosis includes evaluating pertinent history of the current problem, clinical examination, pulpal testing, periodontal probe charting, and recorded radiographic results. If therapy is indicated, then the reasons should be discussed with the patient in an organized way. When other factors affect the prognosis (e.g., strategic importance or restorability of the tooth), the clinician should consider further consultation with the referring clinician or specialists, including a prosthodontist or periodontist or both, before initiating any treatment.

Diagnosis is essential in treatment decisions. Recommending extractions for undiagnosed pain etiology is generally contraindicated. Chronic idiopathic orofacial pain warrants referrals and consultation with other health care professionals lest wholesale extractions worsen the patient’s dental state and not relieve pain (see Chapter 3). For instance, in a long-term follow-up study of patients with chronic facial pain and without recognizable odontologic pathosis, some patients were subsequently diagnosed with maladies ranging from cracked-tooth syndrome to medication-mediated illnesses. Accordingly, referral to other specialists is essential lest a patient be misdiagnosed with idiopathic or atypical facial pain when instead pain etiology was misdiagnosed.
**Diagnostic Tests**

Sound endodontics begins with a proper diagnosis. Otherwise, unnecessary or risky treatment with compromised prognosis follows. Generally, as described in greater detail in Chapter 1, the following endodontic tests should be performed to arrive at a correct and accurate endodontic diagnosis:

1. Percussion
2. Thermal testing
3. Electrical testing (optional)
4. Palpation
5. Mobility
6. Periodontal assessment (pockets, mobility, furcations)

Both positive and negative pulpal testing results should be recorded. Juries, peer review committees, and insurance consultants often disbelieve unrecorded test results. Uncharted test findings may be regarded as never having been done. Reasonable clinicians should record all testing results, both positive and negative.

**Treatment Plan**

Treatment records should contain a written plan that includes all aspects of the patient’s oral health. Treatment plans should be coordinated, preferably in writing, with other concurrent or jointly treating clinicians. If an aspect of the patient’s care is not under direct supervision, the clinician is proceeding improperly. Also the clinician should initiate contact with the other treating clinician. The patient should also be advised of the problem. For instance, endodontic treatment will probably fail if underlying periodontal pathosis is ignored or untreated. Therefore, the clinician should assess the patient’s entire dentition, not just a single root canal system. The clinician should also recommend a periodontal consultation to both the patient and referring clinician if periodontal therapy is required.

**Examination**

After gathering the dental and medical history, findings obtained from the various phases of the clinical and radiographic examinations are recorded as shown in Fig. 11–4. Lists in each category afford the clinician a systematic format for recording details pertinent to an accurate diagnosis. Appropriate descriptions are circled, followed by the necessary notations in the accompanying spaces. Tabular arrangement allows easier recording and comparison of diagnostic test data acquired from one tooth on different dates or from different teeth on the same visit. A pain intensity index (i.e., 0 to 10) or pain classification (i.e., mild +, moderate ++, severe ++++) should be used to differentiate diagnostic test results.
Diagnosis

Careful analysis of accumulated examination data should result in the determination of an accurate pulpal and periapical diagnosis. Clinical conditions and the probable etiologic factors for the presenting problem are circled. Alternative modalities of therapy are considered and analyzed. The recommended treatment plan is circled, followed by a prognostic assessment of the intended therapeutic course.

Patient Consultation

Patients should be advised of each diagnosis and should consent to the treatment plan before therapy is instituted. Consultation should include an explanation of reasonable alternative treatment approaches and rationales and treatment consequences of each alternative therapy, including risks from nontreatment or delayed treatment that may affect the outcome of intended therapy. Such discussion is documented by completing and endorsing the checklist.

Treatment

All treatment provided on a given date is documented by placing a check mark ( ) within the designated procedural category. Only the most frequent re-treatment procedures are included for tabulation. Descriptions of occasional procedures or explanatory treatment remarks should be entered in writing. A separate dated
entry should be made for each patient visit, phone call, e-mail message, and fax communication (e.g., consultations with the patient or other clinicians) or correspondence (e.g., biopsy report, treatment completion letters).

Individual root canal lengths are recorded by (1) circling the corresponding anatomic designation and the method of length determination (e.g., radiograph or electronic measuring device), (2) writing the measurement (in millimeters), and (3) indicating the reference point. For any medication prescribed, refilled, or dispensed, the treatment record should show the date and type of drug (including dose, quantity, and instructions for use) in the treatment table under the heading of Rx. Fig. 11–5 also gives a sample medication log. Periodic recall intervals, dates, and findings are entered in the spaces provided.

If the scope of the examination or treatment is intentionally limited, such as a screening examination or emergency endodontic therapy, the limited scope of the visit should be recorded. Otherwise, the chart appears as if the examination was superficial and treatment incomplete. If a suspicious apical lesion requires subsequent reevaluation, the clinician should record the future reevaluation date and differential diagnosis (e.g., “Small apical lesion on #28 to be evaluated for any changes in 2 months. Also, check for any root fractures.”). If this is not done it appears (on the chart) as if the clinician ignored a potentially pathologic condition, such as suspected root fracture. A soft-tissue examination (including cancer check) is a standard part of any complete dental examination.

**Informed Consent Form**

![Medication Log](http://home.mdconsult.com.eproxy1.lib.hku.hk/das/book/body/0/1357/8...2007-1-20)
After endodontic diagnosis, the benefits, risks, treatment plan, and alternatives to endodontic treatment, including any patient refusal of recommended treatment and consequences of refused treatment, should be presented to the patient or the patient’s guardian. This will document acceptance or rejection of treatment recommendations. The patient or guardian, along with a witness who can be a staff member, should sign and date the consent form. Any informed consent video should similarly be noted. Subsequent changes in the proposed treatment plan should also be discussed and initialed by the patient to indicate continued acceptance and to acknowledge the patient’s understanding of any newly disclosed risks, alternatives, or referrals.

Despite a patient’s confirmed signature on an informed consent form, a jury is free to believe that the patient never understood the informed consent form’s content before signing. If this is the case, the patient was uninformed and consent is legally voidable. For instance, the patient may claim it was impossible to have read the consent form because the patient did not have reading glasses when signing (or that no clinician ever explained the form contents). Another scenario is that the patient may claim to have been told it was a standard consent form that was a mere procedural formality requiring patient signature, rather than a detailed informed consent form. Consequently, numerous legal cases have been lost at trial on the issue of informed consent despite a signed patient consent form.

To obviate a patient’s claim that no explanation ever occurred, a patient questionnaire can additionally be used. Patients can be instructed that unless they score 100%, proposed procedures will not be done (because patient understanding is imperative and essential for cooperation, including postoperative care). To be effective, the patient questionnaire should be relatively short and simple (Fig. 11-4). Also, the patient should be given an opportunity to correct any incorrect answers after the clinician reviews with the patient the reasons why the patient answered incorrectly. It is of interest that the majority of answers are false. This precludes a patient from guessing the correct answer by assuming that all test questions are necessarily true.

Treatment Record: Endodontic Chart

Chart

A suggested chart is presented in Fig. 11–7 to facilitate recording of information pertinent to the diagnosis, recommendations, and treatment of the endodontic patient. Systematic acquisition and arrangement of data from the patient questionnaire, along with clinical and radiographic examinations and careful recording of treatment performed, expedite accurate diagnosis and maximize clinician efficiency. Suggested chart format and use are described in the sections that follow.
General Patient Data

Patient name, address, phone numbers, referring clinician, and chief complaint are printed or typed in the corresponding space at the patient’s initial office visit.

The patient’s appointment and financial record are divided into two parts:

1. The treating clinician or staff completes the first portion after the diagnosis and treatment plan have been formulated and presented to the patient. Tooth number and quoted fee are posted. Treatment plan is recorded by circling the appropriate description. Under “Special Instructions,” specific treatment requests by the referring clinician are circled. Details of planned adjunctive procedures (e.g., hemisection, root resection) may be written in the adjacent space, along with information from the patient data section. The clinician can then use this for general reference during future treatment. The dental secretary can also use this information when scheduling appointments and establishing financial arrangements.

2. Business personnel complete the second portion. Financial agreements, third-party coverage, account status, and appointment data, including the day, date, and scheduled procedure, are recorded.

Either the clinician or the assistant may complete portions of the following diagnosis and treatment sections. However, the clinician should review and approve all entries.
**Dental History**

The chief complaint should note if the patient is symptomatic at the time of examination. Narrative facts regarding the presenting problem are then recorded. Additional details of the chief complaint obtained during successive questioning are recorded by circling the applicable word within each symptom parameter. The pain intensity index (i.e., 0 to 10) or pain classification (i.e., mild +, moderate +++, severe ++++) should be registered alongside the appropriate description. For accurate assessment of the effects of prior dental treatment pertaining to the examination site, a summarized account of such procedures should be documented. In addition, all pretreatment signs and symptoms should be described. It is essential that the patient comprehend all communications with the clinician and staff. If there is any language comprehension difficulty, the clinicianshould ask the patient if the patient understands completely the language the clinician is speaking. The clinician should ask the patient to repeat important information the clinician conveys to verify patient comprehension. A clinician- or patient-provided interpreter may be necessary if language problems exist.

**Medical History**

More medical history information is obtained from a patient-administered questionnaire than from the clinician obtaining an oral history solely from the patient. Maximum information is obtained if the clinician reviews (with the patient) the written health history form that the patient has completed.

**Reference**

Information (e.g., personal physician’s name, address, and phone number; patient’s age; date of last physical examination) is recorded for reference. The clinician can obtain a detailed medical history by completing a survey of common diseases and disorders along with a comprehensive review of corresponding organ systems and assorted pathologic conditions. Specific entities that have affected the patient are circled. Essential remarks regarding these entries (e.g., details of consultations with the patient’s physician) should be documented on an attached blank sheet with dated treatment notes attached to the back of the chart (see Fig. 11–2). A review of the patient’s medical status (including recent or current conditions, treatments, and medications) completes the medical history. Medical histories should be updated at least annually and at reevaluation visits.
A current medical status will alert the practitioner to the potential for interaction between any newly prescribed drugs and drugs the patient is already taking. Older patients are more likely to be taking drugs for medical conditions concomitant with dental treatment. Risks of drug interactions may not be discovered in premarket research-controlled drug trials for newly marketed drugs approved by the U.S. Food and Drug Administration (FDA). Rofecoxib (Vioxx) was withdrawn from the market in September 2004 after an increased incidence of myocardial infarcts and strokes manifested in a postmarket study of 2600 patients. Merck’s voluntary recall followed an FDA researcher’s claim that the FDA tried to ostracize and intimidate him after he raised safety concerns over Vioxx. Currently, pharmaceutical manufacturers budget more for marketing than research and development. Some drug manufacturers have suppressed publication of adverse research, but that withholding of negative findings may change in the near future.

For newly marketed drugs the small number of premarket patients studied may lack sufficient statistical power to expose serious side effects that occur infrequently but are, nonetheless, life threatening. For instance, mibebradil (Posicor) was withdrawn from the market after 1 year because it increased plasma concentrations of 25 other co-administered drugs, including erythromycin. In another example, the popular prescription nighttime heartburn drug Propulsid (cisapride) was linked to 70 deaths and more than 270 significant negative reactions since 1993. In 2000 the FDA office of Post-Marketing Drug Risk Assessment changed the label warnings. The new Propulsid label highlights risks to patients taking a wide range of other medications, including antibiotics such as erythromycin, all protease inhibitors prescribed for patients with acquired immunodeficiency syndrome (AIDS), and the class of antidepressants including amitriptyline (Elavil) and nefazodone (Serzone). In previous, less stringent FDA warnings, taking Propulsid with grapefruit juice was...
Herbal Medications

Until 1962, drug companies were allowed to promote their products for any use as long as they were shown to be "safe" for one use. Manufacturers were marketing drugs with serious side effects for minor conditions and to vulnerable populations, resulting in many injuries and deaths. Ineffective drugs were the rule rather than the exception. When a retrospective review of all drugs was conducted after 1962, the National Academy of Sciences found that fully 80% of the uses for which drugs were being promoted could not be shown to be effective. Since 1962, the FDA has required prescription drug manufacturers to demonstrate safety and efficacy with research trials to gain FDA approval to market new drugs.

Promotion of ineffective drugs can be disastrous. The drug diethylstilbestrol (DES) was promoted to millions of women for preventing miscarriage in the 1950s and 1960s. Twenty years later, it was learned that DES was responsible for thousands of cases of unusual cancers and serious reproductive abnormalities in the children of women given DES. 

The Dietary Supplements Health and Education (DSHE) Act allows dietary supplements to be sold directly to consumers without any oversight or FDA regulation. In response to intense lobbying by the multibillion-dollar dietary supplement industry, Congress in 1994 exempted these products from FDA regulation. Products may contain amounts claimed, but they need not, and nothing can prevent their sale if they do not. For example, an analysis of ginseng products, showed no ginseng at all in some products. The DSHE Act places the burden of proof for dietary supplements' safety on the FDA and not the manufacturer. As a result, consumers of herbal supplements must depend on self-regulation within the industry for assurance of product quality, consistency, potency, and purity. 

An herbal product label can state the way the product is intended to affect "the structure or function" of the body but cannot claim its use for a specific disease. Manufacturers thus use creative language that complies technically with the statute but generally is confusing and deceptive.

Current medication history should include over-the-counter herbal and illicit drugs, because many have the potential for synergistic or antagonistic interaction with clinician-prescribed drugs. Ephedra (ma-huang) has been associated with 54 deaths, primarily involving cranial hemorrhage or stroke. Echinacea increases potential for liver damage when used with steroids. Gingko biloba and feverfew interfere with anticoagulants, such as warfarin (Coumadin). In 1998 California investigators found about one third of 260 imported Asian drugs were either spiked with unlabeled drugs or contained mercury, lead, or arsenic. A Los Angeles police officer who experienced a crippling stroke after taking an ephedra-based energy supplement, Dymetradine Xtreme, was awarded $4.1 million. The retail store owner had read but disregarded 30 journal articles warning of strokes, heart attacks, seizures, and other ailments. The stroke occurred before the FDA banned ephedra from sale in April 2004.

MedWatch

Newly marketed drugs may not list all potential adverse drug reactions or events because of the limited number of patients in research trials before marketing. Therefore the FDA’s MedWatch program encourages clinicians to report known or suspected drug reactions. Clinician reporting to the FDA is confidential and voluntary, and the patient’s identity need not be disclosed. Clinicians can contact the FDA by telephone at (800) FDA-1088 or fax at (800) FDA-0178 to obtain the FDA Medical Products Reporting Program (MedWatch) form (FDA form #3500). The back portion of the Physicians’ Desk Reference (PDR) contains a MedWatch form. Clinicians can also report suspected drug interactions by modem at (800) FDA-7737. Other electronic drug databases are available to report and access important drug interaction information. For FDA-approved safety-related drug labeling on-line, one can go to www.fda.gov/MedWatch. MedWatch encourages and facilitates clinician reporting of serious unexpected adverse drug reactions whose nature and severity are inconsistent with the drug’s labeled warnings.

Adverse drug reactions are injuries occurring when drugs are administered at usual doses. These reactions represent the primary focus of regulatory agencies and postmarketing surveillance. An adverse drug event suggests medication prescribing or dispensing errors that compromise patient safety. Unfortunately clinicians report only about 1% of adverse drug incidents to the FDA since clinician reporting is voluntary.
other hand, drug manufacturers must report adverse drug incidents to the FDA.

Clinicians should document adverse drug reactions not only in the progress notes but also in the allergy section of the chart in order to assess whether future use of the same drug is contraindicated and to prevent a harmful recurrence. Predictable adverse drug reactions that manifest should also be recorded as consideration for future disuse of a particular drug.

**Endodontics and Heart Disease**

Associations between chronic infections such as periodontal diseases and coronary heart disease (CHD) have been suggested. Conversely, supporting evidence linking root canal–filled teeth or teeth with periapical disease to CHD is lacking.

**Abbreviations**

Abbreviated records can be frustrating if the clinician is unable to decipher his own or other clinician’s handwritten entries. Therefore the clinician should use standard or easily understood abbreviations. Pencil entries are legally valid, but ink entries are less vulnerable to a plaintiff’s claim of erasure or alteration. A short pencil is better than a long memory; records remember but patients and clinicians may forget.

A sample of a completed endodontic chart (see Fig. 11–7) illustrates its proper use. Fig. 11–8 gives an explanatory key listing the standard abbreviations used in the chart.
Clinicians are increasingly using computerized record storage as described in Chapter 26. To avoid a claim of record falsification, whatever computer system is used should be able to demonstrate that records indicating earlier treatment were not recently falsified. Software technology, such as the “write only read memory” (WORM) system, used to identify computer data tampering, is not foolproof because it cannot detect tampering where an entire disk of recent origin has been substituted for an earlier version. Periodically a hard copy of computer data should be printed out, hand-initialed, and dated in ink and stored in the chart to provide written verification of the computer records.

The Department of Health and Human Services’ Security and Electronic Signature Standards rule is part of the Health Insurance Portability and Accountability Act of 1996 (HIPAA). This act emphasizes the safeguarding of clinician’s health care information and permits a patient to obtain a copy of the requesting patient’s records. Most states have authorized digital electronic signatures as binding for most contracts and orders. Digital signatures with electronic transactions are authorized by the Third Millennium Electronic Commerce Act (also called the Electronic Signature in Global and National Commerce Act).

Pertinent HIPAA requirements follow:

1. Patients are entitled to inspect or obtain a copy of their records on request. Since the act is silent regarding necessity of written requests, either an oral or written patient records request mandates the
Clinicians who keep brief records risk creating incomplete documentation. Although there is little harm in recording too much information, there is great danger in recording too little. Standard 8½ ×11 inch or larger clinical records possess the advantage of providing the treating clinician adequate space for clinical notes.

**Identity of Entry Author**

Either a clinician or an auxiliary can chart clinical entries unless state law indicates otherwise. What is important is that the correct clinical information is recorded. Each person who makes a clinical chart entry should record the date and initial the entry. Otherwise, the author’s identity may be forgotten if the individual who recorded the entry is needed in a legal proceeding. For instance, initialing the entry makes it easier to identify the particular clinician or auxiliary who, after the original recording, is now employed elsewhere. A separate log of clinician and staff initials should be created and stored for later comparison to identify the entrant’s initials.

<table>
<thead>
<tr>
<th>Clinician</th>
<th>Staff</th>
<th>Initials</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edwin J. Zimmerman</td>
<td></td>
<td>EZ</td>
<td>6-01-06</td>
</tr>
<tr>
<td>Alyssa Malfatti</td>
<td>AM</td>
<td>6-01-06</td>
<td></td>
</tr>
<tr>
<td>Stephen Cohen</td>
<td>SC</td>
<td>6/1/06</td>
<td></td>
</tr>
<tr>
<td>Kelly Fishman</td>
<td>KF</td>
<td>7/1/06</td>
<td></td>
</tr>
</tbody>
</table>

**Patient Record Request**

Patient requests for record transfers or copies must be honored. It is unethical to refuse to transfer patient records, on patient request, to another treating clinician.
Moreover, refusing to provide patient records is illegal in some states, subjecting the clinician to discipline and fines should the records not be provided to the patient on written request, even if an outstanding balance is owed.

**Patient Education Pamphlets**

Patient education pamphlets may be used in litigation as evidence that a patient was properly informed and given endodontic alternatives but instead chose extraction. Such pamphlets include the American Dental Association’s (ADA’s) *Your Teeth Can Be Saved by Endodontic Root Canal Treatment* or the American Association of Endodontists’ (AAE’s) *Your Guide to Endodontic Treatment, Your Guide to Endodontic Retreatment, and Your Guide to Endodontic Surgery*. The clinician should indicate in the patient’s chart which particular pamphlets the patient was provided since this may prove useful should the patient later deny being informed of an endodontic alternative.

**Postoperative Instructions**

It is unlikely a patient will remember oral postoperative instructions unless accompanied with written instructions. After endodontic procedures the patient may be sedated or affected by analgesic drugs. Accordingly, written postoperative instructions are beneficial. Emergency phone numbers to contact the treating clinician should be included on the form. Written instructions reduce postoperative morbidity and pain and improve patient compliance. The clinician should document that written and oral postoperative instructions were provided.

**Recording Referrals**

Every clinician, including the endodontic specialist, has a duty to refer under appropriate circumstances. If consultations with additional experts or specialists become necessary, referrals should be recorded, lest they be forgotten or refused. Carbonless, two-part referral cards allow the clinician to provide an original referral slip to the patient while retaining a copy for the patient’s chart. The clinician or staff member should document the fact that the original referral card was given to the patient and record the name of the person who provided the referral card and the date on which it was provided. If it is mailed to the patient, that fact should also be recorded in the chart. A copy of the referral card should also be sent to the referred doctor. If the patient fails to keep the referral appointment, this copy will provide proof that a referral was made. The clinician should request that the patient and the referred clinician report back if the referral appointment is cancelled; staff should verify that the referral consultation occurred.

**Record Correction**

Records must be complete, accurate, legible, and dated. All diagnosis, treatments, and referrals should be recorded. Chart additions may expand, correct, define, modify, or clarify (as long as they are currently dated to indicate a belated entry).

To correct an entry, the clinician should make a line through (but not erase or obscure) the erroneous entry. The correction should then be written on the next available line and dated. Handwriting and ink experts use ink chemical tags, age dating, and infrared technology to prove falsified additions, deletions, or substitutions. If records are proved to be falsified, the clinician may be subject to punitive damages in civil litigation. In addition, the clinician may be subject to license revocation for intentional misconduct. Professional liability insurance policies will usually not indemnify punitive damages if the clinician is found to have committed fraud or deceit. In addition, insurance carriers may deny renewal of professional liability coverage to a clinician who fraudulently alters dental records.

If an erroneous entry occurs, the clinician should add another entry dated as a late entry to demonstrate later corrected information. Figure 11-10 gives an example of the proper method of belated record correction.

- 10-13-05-Corrected entry for 10-12-05. (Entry should have recorded): Hot, cold, and percussion tests plus one. Recommend re-evaluation in 24 hours and repeat pulpal tests. Next visit scheduled 10/13/05 at 9 a.m.

**Figure 11-10** Belated record correction.
When patient records have been requested or subpoenaed, it is wise to refrain from examining them to avoid the temptation to clarify or amplify an entry. Alteration of clinical records is a cause of large settlements.

**Spoliation**

Spoliation occurs when the wrongdoer alters, changes, or substitutes dental records in an attempt to defeat a civil lawsuit. It is better to defend a dental negligence lawsuit with poor records than with altered (falsified) records. Otherwise, the jury may conclude the clinician acted with consciousness of guilt rather than with clerical oversight in maintaining adequate clinical records. Dental records, like all business records, deserve accuracy and completeness.

Record falsification or alteration may be detected by questioned document experts who utilize ink age dating, examine watermarks, or apply infrared techniques to ascertain substituted pages and additions or deletions in records, including prior erasures, entries underneath whiteouts, and indentations made when one page is overwritten on another page. Infrared technique analyzes these patterns of indentations underneath the altered pages that detect belated second entries. In one case the defendant clinician claimed a written referral was made to a specialist in 1998 but the patient refused the referral. During litigation the patient denied the referral and subpoenaed records of the print shop where the specialist’s referral forms were printed. These subpoenaed records proved the form used for the purported 1998 referral was first printed in 2000; that is, 2 years after the alleged referral was made.

Altered records were detected in nine different entries in one medical negligence case involving an undiagnosed malignancy. The physician’s carrier subsequently settled for 1 million dollars. Also the defendant personally paid a separate fine to the court. As part of the settlement the defendant authored an article for the Washington Medical Association detailing why records falsification is wrong.

Records are subjected to (1) audits by insurance carriers for documentation that treatment was performed, (2) review by peer review committees, and (3) subpoena by state licensing boards or agencies for disciplinary proceedings. Accordingly, falsified records expose the clinician not only to civil liability for professional negligence but also to criminal penalties for criminal offenses, such as insurance fraud.

Deliberate record alteration with intent to deceive may also subject the clinician to licensing, ethical discipline and/or punitive damages for deceitful misconduct. Insurance carriers may defend but not indemnify for intentional material alteration of dental records done with intent to deceive.

Texaco paid a record settlement of $176 million when tape recordings of company executives revealed a plan to destroy documents evidencing discriminatory employment practices. In addition, the Texaco executives were criminally prosecuted for obstruction of justice.

Digital radiography may have dental advantages, but because the digital images originally may be computer manipulated, they may be legally suspect as altered. Therefore hard copies of the digital images should also be printed and dated in ink to show the informational baseline upon which the clinician based diagnostic or therapeutic decisions. This also protects against computer glitches, such as disk drive crashes, electrical power surges, computer viruses, and operator delete errors.

**False Claims**

Performing or billing for unnecessary endodontic therapy, such as prophylactic endodontic therapy with every crown preparation, subjects the practitioner to fraud. In nonpulpal exposure crown preparation, the likely incidence of subsequent endodontic therapy is approximately 3%. Therefore performing prophylactic endodontics on the other 97% of patients represents unnecessary and therefore fraudulent treatment. Excessive treatment also ethically violates the Hippocratic Oath of “primum non nocere” (i.e., “first, do no harm”).

The Federal False Claims Act carries both civil and general penalties of treble damages, fines, and attorneys’ fees for fraudulently billing government programs, such as the CHAMPUS (Civilian Health and Medical Program of the Uniformed Services) or Medicare. Fines between $5000 and $10,000 per claim form apply if the U.S. mail was used for a false-claim submission. If any portion of the claimed treatment was fraudulently misrepresented, even if a small minority, a violation results. Fraudulent intent need not be
conclusively proved. Reckless disregard for the accuracy of submitted data is all that is necessary to obtain a federal criminal conviction or prove civil wrongdoing.
Malpractice Prophylaxis: Importance of Records

Good clinicians keep good records. Records re-present the single most critical evidence a clinician can present in court as confirmation that an accurate diagnosis, proper treatment, and informed consent were provided.

Prevention is the goal of modern dental care. Competent endodontic treatment performed within the requisite standard of care not only saves endodontically treated teeth but also helps prevent a lawsuit for professional negligence. Thus sound and carefully applied endodontic principles protect both clinician and patient. Prudent practices reduce avoidable and unreasonable risks associated with imprudent endodontic diagnosis or therapy.

Standard of Care

Good endodontic practice, as defined by the courts, is the standard of reasonable care legally required to be performed by a reasonably careful clinician. The standard of care does not require perfection; instead, the legal standard is the reasonable degree of skill, knowledge, and care ordinarily possessed and exercised by reasonably careful clinicians under similar circumstances. Although the standard of care is flexible to accommodate individual variations in treatment, it is objectively tested based on what a reasonable clinician should do. Reasonable conduct represents a minimum standard required for legal due care. Additional precautionary steps that rise above this minimal floor of reasonableness and approach the ceiling of ideal care are laudable, but they are not legally mandated.

Health Maintenance Organization Care versus Standard of Care

Reasonably careful or prudent practitioners (not insurance carriers) set the standard of care. Third-party payers may limit reimbursement but should not limit access to the quality of care. Clinicians have an affirmative duty on behalf of patients to appeal insurance carrier care denial decisions and, in some states, are protected against retaliation. The clinician who complies (without protest) with the limitations imposed by a third-party payer when sound judgment dictates otherwise cannot avoid ultimate responsibility for the patient’s care.

Although dental insurance companies do not set the standard of care, insurance carriers may contractually limit dental benefits. Therefore a clinician is obligated to inform patients of their dental needs, regardless of carrier reimbursement. Patients may then elect to pay out of pocket or decline uninsured services. Informed choice is uninformed if the clinician fails to provide patients with all reasonable options and alternatives. If an insurance carrier denies endodontic therapy or limits endodontics to only certain clinical conditions, a prudent clinician must provide informed consent to the patient both legally and ethically that a tooth may be endodontically treated and retained rather than extracted. The California Dental Association’s Dental Patient Bill of Rights advises patients that “You have the right to ask your dentist to explain all treatment options regardless of coverage or cost.”

Clinicians may agree to a discounted fee with a health maintenance organization (HMO) carrier but must never discount the quality of care provided. Peer review and the courts recognize only one standard of care: a lower or double standard for reduced-fee HMO plans is not legally recognized. Improved efficiency should not be accomplished at the expense of quality patient care.
An Illinois appellate court held that a clinician may be sued for injuries that a patient experiences as a result of the clinician’s failure to disclose a contractual arrangement with the patient’s HMO that creates financial incentives to minimize diagnostic tests and referrals to specialists. The court recognized a distinct cause of action for breach of fiduciary duty for failure to disclose these types of financial incentives. In reaching its conclusion, the court cited an American Medical Association (AMA) ethics opinion that stated that a clinician must ensure that a patient is aware of financial incentives through which health insurers limit diagnostic tests and treatment options.

Managed care organizations use a variety of strategies to influence the practice styles of providers. One of the most controversial of these methods is the use of financial incentives designed to limit referrals to specialists. Such financial incentives usually take the form of bonus payments drawn from surpluses in risk pools funded by “withholds.” These funds are deducted from the primary care provider’s base payments or otherwise reserved under contracts in which the care provider bears financial risk. Thus bonuses are based on referral limitations.

Plans that delay treatment approval resulting in endodontic complications or tooth nontreatability may be subject to liability. HMO carriers have not always succeeded in arguing that the 1974 Employee Retirement Income Security Act (ERISA) preempts state law for dental negligence claims against entities who administer health care benefits to an ERISA plan and shift blame to the clinician.

Capitation systems have a built-in incentive to undertreat, to delay, or to discourage treatment and access to care. For the HMO-paid clinician, the patient may be perceived as a threat to profits. Thus capitation creates incentives that can transform clinicians from the patient’s advocate to the patient’s adversary.

Although clinicians seem like double agents serving two masters (i.e., managed care carriers and patients), the law is clear that the clinician must always act in the patient’s best interest since the clinician owes a fiduciary obligation to the patient. Should the carrier deny requested care, the clinician is legally obligated to appeal the decision to protect the patient’s dental health.

Although profitable to insurance carriers, the success of denying or limiting benefits has created an era of rightfully indignant patients and frustrated clinicians. Consequently, the clinician must guard against patient disappointment with limited insurance benefits by explaining that although insurance carriers determine coverage under their patients’ insurance policy, carriers do not set the standard of care. Regardless of how much or how little is covered by the patient’s insurance carrier, prudent and reasonably careful clinicians set the standard of care. Providing less than necessary care because of insurance carriers’ dictates may explain resulting deficient endodontics but does not excuse such conduct.

**Dental Negligence Defined**

Dental negligence is defined as a violation of the standard of care (i.e., an act or omission that a reasonably careful or prudent clinician under similar circumstances would not have done). Negligence is equated with carelessness or inattentiveness. Malpractice is a lay term for such professional negligence. Dental negligence occurs for two reasons:

1. A clinician does not possess a reasonable degree of education and training to act prudently, or
2. Despite reasonable schooling, training, and continuing education, the clinician acts with unreasonable carelessness or imprudently fails to act as a reasonably careful clinician should act.

One simple test to determine if a particular treatment outcome results from negligence is to ask the following question: Was the treatment result reasonably avoidable? If the answer is “yes,” it is probably malpractice. If the answer is “no,” it is probably an unfortunate incident that resulted despite an attempt at reasonable care.

Not all examples of negligent endodontic treatment are included in this chapter because the myriad of malpractice incidents far exceeds the scope of this chapter. Rather, only select examples are elucidated for educational purposes.

**Locality Rule**

The locality rule, which provides for a different standard of care in different communities, is rapidly becoming
outdated. Originating in the nineteenth century, the rule was designed to acknowledge differences in facilities, training, and equipment between rural and urban communities.

The trend across the United States is to move from a locally based standard to a statewide standard, at least for generalists. For endodontists, a national standard of care is applied since the AAE board is national in scope. Because of nationally published endodontic literature, advances in Internet communication, continuing education courses, and reasonably available transportation for patients, no disparity generally exists between rural and urban endodontic standards.

A clinician should provide reasonably careful endodontic care to a patient regardless of treatment locality. Rather than focusing on different standards for different communities, other more important considerations include knowledge of endodontic advances in the field gained with continuing education and using improved diagnostics, instrumentation, and therapeutic interventions.

The locality rule has two major drawbacks. In areas with small populations, clinicians may be reluctant to testify as expert witnesses against other local clinicians. Also, the locality rule allows a small group of clinicians in an area to establish a local standard of care inferior to what the law requires of larger urban areas. Publications are available to all clinicians in print and on-line. In addition, clinicians can easily travel great distances to attend continuing education courses. Therefore to blame ignorance on a clinician’s rural location is inexcusable with modern media, computer technology, and travel ease.

Standards of Care: Generalist versus Endodontist

A general practitioner performing treatment ordinarily performed exclusively by specialists, such as apical endodontic surgery, periodontal surgical grafting, or full bony impaction surgery, will be held to the specialist’s standard of care. A generalist should refer to a specialist rather than perform procedures that are beyond the general practitioner’s training or competency to avoid performing treatment that is below the specialist’s standard. The three levels of clinical skill are (1) competency or beginning level, (2) proficiency, and (3) mastery. The ability to “know what we don’t know” is an important feature of any competent, ethical practice.

Approximately 80% of general practitioners in the United States provide some endodontic therapy. Endodontic expansion into the realm of the generalist can be linked to (1) refinements in root canal preparation and improved obturation (i.e., packing) techniques currently taught in dental schools; (2) continuing education courses; and (3) significant improvements in the armamentarium of instruments, equipment, and materials available to clinicians.

Higher Standard of Care for Endodontists: Extended Diagnostic and Treatment Responsibilities

Endodontists, as specialists, in certain instances may be held to a higher standard of skill, knowledge, and care than general practitioners. Endodontists set the standard for routine endodontics. Therefore if the endodontist’s standard of care cannot be met, the generalist should refer the patient to an endodontist.

Endodontists should not forget their general dentist training. Even though a patient may be referred for a specific procedure or undertaking, the endodontist should not overlook sound biologic principles inherent in the overall treatment. A specialist may also be held liable for relying solely on the information referral card or radiographs of the referring clinician if the diagnosis or therapeutic recommendations prove incorrect or the referral card lists the wrong tooth for treatment. Fig. 11-11 demonstrates a general clinician’s radiograph showing apparent complete endodontic fill within the canal space, whereas Fig. 11-12 demonstrates an endodontist’s radiograph showing a transported canal. This difference is explained by radiographic quality and angulation.
Endodontists should not provide rubber stamp treatment to what the clinician refers or recommends. Without performing an independent examination, the endodontist risks misdiagnosis and resulting incorrect treatment. Prevention of misdiagnosis or incorrect treatment requires an accurate medical and dental history preceding a clinical examination (not only of the specific tooth or teeth involved but also of the general oral condition). Obvious problems, such as oral lesions, periodontitis, or gross decay, should be noted in the chart and the patient advised regarding a referral for further examination, testing, or another specialist’s consultation.

Radiographs from the referring clinician should be reviewed for completeness, clarity, and diagnostic accuracy. An endodontist should expose a new radiograph to verify current status before treatment and only use the referring clinician’s radiograph for historical comparison. Unfortunately, the referring clinician may surreptitiously send a pretreatment film with the referred patient, rather than the clinician’s own posttreatment film depicting a perforation or broken file that necessitated the referral. This may occur whenever an errant clinician attempts to fraudulently conceal negligently performed endodontic treatment in an attempt to shift blame for bungled treatment to the endodontist. In such cases the endodontist learns a valuable lesson by exposing independent pretreatment radiographs, rather than relying exclusively on the referring clinician’s pretreatment radiographs.

Poor oral hygiene may contribute to periodontal disease. In such cases endodontic treatment may be compromised unless the associated periodontal condition, along with the tooth being tested endodontically, is brought under periodontal disease control (see Chapter 17 for more information). Referral to a periodontist may be necessary before or contemporaneous with completion of endodontic treatment.

In summary, it is necessary for the endodontist to do the following:

1. Be alert to any contributory medical or dental condition within the operative area of endodontic treatment that can affect treatment.
2. Undertake an independent diagnostic and radiographic examination of the treatment area and treatment plan rather than relying solely on the referring clinician.
3. Perform a general dental examination (at least a screening) to diagnose any hard- and soft-tissue pathosis.
4. Evaluate status and prognosis of adjacent and opposing teeth.
5. Advise the referring clinician and patient of pertinent findings.
Ordinary Care Equals Prudent Care

Ordinary is commonly understood (outside its legal context) to mean “lacking in excellence” or “being of poor or mediocre quality.” As expressed in the context of actions for negligence, however, ordinary care has assumed a technical legal definition somewhat different from its common meaning. Black’s Law Dictionary, ed 4, describes ordinary care as “that degree which persons of ordinary care and prudence are accustomed to use or employ — that is, reasonable care.”

In adopting this distinction the courts have defined ordinary care as “that degree of care which people ordinarily prudent could be reasonably expected to exercise under circumstances of a given case.” It has been equated with the reasonable care and prudence exercised by ordinarily prudent clinicians under similar circumstances. It is not extraordinary or ideal care. Thus ordinary care is not average care but instead equates with prudently careful care.

Although the standard required of a professional cannot be only that of the most highly skilled practitioner, neither can it be limited to the arithmetic average member of the profession, because those who possess somewhat less-than-median skill may still be competent and qualify. By such an illogical definition of average care, half of all clinicians would automatically fall short of the mark and be negligent as a matter of law. As one court stated: “We are not permitted to aggregate into a common class the quacks, the young men who have not practiced, the old ones who have dropped out of practice, the good, and the very best, and then strike an average between them.”

Customary Practice versus Negligence

Customary practice may constitute evidence of the standard of care, but it is not the only determinant. Moreover, if the customary practice constitutes negligence, it is not considered reasonable (although or even if customarily practiced by a majority of clinicians). Rather, the reasonably careful clinician is the standard of care and not an average or mediocre practitioner. For instance, a majority of clinicians did not perform biologic testing of the dental unit water lines despite ADA recommendations to do so. However, careful clinicians would follow this recommendation.

Typical examples of negligent customs include the following:

- Failing to probe and record periodontal pockets
- Failing to take diagnostic-quality radiographs
- Failing to refer patients for complicated procedures
- Failing to use aseptic practices, such as gloves and face masks
- Failing to use rubber dams for endodontics
- Failing to install or periodically check valves in dental units to prevent water retraction, suck-back, and cross contamination
- Failing to do thermal pulp testing as an aid to diagnose pulpal disease (see Chapter 1)
- Failing to discontinue quaternary ammonium chloride – based products for precleaning and/or disinfection of environmental surfaces

Merely because a majority of clinicians in a community practice a particular method does not establish it as the standard of care if such practice is unreasonable or imprudent. Ultimately, the courts determine what constitutes reasonable practice by considering available dental knowledge and evaluating the relative risks versus benefits of a particular procedure.

The law does not require dental perfection. Instead, the legal yardstick by which prudent conduct is measured is what a reasonably prudent clinician should do under the same or similar circumstances, regardless of how many or how few clinicians conform to such standard.

In one case it was not customary practice in the state of Washington for ophthalmologists to test patients under 40 years old for glaucoma, because the incidence was only 1 in 25,000 patients. Nevertheless, the Supreme Court of Washington state held that the defendant ophthalmologist was negligent as a matter of law, irrespective of customary medical practice, since a negligent custom is no defense.
Little excuse exists for failing to routinely probe and chart periodontal pockets before rendering endodontic therapy, no matter how many other clinicians in the community may fail to do so. The benefit of probing for periodontal disease substantially outweighs the virtually nonexistent risk of conducting this valuable diagnostic procedure. A legal defense likely to invoke a jury’s wrath is to claim that a necessary diagnostic or prophylactic procedure is “too time consuming,” when dental and medical patient health are placed at risk if not done.

**Continuing Education**

Continuing education should not add new skills at the expense of compromising or eliminating core clinical values. A prudent practitioner should be cautious adding a new methodology that is counterintuitive to basic biomechanical principles.

**Scientific Research Evaluation**

In evaluating scientific research the clinician should remember that epidemiologic data of risk factors are not always equivalent to etiology. Thus epidemiology is not a synonym for etiology. The scientific community has never exclusively relied on epidemiology as the accepted method of evaluating cause-and-effect relationships in an effort to make clinical decisions. Accordingly, clinicians should not consider only one class of data to supply ultimate proof when conducting an evaluation. Instead, clinicians should consider the strength of any study to be related to the presence and contributing cause of other co-factors. Thus the unusual characteristics of a particular patient can place the patient at higher risk than the average patient.

New products and procedures are often introduced faster than epidemiologic and toxicologic studies are implemented to evaluate their potential risks. Academic medical/dental centers are facing severe pressure on their reimbursement for health care services and post-graduate education. This creates the need to examine additional sources of revenue to fund their tripartite mission of education, research, and patient care delivery. Reduced government spending for research has resulted in proprietary interests (with proprietary goals) funding more research. Since 1984 the New England Journal of Medicine’s policy is to refuse publication of research done by those with financial ties to drug makers. However, in 1999 the journal admitted conflicts in nearly one half of the drug studies published since 1997. The next year, the retiring editor of the New England Journal of Medicine concluded that despite tax-supported privileges and extraordinary pharmaceutical industry profits, the best interests of society are not always served. A public trust more accountable to science is needed.

**Evidence-Based Endodontics**

Although much emphasis is currently placed on evidence-based medicine and dentistry, most clinical practices are not based on data derived from randomized clinical trials. It is virtually impossible to conduct a trial to test the validity of every possible patient management option. Many therapeutic choices are so compelling that a test would be unethical; others are so trivial that a test might not be worth the time or effort. Clinicians do not always practice in conformity to evidence-based research, even when evidence is available from randomized clinical trials. This is because knowing the right answer is only the first step in the process of adopting a new treatment methodology. Many clinicians will not use a new drug simply because supporting research data indicate that it works. Instead, identification of the probable mechanism of action is often a prerequisite before adopting a new treatment. Moreover, the test of time may eventually reveal an adverse effect of a particular drug or device; i.e., defects that were not identified before marketing.

Nevertheless, clinicians should not avoid using certain drugs if the data supporting their use are overwhelming. When the results of a clinical trial conflict with a widely held mechanistic model, many clinicians doubt research-based evidence. However, when the results from well-researched clinical trials become so convincing that the evidence can no longer be ignored, a prudent clinician embraces the new paradigm and discards previously held concepts. Endodontic science advances as disproved older concepts retreat. For example, delaying extractions until after several days of antibiotic use to reduce infection is no longer the accepted practice. Rather, immediate extraction, along with any necessary antibiotics, is the preferred current therapy.

**New Products**

New devices that lack definitive research studies should be used cautiously. For instance, high-intensity,
wireless, fast-curing lights may generate heat at the wand tip and cause pulpal pathosis. First-generation halogen bulbs require longer composite curing time to achieve polymerization but generate only 400 to 800 mW/cm. Plasma arc bulbs reduce curing time but generate 2000 mW/cm.

Hydron was marketed without long-term clinical testing. Its purported biocompatibility and reduced inflammation portended an improved endodontic drug for obturation. Postmarketing failures resulted from inadequate premarket testing that lacked long-term research. Thus Hydron’s inability to obturate canals with a durable filling material resulted in both clinicians and patients being harmed as postmarket guinea pigs. Hydron’s in vitro research did not match in vivo patients’ experiences.

Another example is Advance cement, which was touted as an improved cement for retaining permanent restorations. The high incidence of marginal leakage with Advance resulted in its withdrawal from the market in 2000. A class action settlement is pending against the manufacturer on behalf of California dentists with unsealed margins of crowns cemented with this luting agent.

Older devices over time, with sufficient patient experience, may manifest adverse events. Overheating with ultrasonic tips for post removal has resulted in teeth and tissue loss (Fig. 11–13). Accordingly, despite insufficient label warnings on ultrasonic devices, ample water coolant and avoidance of prolonged ultrasonic device use are needed for safe post removal.

**FDA Approval**

Despite FDA approval, some drugs are marketed with fraudulent concealment of the number and nature of adverse event incidents. More than 1 billion dollars was paid to settle 2771 lawsuits against the drug manufacturer of Baycol, a cholesterol-lowering drug potentially causing serious adverse injurious results including rhabdomyolysis fatalities.

**Postmarketing Drug Surveillance**

Clinicians and patients expect that when medications are prescribed correctly for FDA-approved, labeled indications and used as directed, these medications will produce beneficial effects and not cause significant harm. This confidence in pharmaceutical products reflects trust in the effectiveness and integrity of the drug approval and monitoring process. The FDA’s premarket approval process is designed to maximize the likelihood that FDA-approved drugs are both safe and effective for intended use.

Studies have estimated that between 28% and 56% of adverse drug events (ADEs) are preventable.
United States spends $122 billion annually on pharmaceuticals. Fatal ADEs are the fifth leading cause of death. According to a 1990 study by the U.S. General Accounting Office, 51% of approved drugs have serious adverse effects undetected before FDA approval, yet the governmental resources expended to ensure drug safety are extraordinarily limited.

Adverse reactions occurring in 1% or more of exposed patients are usually well described on marketing. However, less frequent reactions are not well described until after marketing. To provide the missing adverse data information, the FDA maintains a postmarketing surveillance system including passive voluntary clinician (MedWatch) reports of adverse drug reactions (ADRs) to detect adverse drug events. Calculation of true ADR rates requires an accurate number of events in the exposed population (numerator) and an accurate number of exposed individuals (denominator). There is no true numerator because with voluntary reporting it is unclear how many ADRs actually occur in a specific population. Accurate denominators likewise are unavailable since the actual number of patients taking prescribed drugs is unknown because the same patient may have numerous refills of the prescribed medication at risk. Because of these limitations, ADR reports are primarily useful for hypothesis generating rather than hypothesis testing.

In the United States, after a drug is approved for marketing, there is no FDA regulatory scheduled re-review of the drug. In Europe, drug approvals are re-reviewed every 5 years. The European process encourages companies to address outstanding issues, such as launching promised phase 4 trials, before the scheduled re-review. Some European companies have withdrawn drugs from the market rather than participate in a re-review. Europe also assesses drug manufacturers a postmarketing fee that contributes to postmarketing safety surveillance efforts.

In the late 1980s and early 1990s pharmaceutical manufacturers lobbied not for additional safety evaluations but rather for shorter FDA approval times. In response to political pressures that the FDA approval times were too long, the U.S. Congress introduced new drug application user fees in 1992. User fees enabled the FDA to hire additional FDA staff to reduce new drug applications’ approval time. However, the 1992 User Fee Act and its reauthorization in 1997 prohibited the FDA from spending users’ fees on postmarketing surveillance or other drug safety programs. Also, the FDA received no additional funds from the U.S. Congress for postmarketing safety. Faster new drug approvals, without additional funds for safety surveillance, shifted more of the burden from the FDA to the pharmaceutical industry to conduct its own postmarketing safety evaluations.

Since adoption of the 1992 Prescription Drug User Fee Act, which augmented the budget of the FDA by charging “user fees” to pharmaceutical firms, the FDA received approximately $825 million in fees from drug and biologic manufacturers from fiscal years 1993 through 2001. Median approval times for standard (i.e., nonpriority) drugs decreased from 27 months in 1993 to 14 months in 2001. However, drug recalls following approval increased from 1.56% for 1993 to 1996 to 5.35% for 1997 to 2001. Unsurprisingly, an investigation of 18 FDA expert advisory panels revealed that more than one half of the panel members had direct financial interest in the evaluated drug.

Detecting serious ADEs accurately and using them to determine incidence rates is difficult with the existing passive system for voluntary clinician reporting of ADEs. Some companies neglect to fully acknowledge reports that indicate harm and fail to initiate proper studies to determine risk. Also, drug event data evaluations are delayed when drug manufacturers fail to report in a timely manner. Companies’ financial incentives may influence interpretation of adverse event data and further delay full and complete FDA reporting.

Companies have funded highly defensive published journal articles as well as intimidated authors intending to publish contrary data that impair dissemination of negative product information. With pharmaceutical and biotechnology companies accounting for 9 of the top 50 largest public companies in the world, the financial resources for defensive tactics are substantial.

Fewer than one half of the postmarketing studies that manufacturers have committed to conduct as a condition of new drug approval have been completed. Many were never initiated. Despite the mandatory adverse event reporting system for companies subject to the FDA’s postmarketing safety reporting regulations, drug manufacturers too often fail to conduct appropriate studies to rigorously and promptly investigate potential risks. Between 1975 and 1999 the FDA approved 548 new chemical entities of which more than 10% received one or more black box warnings (N = 45) or were withdrawn from the market (N = 16).
Because of withheld data, the two pivotal trials designed to demonstrate lower rates of gastrointestinal problems of cyclooxygenase-2 (COX-2) inhibitors compared with nonsteroidal antiinflammatory drugs reported results much more favorable about these drugs’ safety than the companies’ research warranted. Crucial trial data with celecoxib was not revealed. For example, the authors submitted 6-month trial data when 12-month data from the trial were available at the time of submission for publication. With rofecoxib, the published data showed that gastrointestinal toxicity with rofecoxib was significantly less than that of the comparison drug (naproxen [Naprosyn]). Nevertheless, the increased cardiovascular toxicity was relegated to a brief paragraph in the discussion and erroneously dismissed as being due to the coronary protective effect of Naprosyn.[38]

After negative publicity of FDA-approved drugs concerning (1) antidepressants and associated risks of teenage suicide and (2) rofecoxib (Vioxx) and increased cardiovascular risks, the FDA began strengthening the safety program for marketing drugs. Promised FDA commitments include (1) sponsoring an Institute of Medicine study of its drug safety system; (2) implementing a program for adjudicating differences of professional opinion between FDA staff and outside experts; (3) appointing a director for the Office of Drug Safety (a position vacant for 14 months); (4) conducting drug safety/risk management consultations with other agencies, academia, the pharmaceutical industry, and the health care community; and (5) publishing risk management guidelines to help pharmaceutical firms in identifying and assessing potential safety risks.[42] Time and political fortitude will determine if the FDA delivers on its promises.

Negligence Per Se

Compliance with a health safety statute does not conclusively establish due care, because regulations require only minimal care and not (necessarily) prudent care or what the law regards as due care.[48] A civil liability duty of care may be imposed by statutes and safety ordinances. For example, a clinician’s violation of a health safety statute may create a presumption of the clinician’s negligence.[49] Although at trial the plaintiff ordinarily has the burden of proving negligence, a refutable presumption of negligence shifts the burden of proof to the defendant, if the following conditions are met:

1. Violation of a health safety statute, ordinance, or regulation of a public entity that caused injury
2. Injury resulted from an occurrence that the statute, ordinance, or regulation was designed to prevent
3. Person suffering the injury was one of the persons for whose protection the statute, ordinance, or regulation was adopted.[49]

Ability to Foresee Unreasonable Risk

Each endodontic procedure has a variable degree of inherent risk. The standard of care requires that the clinician avoid unreasonable risks that may harm the patient. Treatment is deemed negligent when a reasonably careful clinician would have foreseen some unreasonable risk of harm to the patient. Failure to follow the dictates of sound endodontic practice increases the risk of negligently induced deleterious results. Accordingly, prophylactic endodontic practice is designed to prevent foreseeable or reasonably avoidable injury risks. Foreseeability connotes predictability.

It is not necessary that the exact injuries that occur be foreseeable. Nor is it necessary to foresee the precise manner or circumstances under which injuries are inflicted. It is enough that a reasonably prudent clinician would foresee that injuries of the same general type would likely result in the absence of adequate safeguards.[4]

Informed Consent Principles

In General

The legal doctrine of informed consent requires that the patient be advised of reasonably foreseeable material risks of endodontic therapy, the nature of the treatment, reasonable alternatives, and the consequences of nontreatment.[14] This doctrine is based on the legal principle that individual patients have the right to do with their own bodies as they see fit, including the right to prematurely lose teeth, regardless of recommended dental treatment. Thus, once the clinician has informed the patient of the diagnosis, treatment risks, prognosis, and nontreatment risks, as well as recommendations for corrective treatment or alternative therapy, the patient has the right to decide how to proceed. An adult of sound mind is entitled to elect to do nothing about existing endodontic disease. Rather than elect corrective treatment, the patient may elect to
suffer any nontreatment consequences including future or present tooth loss or apical abscess.

To be legally effective, a patient’s consent to treatment involving potentially serious injury must include informed consent. Accordingly, a clinician has a fiduciary duty to disclose all material essential information necessary for the patient to make a decision[54]. The scope of a clinician’s duty to disclose information is measured by the amount of knowledge a reasonable patient requires to make an informed choice. Material information is that disclosure a clinician knows (or should know) that would be regarded as significant by a reasonable person in the patient’s position who must decide whether to accept or reject a recommended endodontic procedure.

If a clinician fails to reasonably disclose information that would make a reasonable person in the patient’s position decline the procedure, the clinician may be liable should an undisclosed risk manifest. Beyond the foregoing minimal disclosure, a clinician must also reveal such additional information as a skilled practitioner of good standing would provide under similar circumstances.

The personal bond between clinician and patient has long been considered an essential element of the therapeutic environment. Information is empowering. Laws requiring informed consent place patients on a closer footing with their clinicians. In addition to the transfer of information in both directions, bonding takes place when the clinician and patient engage in a conversation of length and substance. Canned disclosure displaces this human interaction. One of the surest safeguards clinicians can have against malpractice litigation is the bond of personal relationship forged with their patients.

Consent

Simple consent occurs when the clinician makes the treatment decision unilaterally and obtains the patient’s consent without offering the patient a choice. Conversely, informed consent is a joint decisional process whether to proceed with treatment or not.

Patients are legally empowered to decide for themselves when substantial competing risks are involved with each separate treatment choice. A patient’s therapeutic choice is particularly apt when there is no professional consensus for the best treatment. For instance, different implant systems exist with arguably different risks for each. A decision to proceed with an immediate implant versus waiting for osseointegration before initiating restorations requires that a risk versus benefit analysis be provided to the patient. Such decisions should include comparative peer-reviewed longevity research results compared with newer short-term immediate implant research. The benefits of immediate implant placement are attractive to both patient and clinician. To fairly compare researched implant survivability studies, the variables should similarly be controlled for each study, such as whether the implants are placed in native bone, socket size, and shape.

Emergency endodontic treatment often requires that the patient be provided pain relief. Acute pain clouds the patient’s decisional process. Therefore palliative treatment provides immediate pain relief so that on a return visit the patient can rationally decide among treatment choices. With ample time the patient can rationally decide and compare choices such as completion of endodontics and a crown versus extraction followed by an implant with crown. Also, an extraction which may result in alveolar ridge bone loss and the need for bone grafting are considerations that the clinician should explain to the patient.

Patient choices may be influenced by cost, convenience, time off work, travel needs, esthetics, or a myriad of other reasons. Thus the clinician plants the seeds of the decisional tree, but the patient decides which branch of the tree should be followed.

Informed Consent Application

Informed consent is a flexible standard that considers reasonably foreseeable consequences, depending on the clinical situation present both before and during treatment. For instance, a fractured or separated endodontic instrument left in the root canal creates the possibility of root canal failure or impaired success (depending on whether the fracture occurred in the coronal, middle [least favorable], or apical third of the root canal). Therefore the clinician must advise the patient of the relative risk of future failure and suggest treatment alternatives to correct the problem. An adequately informed patient can better make an intelligent choice among apicoectomy, referral to an endodontist for attempted retrieval, or close radiographic observation at recall visits. In Fig. 11–14 the clinician overinstrumented and perforated the inferior alveolar nerve, causing both a permanent dysesthesia and paresthesia. The clinician should have immediately referred the patient to an endodontist for attempted gutta-percha retrieval before the endodontic sealant...
containing eugenol set and caused more deleterious chemical injury to the inferior alveolar nerve. If retrieval was unsuccessful, the patient should have been referred to a microsurgeon within 36 hours from occurrence for optimal opportunity to prevent chemical cytotoxic injury to the inferior alveolar nerve.

Adequate disclosure includes clinical judgment and experience, which assesses current research and applies it to the clinical needs of each patient. Today’s advance may be tomorrow’s retreat if materials, devices, or instruments lacking adequate, long-term study of safety and efficacy are used but fail. For instance, the one-component bonding agent is more technique sensitive than its two-component predecessor. This is because the one-component agent contains acetone that desiccates the tooth surface and requires a moist surface to avoid postoperative sensitivity. Long-term testing before marketing would have revealed that the two-step system is more reliable and forgiving.[123] Reasonable clinicians do not sacrifice patient safety for speed and profit and then compensate with desensitizing agents. Clinicians should be more sensitive to limited research on new products or devices lest the patient be the injured guinea pig.

Material disclosure concerns whether the patient was provided sufficient information for a reasonable patient to achieve a general understanding of the proposed treatment or procedure. This disclosure includes information concerning any dentally acceptable alternatives, any predictable risks of serious injury, and any

![Figure 11-14](http://home.mdconsult.com.eproxy1.lib.hku.hk/das/book/body/0/1357/8...
likely consequences should the patient refuse the proposed therapy. The standard to be applied is whether a reasonable person in the patient’s position would have consented to the procedure or treatment in question if adequately informed of all significant perils. Informed consent applies only to inherent risks of nonnegligent treatment, because a patient’s consent to negligent treatment is voidable as being contrary to public policy. Accordingly, a patient who refuses necessary diagnostic radiographs should be refused treatment.

If warnings are limited to some risks but not others, some courts have held that the patient can recover for all surgical injuries including warned risks.

Restorative Informed Consent

Patient choices for restorations may discount longevity and elect instead aesthetics. For instance, in one study amalgams lasted 15 years, composites 6 years, and conventional glass isomers 7 years. Short-term restorations’ longevity increases the frequency of restoration replacement and increased potential for endodontic therapy with each replacement. Nevertheless, it is the patient’s treatment choice after the clinician first explains relative risks, benefits, and alternatives to the patient.

Different Schools of Thought.

After the clinician advises treatment, if other reasonable clinicians would disagree or if there are other respectable schools of thought on the correct treatment, this material information should be disclosed to the patient. For example, there may be two schools of thought concerning the optimal treatment for retrofitting and apicoectomy. One school posits that a retrograde with intermediate restorative material (IRM) mineral trioxide aggregate (MTA) is the appropriate procedure, whereas the minority review asserts that retrograde with Super EBA is the preferred treatment. One can assume further that an explanation of these two different methods of treatment constitutes material information for the purposes of informed consent. The mere fact that there is a disagreement within the relevant endodontic community does not establish that the selection of one procedure as opposed to the other constitutes negligent endodontic therapy. Because competent endodontists regularly use both procedures, a patient would have a difficult time proving dental negligence (i.e., that the endodontist failed “to have the knowledge and skill ordinarily possessed, and to use the care and skill ordinarily used, by reputable specialists practicing in the same field and in the same or a similar locality and under similar circumstances”). Moreover, neither school of thought possesses long-term clinical research results to prognosticate apical sealant insolubility rates in an 18-year-old patient with an additional 60-year life expectancy. Long-term durability depends on an insoluble seal to reduce the risk of bacterial leakage. Fig. 11–15 represents a preoperative and postoperative radiograph of a successful apicoectomy and retrograde in a 14-year-old.
On the other hand, the specialist would have a duty under the above hypothetical circumstances to disclose the two recognized schools of treatment so that the patient could be sufficiently informed to make the final, personal decision. An endodontist, being the expert, appreciates the risks inherent in the procedure prescribed, the risks of a decision not to undergo the treatment, and the probability of a successful outcome of the treatment. Once this information has been disclosed, this aspect of the endodontist’s expert function has been performed. The weighing of these risks against the individual subjective fears and hopes of the patient is not an expert skill. Such evaluation and decision constitute a nondental judgment reserved for the patient alone. In this hypothetical situation, failure to disclose such material information would deprive the patient of the opportunity to weigh the risks. Consequently, the clinician would have failed in the duty of disclosure, which the doctrine of informed consent requires.

When improved technology offers clearly superior results, it no longer becomes a patient choice issue but, rather, a requisite requirement to fulfill the standard of care. Apical microsurgery with ultrasonic tips for retrofilling exemplifies improved technology and the current standard of practice. Likewise, apical retrogrades should be done with MTA and not with amalgam. Finally, microscopic endodontics represents the current standard of care for apical surgery or fractured instrument retrieval.

Avoiding Patient Claims.
If a clinician fails to obtain adequate informed consent, a plaintiff can recover damages (even in the absence of any negligent treatment) should the patient testify that performed treatment would have been refused if the clinician had provided information concerning possible risks. Therefore discussions of treatment risks with the patient must be documented. Informed consent forms are very helpful, although not legally mandated, because a jury may believe that the patient was informed orally. Equally if not more important than consent forms is a chart notation indicating that the clinician discussed informed consent risks and alternatives (and that the patient understood and accepted this information). Patients may mentally block out frightening information. Trauma and a potent anesthetic agent can create retrograde amnesia. Therefore clinicians must document (in the patient’s chart) any risks, benefits, alternatives, and consequences of nontreatment provided to the alert patient before sedation.

Clinicians should follow only the patient-authorized and consented treatment plan. If an emergency precludes advising treatment risks to the minor patient, lack of informed consent may be defensible as implied consent (because no reasonable parent would refuse necessary, emergency treatment).

The following example demonstrates how a clinician should record any recommended treatment that the patient has refused and the reason for refusal:

“Patient refused endodontic referral for consultation with endodontist (Dr. Goodguy) because husband was laid off work last month and cannot afford treatment. After Dr. G. provided explanation, patient states she understands detrimental delay risks. ”

Patients may initial any referral refusal on the chart. Although patient signature is not mandatory, it will enhance the clinician’s credibility should the patient later dispute a referral was made.

Reasonable familiarity with a new product or technique is required before it is used. In addition, a patient is entitled to know the clinician’s personal experience with a particular modality because the patient has a right to chose between reasonable alternatives or to seek care from a clinician who has more extensive experience with a particular modality or new product. A clinician who fails to obtain informed consent may be liable for injury caused by a product or instrument. The fact that the clinician followed the manufacturer’s instructions is no defense if the clinician did not provide adequate information concerning a product or instrument risk (to permit the patient to intelligently weigh the disclosed information and choose among treatment options).

**Endodontic Informed Consent**

If the practitioner’s own statistical experience varies significantly from national statistics, using statistics presented in national literature regarding success rates for endodontic procedures is considered insufficient disclosure and does not fulfill the legal requirements of informed consent (Fig. 11–16).
Among specialists the reported incidence of treatment complications in endodontics is relatively low. Based on a Southwest Endodontic Society retrospective study, a reasonable endodontist or a practitioner with similar abilities should disclose the following facts to patients[115]:

Video-Informed Consent.

An animated video-informed consent shown to the patient is a dynamic method of providing informed consent. Because the video-informed consent is considered part of the clinician’s records, in the event the patient disputes having ever been advised of (1) the nature of endodontic disease, (2) the availability of endodontic specialists, or (3) the relative indications for nonsurgical versus surgical endodontic care, the videotape can be played back to the jury as proof that the patient was informed. It is doubtful a jury would believe a forgetful
patient who admits having previously viewed the videotape, because the videotape refreshes the stream of memories that may have otherwise faded into the unconscious.

A patient viewing the videotape is more likely to understand the informed consent disclosure of a technical procedure. After viewing the videotape and discussing its contents with the clinician, the patient should sign a video consent form to verify that the video was viewed and all the patient’s questions were answered.

**Alternative Technique Choices**

Filling the root canal with the lateral compaction method or instead using vertical warm gutta-percha delivery systems, including heat-transfer units for warm gutta-percha, is the currently taught methodology. Each technique has zealous advocates. Both methods are reasonable and acceptable choices, and each method conforms to the standard of care. The choice of techniques changes as new products are introduced and scientific research is conducted. The vertical warm gutta-percha technique promises to deliver improved flow to fill lateral canals and is likely to predominate in the twenty-first century as the preferred methodology. Nonetheless, lateral compaction has a long-term proven track record, particularly with less-experienced practitioners.

**Ethics**

Endodontics is one of eight ADA-recognized dental specialties. Although any licensed clinician may legally practice endodontics, it is unethical to announce that one specializes in endodontics without specialty training or being “grandfathered” into endodontic practice. It is ethically impermissible for a general practitioner to characterize a general practice as “limited to endodontics.” However, the general practitioner is permitted to emphasize endodontics by advertising as a “general practitioner of endodontics.”

**Referrals to Other Specialists**

Every clinician, including specialists, will at some time need to refer a patient to another specialist for treatment to comply with the standard of care required of a reasonably careful clinician.

Generally, if the referral takes place within the same dental practice, the legal doctrine of respondeat superior (“let the master answer”) may be applicable. Under this doctrine, a clinician is liable for the dental negligence of a person acting as his or her agent, employee, or partner. Liability is determined by whether the principal clinician controls the agent clinician’s activities or methodology, regardless of whether such control is actually exercised.

If the referral is made (even within the same physical environment) to an “independent contractor” endodontist who does not diagnose or treat under the direction or supervision of the referring clinician and that referring clinician has no right of control as to the mode of performing the treatment, the principle of agency and responsibility for the acts of another does not apply. The legal test for agency is the principal’s right to control, regardless if the control is exercised over the agent. However, if the independent contractor or referring clinician does not provide adequate notice of this independent relationship to the patient, the independent contractor will still be liable under the legal doctrine of ostensible agency. Thus, despite an independent contractor agreement, a patient can legally infer the so-called independent clinician is instead an employee since neither clinician disclosed an independent contractor relationship to the patient.

To ensure that the referred clinician is not considered the agent of the referring clinician within the same facility, fees for the referred clinician should not be set by the referring clinician nor should the fees be divided equally or shared based on some other arrangement. Also, the referred clinician should bill separately and exercise independent diagnostic and therapeutic judgment. The patient should be advised that the referred clinician is independent of the referring clinician. Otherwise, the referred clinician or specialist may be regarded or inferred to be the ostensible agent of the referring clinician in the same office (although this is not the case). The legal test for agency is how the facts or circumstances appear to a reasonable patient, regardless of the clinician’s understanding or intent that the other treating clinician be considered an independent contractor. Thus agency may be actual in fact or, alternatively, ostensible (i.e., implied by circumstantial conduct).

**Surgical versus Nonsurgical Endodontics**
Litigation to determine whether nonsurgical or surgical endodontics was the proper treatment choice will not be decided by any one clinician, the ADA, the AAE, or the ablest of judges. Rather, after considering all the evidence and the opinions of experts, a jury of the patient’s peers will decide the disputed matter. Depending on the individual case, the jury may decide that either a combination of nonsurgical and surgical endodontic therapy, rather than one method exclusively, should have been attempted. The jury may also decide that the patient should have been advised of the availability of such alternative therapy. Similarly, the jury may determine that apical surgery should have been done microscopically, rather than macroscopically, depending on expert testimony regarding the relative advantages of each method or on presenting clinical circumstances (e.g., suspected calcification, viewing a separated instrument).

Microscopic Endodontics

Microscopic endodontics improves posture and reduces neck and back fatigue. Identification of microfractures in teeth and removal of diseased dental tissue are easier and more accurate when done microscopically.

“The operating microscope is an indispensable tool for state-of-the-art endodontic treatment. The specialty practice should not be without a microscope; this instrument is useful in all phases of endodontic treatment from diagnosis to placement of the final restoration.”

Failing endodontics that necessitate endodontic disassembly should first be considered for a nonsurgical option because it is less invasive and therefore represents risk reduction. The clinician should first evaluate for coronal leakage, fractures, missed canals, silver point corrosion, and incomplete obturation. Root canal systems can then be recleaned or correctly transported and then thoroughly disinfected, reshaped, and packed in three dimensions to avoid apical surgery by providing instead adequate coronal, lateral, and apical seal nonsurgically.

New Products

Today’s clinician exploring ways to improve the quality and success of endodontic therapy is constantly presented with new dental products and techniques. For prescribing and using drugs or other agents, the ADA’s Principles of Ethics, Section 5D, provide this guideline:

“Except for formal investigative studies, dentists shall be obliged to prescribe, dispense, or promote only those devices, drugs and other agents whose complete formulae are available to the dental profession. Dentists shall have the further obligation of not holding out as exclusive any device, agent, method or technique if that representation would be false or misleading in any material respect.”

Ethical clinicians should not indiscriminately adopt every new product. Instead, the supporting research should be reviewed, rather than risk the patient’s welfare with inadequately tested or researched products only tested in vitro.

Separated Instruments

Risk reduction of broken files can be accomplished if all hand and rotary nickel and titanium (NiTi) cleaning and shaping files are not resterilized and reused but are discarded after single-tooth use. Efficiency is also increased because approximately 50% of cutting efficiency is lost after initial use. Episodes of broken instruments will be dramatically reduced and nearly eliminated when files are used correctly and discarded after single-tooth use. Breakage increases sharply when hand or rotary shaping files are reused. Therefore the clinician should discard rotary instruments after a single-use visit. Chair and staff time efficiency, along with improved safety, dictates single-visit use of files.

The clinician should save broken or defective instruments (e.g., the remaining portion from a needle that has broken and become lodged in a patient’s soft tissue) (Fig. 11 – 17). The instrument manufacturer may be liable because the product was defective, rather than the clinician being liable for dental negligence. Electron microscopy spectrographic analysis can determine if manufacturing defects with contaminants caused the break, rather than the clinician excessively stressing the instrument.
Equipment and Supplies

Equipment should be kept in good repair by checking and following the manufacturer’s recommended maintenance schedule. The clinician should carefully read the manufacturer’s instruction warnings on instruments and inform staff of any important points. Infection control in operating dental equipment is mandatory, such as updating and maintaining dental units with check valves to prevent water retraction or suck-back. The clinician should inspect check valves monthly and change clogged valves immediately.[10] Water retraction testers, at no charge to the clinician, are available from some manufacturers (A-dec [Newberg, OR], for instance). The clinician or a staff member should also disassemble the unit’s handpiece, run water through the line for a few seconds, and then stop. If a bubble of water is visible at the end of the water hose holes, the check valve is operating properly. If a bubble of water is not visible, water may be sucked back because of an absent or clogged check valve. An absent or clogged check valve is a source of cross contamination. Therefore it is important for the clinician or staff to perform weekly spore testing of the autoclave and monthly bacteriologic testing of water lines.[11] The clinician or staff should consider using filters and should flush daily with FDA-approved chemical disinfectants of dental unit water lines to reduce water tubing biofilm. Some chemical disinfectants claim improved cost effectiveness by increasing handpiece and bur longevity concomitant with water line purging or with continual use during treatment. Fig. 11 - 18 shows a student who was burned because of an inadequately maintained handpiece that overheated. This case settled for $280,000.00.

Figure 11-17  A, Broken 30-gauge needle on day of fracture. B, Failed surgical attempt at needle removal resulting in further needle migration. C, Subsequent oral surgeon removed needle. (Courtesy Anthony Pogrel, DDS, MD.)
Drugs

Clinicians should exercise extreme caution when administering or prescribing dangerous drugs. For sedative or narcotic drugs, cautionary directions should be written on prescriptions, and the pharmacist should place these directions on the prescription container as a patient reminder. For example, for the appropriate drugs, the clinician should prepare a prescription rubber stamp or obtain preprinted prescriptions that state the following:

“Do not drive or operate dangerous machinery after taking medication because drowsiness is likely to occur. Alcohol, sedative, or tranquilizing drugs will cause drowsiness if taken in combination with this prescribed drug.”

The ADA and American Medical Association (AMA) provide prescription drug warning pads. Clinicians should document each drug information form provided with the prescription in the patient’s chart.

Overuse of antibiotics risks resistant-strain development and side effects. Studies demonstrate generally no increased therapeutic efficiency of endodontic therapy with antibiotics when performed in the absence of facial swelling.\[130\] Unless persistent infections occur or compelling systemic reasons exist (e.g., uncontrolled diabetes, antibiotic prophylaxis necessary because of mitral valve regurgitation), antibiotics should not be prescribed prophylactically.\[7\] Neither pain nor localized swelling justifies antibiotics. However, extraoral

Figure 11-18 A, Before injury. B to D, A music student was burned by an inadequately maintained handpiece that overheated. This lawsuit was settled for $280,000.
swelling, cellulitis, or lymphadenopathy may require surgical drainage or antibiotics or both. The U.S. Centers for Disease Control and Prevention (CDC) estimates about one third of all antibiotic outpatient prescriptions are unnecessary.[7]

Product liability may include whether the manufacturer provides adequate hazard warnings for safe use of its product (Fig. 11-19).

**Clinician’s Liability for Staff’s Acts or Omissions**

A clinician is liable for the acts or omissions of the clinician’s staff under the doctrine of *respondeat superior* ("let the master answer"). This is termed *vicarious liability*, which means that the clinician is responsible, not because of wrongdoing personally, but because the clinician assumes legal responsibility for the conduct of employees and agents who act in the course and scope of their employment.

The clinician should instruct the staff in advising patients regarding posttreatment complaints. For example, if the staff ignores signs of infection, such as difficulty in swallowing or breathing or elevated temperature, and dismisses the patient’s complaints as normal postoperative swelling, the clinician may be held liable for injury to the patient, such as delayed cellulitis, diagnosis or treatment of Ludwig’s angina, brain abscess, or other serious complications.

A clinician must be cautious when delegating responsibilities and give clear instructions to ensure that staff members properly represent the clinician and the chosen practice methods. Auxiliaries should not be allowed to practice beyond their competency level or license. For example, in states where assistant-placed restorations are legally permissible, the clinician should check any assistant-placed restoration before patient dismissal. Staff members should not make final diagnoses or handle patient clinical complaints without the clinician’s involvement and consultation. Staff should be instructed to ask appropriate questions and to relay the patient’s answers to the clinician so that the clinician can adequately determine what should be done.

**Abandonment**

Once endodontic treatment is initiated, the clinician is legally obligated to complete the treatment regardless of the patient’s payment of any outstanding balance. This requirement is posited on the legal premise that any person who attempts to rescue another from harm must reasonably complete the rescue with beneficial intervention unless another rescuer (i.e., clinician) is willing to assume the undertaking. Another view is that should a patient be placed in a position of danger unless further treatment is performed, the clinician must institute reasonable therapeutic measures to ensure that adverse consequences do not result.

A clinician performing endodontic therapy should have reasonable means of communicating with patients after regular office hours to avoid a claim for abandonment. A recorded message is inadequate if the clinician fails to check for recorded messages frequently. Therefore answering services, pagers, and cell phones are required by the standard of care.

If the clinician providing endodontic therapy is away from the office for an extended period, a substitute on-call clinician should be available for any endodontic emergency and to answer patients’ emergency calls. The endodontic treating clinician should arrange in advance for emergency service with a covering clinician. Leaving a name on the office answering machine or with the answering service without first determining the availability of the covering clinician is a mistake.
To avoid an abandonment claim, several prophylactic measures apply:

1. No legal duty requires a clinician to accept all patients for treatment. A private practice clinician may legally refuse to treat a new patient, despite severe pain or infection, except on the grounds of race or disability. If treatment is limited to emergency measures only, the clinician must advise the patient that only temporary emergency endodontic therapy is being provided and that endodontic treatment is incomplete. The clinician should record this information in the patient’s chart. For example:

   “Emergency palliative treatment only. Patient advised endodontic treatment of tooth #8 needs to be completed, either here or with another clinician. Explained complications likely if not soon completed, including infection recurrence or tooth loss or both.”

2. No legal duty requires a clinician to continue treating former patients on recalls or subsequent emergency care once treatment is complete. Thus completion of endodontic treatment for tooth #19 does not legally obligate the clinician to initiate endodontic therapy for tooth #3 if endodontic disease began months after the clinician completed treatment of tooth #19.

3. Any patient may be discharged from a practice for any arbitrary reason, except on the grounds of race or disability, so long as all initiated treatment is completed. Accordingly, a former patient who evokes memories of a “frictional” relationship, who is financially irresponsible, or who arrives at the office after an absence of several years with an acute apical abscess in a site where previous care was not rendered may legally be refused treatment.

4. It is not considered abandonment if a patient is given reasonable notice to seek endodontic treatment with another clinician and the patient is willing to seek endodontic services elsewhere. Thus if rapport with the patient dissolves, the clinician should not hesitate to suggest that the patient would be better served if any remaining endodontic treatment were performed by a different clinician.

The clinician may discontinue treatment provided it is not done at a time when the patient’s dental health will be jeopardized (e.g., in the middle of treatment). To discontinue treatment, the clinician should do the following:

1. Notify the patient of the plan to discontinue treatment after a certain date.
2. Allow enough time for the patient to obtain care with another clinician, usually 30 days.
3. Offer to make emergency service available during the interim 30 days until a new clinician is obtained.
4. Provide diagnostic-quality records, copies of radiographs, and other pertinent clinical information in transfer records to the new treating clinician.
5. Allow the patient to select a new clinician or suggest referral by the local dental society if a referral service exists.
6. Document all of the above in the patient’s records, including a copy of a certified letter sent to the patient proposing discontinuance of treatment.

**Expert Testimony**

The standard of care that a clinician must possess and exercise is particularly within the knowledge of dental experts. However, there are occasional exceptions where the conduct involved is within the common knowledge of laypersons, in which case expert testimony is not required. In determining whether expert testimony is required to establish negligence, one California court commented: “The correct rule on the necessity of expert testimony has been summarized by Bob Dylan: ‘You don’t need a weatherman to know which way the wind blows.’”

Incorrectly operating on the contralateral side because of mismounted radiographs or marking the wrong tooth on an endodontic referral card is an example of negligent conduct within the common knowledge of laypersons for which expert testimony is not required.
Increasingly, courts act as gatekeepers regarding the admissibility of scientific expert testimony. Anecdotal comparisons appear compelling, but such evidence may be judicially excluded in the courtroom. Some experts rely solely on their skill for experience-based observation, rather than research testing of risk factors, such as occurs with epidemiologic research.

The U.S. Supreme Court (in the *Daubert* four factors check list) advises that an expert’s testimony may be reliably admitted into evidence based on the following:

1. Whether the expert’s technique or theory may be tested or refuted
2. Whether the technique or theory has been the subject of peer review or publication
3. Known or potential rate of technique error
4. Degree of acceptance of a theory or technique within the relevant scientific community

Courts determine whether testimony is based on the application of scientific principle or clinical experience. In general, courts are flexible and adaptable in determining whether a bright line separates scientific and unsupported nonscientific evidence. Often technical and specialized knowledge gained through continuing education and scientific journals, rather than an expert performing the research, is considered sufficient as long as the expert’s opinion complies with the *Daubert* principle.

State courts are not bound to follow the Federal Rules of Evidence, but many do comply. Nonetheless, U.S. Supreme Court decisions influence state courts that consider placing limitations on expert testimony. State court trial judges may either be more liberal or more restrictive in admitting expert witness testimony. If the trial court judge denies admission of scientific evidence as unreliable, untrustworthy, or irrelevant, the end result may be to preclude an expert offering any opinion. On the other hand, the court may admit such evidence and instruct the jury members that they may consider the scientific basis for the expert opinions and give such evidence the evidentiary weight it deserves.

In *Weisgram v Marley Co.*, the U.S. Supreme Court held that, under Federal Rule of Civil Procedure 50 (a), either a district (trial) court or a court of appeals may enter judgment for defendant notwithstanding the plaintiff’s verdict if either court determines that admitted expert testimony was unreliable and inadmissible under *Daubert v Merrell Dow Pharmaceuticals, Inc.*

**National Practitioner Data Bank**

Insurance carriers are obligated to report all settlements to the National Practitioner Data Bank. These data are only accessible to hospitals for staff privilege credentialing and state licensing boards but not individual patients.

Medical negligence occurring in hospitals is too often underreported. The Public Citizens’ Health Research Group report that more than one half of U.S. hospitals have never reported an adverse incident to the National Practitioner Data Bank.

**Professional Negligence Incidence**

A 2003 report submitted to Congress by the General Accounting Office found that malpractice awards are only one factor contributing to increases in premiums for medical professional liability insurance.

Other factors cited include falling investment returns for insurance companies and normal business cycles. The report concluded that assertions that insurance premiums are driving clinicians out of business and making health care inaccessible were “not substantiated or did not affect access to health care on a widespread basis.” The report also stated that it is not possible to prepare a full analysis of the issue because comprehensive insurance data are not available.

Since malpractice premiums account for about 1% of health care spending, imposing caps in liability cases would therefore have essentially no impact on the cost of health care. Evidence that this unnecessary remedy for a perceived but absent wrong is the National Association of Insurance Commissioners’ data from 1995 to 2000, which show new medical malpractice claims declined.

The existing civil liability system permits each state autonomy to regulate the resolution of professional liability actions within its borders. This is a hallmark of our American justice system.
The popular image holds that jurors are overly sympathetic to patients with unfortunate dental outcomes regardless of whether anyone is to blame. However, research on juror attitudes demonstrates the opposite. Thus weak cases seldom succeed despite serious injuries.

Some malpractice is inevitable. Even the best clinician is capable of making a mistake. About 5% of clinicians account for the majority of all malpractice claims, according to reports filed with the National Practitioner Data Bank. Among clinicians who have settled five or more malpractice claims, only 13.3% have been subject to professional discipline, according to the Public Citizens’ Health Research Group’s analysis of the data. Forty-five percent of otolaryngologists admit medical errors in all phases of their practice. However, even this proportion of clinicians reporting medical errors is underestimated. A recent study estimates the number of fatal medical errors has doubled in the past 3 years.

**Managed Care and the Employment Retirement Income Security Act**

Ten states passed managed care liability laws that permit patients to sue managed care organizations for damages resulting from delayed or refusing authorizations for treatment the clinician recommended as medically necessary. A recent U.S. Supreme Court decision nullified those state laws for the 140 million Americans covered by health plans that are regulated by the Employment Retirement Income Security Act of 1974 (ERISA). ERISA restrictions do not apply to government employees’ dental insurance.
MALPRACTICE INCIDENTS

Screw Posts

Screw posts represent a restorative anachronism. The risk of root fracture is too great compared with the benefit, particularly when reasonable and superior passive alternatives exist (see Chapter 21 and Figure 11–34). Even if the screw post is initially placed passively, the temptation to turn the screw is too great, considering human nature. Therefore screw posts are not a reasonable and prudent treatment choice.

DENTAL AUXILIARY CONFIDENTIALITY AGREEMENT

I, ____________________________, have been informed by

__________________________, DDS, that all dental, medical, and

__________________________, financial information concerning patients is confidential.

As a condition of employment, I agree to maintain the confidentiality of all oral and written information, including treatment charts, and to not disclose such information to any unauthorized outside persons, including any family members, except upon request and authorization by the patient, the patient’s agent, or supervising dentist.

I understand and agree that breach of this employment agreement shall constitute good cause for my discharge from employment. I acknowledge that I may be personally liable for any violation of a patient’s privacy or civil rights including HIPPA committed by me without consent of the patient, or the patient’s agent, or approval by above-named dentist.

Date: ________________________

Witness: ________________________

Signature of Dental Assistant

Figure 11-34 Dental auxiliary confidentiality agreement.

Paresthesia

Endodontic surgery in the vicinity of the mandibular canal or mental foramen carries with it the significant risk of irreversible injury to the inferior alveolar or mental nerve, respectively. Consequently, the clinician must advise the patient in lay terms of the risk of temporary or permanent anesthesia or paresthesia before any surgery near these structures is performed. To document that adequate informed consent was provided, the clinician should have the patient execute a written informed consent form confirming that the patient was so advised. Informed consent is not highly pertinent if the surgery was negligently chosen or negligently performed, because informed consent only applies to nonnegligent treatment risks.

Treatment Failure

A clinician should not guarantee treatment success. It is foolish to assure the patient of a perfect result. Endodontic failures may occasionally occur despite adequate endodontic care. Nevertheless, negligent contributing factors to endodontic failures include perforation, missed or transported canal, uninstrumented portion of a root canal, bacterial infiltrates by way of a leaky coronal restoration contaminating the root canal filling, overextension errors, and inadequate isolation of the tooth from contaminants during instrumentation because of lack of a rubber dam.

To avoid claims based on failed endodontics, the patient should be advised in advance of treatment of the inherent (but relatively small) risk of failure (i.e., about 5% to 10%). It may be adequate to advise the patient of
the high statistical probability of success in endodontics as long as the clinical condition of the tooth and the clinician’s past success rate warrant such representation. Clinicians should avoid quoting the national success rate of endodontics when (1) the patient’s tooth is of questionable endodontic and periodontal status and (2) the clinician is known to have an unusually high endodontic failure rate; for example, a rate that varies markedly from national statistics, which also suggests referral.

An endodontic treating clinician is also liable for failure to disclose evident pathosis in the quadrant being treated. The patient should be advised of any periodontal disease that adversely affects the prognosis of abutment teeth for partial dentures, bridges, or an implant with a need for grafting if the endodontically treated tooth is lost. A clinician should also advise of cysts, fractures, or lesions of suspected neoplasms. In addition, the clinician must be careful not to ignore any evident pathosis that, if untreated, may adversely affect the dental or medical health of the patient. A clinician who fails to plan treatment properly is planning for treatment failure.

The doctrine of informed consent protects both the clinician and the patient so that there will be no surprises or patient disappointment if a nonnegligent adverse result occurs. Should nonnegligent failure or complication occur, the availability of a signed informed consent form can serve as a reminder to the patient that the risk of complications, including failure, was discussed in advance of treatment and that, unfortunately, the patient’s endodontic treatment fell outside of the usual 90% or greater success rate.

**Slips of the Drill**

A slip of the drill, like a slip of the tongue, may be unintentional. Nevertheless, it can cause harm. When a cut tongue or lip occurs, it is usually the result of operator error. To paraphrase Alexander Pope, to err is human, but to forgive divine. To increase the likelihood that a patient will forego filing suit because of a cut lip or tongue, the clinician should follow these steps:

1. Inform the patient that the clinician regrets having injured the patient. This is not a legal admission of guilt but rather an admission that the clinician is a compassionate human being.
2. Repair the injured tissues or refer the patient to an oral or plastic surgeon, depending on the extent of the injury and whether a plastic revision is necessary if scarring is likely.
3. Advise the patient that the clinician will pay the bill for the referred treatment of the oral or plastic surgeon. Request the oral or plastic surgeon to send the bill directly to the clinician for payment. Send the oral or plastic surgeon’s bill to the clinician’s professional liability carrier. Most carriers will pay the claim under the medical payments provisions of the general liability policy for an “accident” rather than as a malpractice incident compensable under the professional liability policy. Call the patient periodically to check on healing, recovery, and follow-up plastic surgery.

**Leakage**

Long-term seal of the root canal system is determined apically by the sealer and coronally by the final restoration. Therefore root canal–filled teeth should be permanently restored without undue delay to prevent leakage contamination of the previously obturated canal system. Bonded seals covering the canal surfaces should be used to control any leakage after obturation until a permanent restoration is cemented. Besides an adequate coronal sealing, an adequate apical sealer should be well adhered to the canal walls.

The endodontic goal is to prevent bacterial contamination of the periradicular tissue by predictably providing adequately cleaned, shaped, and filled root canal systems. Any residual bacteria should be entombed in the root canal filling. A bacteria-tight apical seal should be designed to last long term with sealed portals to prevent reentry of microorganisms, which cause reentry recontamination and lead to endodontic failure.

**Electrosurgery**

Electrosurgery can cause problems if mishandled. Damage to the oral cavity caused by improper use of electrosurgical devices consists primarily of gingival necrosis, osteonecrosis, sloughing adjacent to the surgical field, and pulpal necrosis of affected teeth.

All equipment should be properly maintained and certified to meet the American National Standard (ADA specification no. 44 on electrical safety standards). Current equipment should be checked to see that units meet these standards and those electrical cords and other components are in good repair. Electrical
receptacles should meet the requirements of the National Electrical Code for circuit grounding and ground
fault protection. During use, the dispersive electrode plate should be well away from metal parts of the dental
chair and the patient’s clothing, because skin contact can cause burns. Therefore use of plastic mirrors,
saliva ejectors, and evacuator tips is strongly recommended.

Apical Surgery

The most frequent cause of failure in endodontic apical resection is incomplete apical sealing between the
root canal system and adjacent periradicular tissues. Achieving an adequate seal with apical surgery requires
use of an ultrasonic rotary root end cavity preparation of at least 3 mm in vertical length.

Reasonable Versus Unreasonable Errors in Judgment

Although a clinician is legally responsible for unreasonable errors in judgment, mistakes occasionally happen
despite adherence to the standards of reasonable care. A mistake does not prove malpractice, unless the
mistake is caused by a malpractice error or omission.

For example, accessory or fourth canals on molar teeth are frequently difficult to locate and may tax the best
clinicians. Failure to locate an accessory or fourth canal does not conclusively constitute an unreasonable
error of judgment. Rather, this may represent a reasonable error of judgment in the performance of
endodontics. Nevertheless, if the additional canal was readily apparent radiographically, the existence of a
fourth canal should have been considered and treatment should have extended to instrument and seal it. Also
if symptoms persist, consideration for re-treatment to locate a fourth or accessory canal should be considered.

Incorrect Tooth Treatment

A reasonable, nonnegligent mistake in judgment may occur because the clinician has difficulty localizing the
source of endodontic pain. Vital pulps may, on occasion, be sacrificed in an attempt to diagnose the pain
source. Nevertheless, it is unreasonable and therefore inexcusable to treat the wrong tooth because it is not
adequately tested with pulp tests, because it has been recorded incorrectly on the referral slip, or because the
radiographs are mounted incorrectly. Also, treating large numbers of teeth endodontically (e.g., an entire
quadrant) when attempting to localize chronic pain suggests pain is of pulpal origin.

If the wrong tooth is treated because of an unreasonable mistake in judgment, the clinician should be
compassionate, waive payment for all endodontic treatment, and offer to pay the fee for crowning the
unnecessarily treated tooth.

Root Reinforcements

The potential risk of root fracture increases from overinstrumentation while cleansing and shaping the root
canal system. Various post devices designed to strengthen roots have not proved successful. Thus the
necessity for post placement has declined. Newer materials besides metal posts include dentin-bonded resin
post and core systems and quartz and glass fiber posts. Horizontal fractures predominate with fiber-reinforced
resin restorations compared with vertical fractures associated with cast posts and cores. Resin
reinforcement of the root structure is postulated to increase but not entirely eliminate root fracture resistance.

Post Retrieval

Ultrasonic instruments will vibrate loose the cement around posts. The clinician can avoid overheating the
post by proceeding slowly with a water coolant and checking the post temperature periodically to be
reasonably certain overheating is not occurring. The use of a medical temperature probe may prove helpful.

 Broken Files

Leaving broken files behind without referring the patient to an endodontist for microscopic retrieval or advising
the patient of leakage potential may constitute fraudulent concealment. (Figs. 11–20, 11–21, 11–22).
Figure 11-20  Tooth #31 with three separated files, one in each canal. K-files used for cleaning canals and also obturation (1996).

Figure 11-21  No apparent radiographic changes in 1998.
Swallowing or Aspirating an Endodontic Instrument

Use of a rubber dam in endodontics is mandatory. Even if the endodontically treated tooth is broken down and cannot be clamped, a rubber dam, regardless of required modification, should be used in all instances (see Chapter 5). Not only is microbial contamination reduced with the use of a rubber dam but also the risk of a patient’s aspirating or swallowing an endodontic instrument is eliminated (Fig. 11-23). Accordingly, if a swallowing or inhalation incident does occur, the clinician should do the following:

1. Advise the patient that the clinician regrets what occurred.
2. Refer the patient for immediate medical care, including radiographic imaging, to determine if the instrument is lodged in the bronchus or stomach so that appropriate medical measures are taken promptly to remove it.
3. Offer to pay for the patient’s out-of-pocket medical expenses and wage loss. Most professional liability policies will cover the incident as medical payment for an accident and not as a malpractice claim.

Overextensions

A very slight overextension of root canal filling with conventional obturation or sealants can occur without violating the standard of care (see Chapter 10). Gross overextension usually indicates faulty technique. Nevertheless, so long as the overextension is not in contact with vital structures, such as the inferior alveolar nerve or sinuses, permanent harm is unlikely, unless the root canal is filled with a paraformaldehyde-containing sealant (causing a neurotoxic chemical burn type of injury).

If, however, severe postoperative pain is foreseeable as a result of overextension, the patient should be advised of the likelihood of postoperative discomfort because of contact of the sealant material with the surrounding tissue. Similarly, if the overextension is very slight and increased postoperative pain is unlikely, the patient need not be advised, lest it cause unnecessary alarm. However, a note should be made on the patient’s chart of the overextension and of the reason for not informing the patient in case symptoms later manifest. The clinician should observe with close follow-up visits and patient phone calls to rule out severe postoperative pain. Fortunately, slight to moderate overextensions with inert conventional endodontic sealers, such as gutta-percha with Grossman’s sealant, often repair themselves and produce no irreversible changes without direct contact into the sinus or inferior alveolar nerve.

Overextending the root canal filling material risks permanent consequences if the underlying inferior alveolar nerve is initially penetrated with files. Portal of entry into the inferior alveolar nerve canal results from overinstrumentation penetration. Flexible gutta-percha alone probably will not penetrate beyond the mature root into the inferior alveolar nerve canal without prior excessive instrument perforation into the inferior alveolar nerve canal.

Paraformaldehyde-containing sealants can create cytotoxic chemical destruction of the inferior alveolar nerve if placed in close proximity to, although not directly contacting, the underlying inferior alveolar nerve. On the other hand, conventional packing and sealants usually require direct contact with the inferior alveolar nerve.
before resulting permanent anesthesia or paresthesia occurs (Fig. 11–24). Consequently, the incidence of permanent sequelae with conventional filling materials is extremely low compared with the greater cytotoxic potential with paraformaldehyde-containing sealants. Because of the higher risks associated with paraformaldehyde-containing endodontic materials, use of N-2 or similar pastes is contraindicated and violates the standard of care since permanent injury risk is substantially less with traditional eugenol-containing filling materials. When safer, less risky alternative therapy exists, it is unreasonable (and substandard) to elect an unsafe alternative methodology. Also, the doctrine of informed consent is highly relevant because it is contrary to public policy to request a patient to assume inherently dangerous treatment risks that are reasonably avoidable with safer and more predictable methodologies.

Any significant overextension should be considered for immediate re-treatment by attempted retrieval of the overextended gutta-percha. The clinician also has the option of immediately referring the patient to an endodontist for retrieval before the sealant sets. Conventional filling agents, such as gutta-percha, do not penetrate the cortical walls of the inferior alveolar nerve canal unless preceded by prior penetration with overinstrumentation. This principle can apply to sinus perforation. If despite local anesthesia the patient feels an electrical shock during mandibular molar or premolar instrumentation, this may be a warning sign that the inferior alveolar nerve was pierced with endodontic files. If this occurs, the root canal should not be filled; instead, a periapical radiograph should be exposed with instruments in place to confirm any inferior alveolar nerve penetration. Removal of gutta-percha and sealants that have entered the inferior alveolar nerve canal should be attempted as soon as possible (preferably within the first 24 to 36 hours). The eugenol component of the sealant causes an inflammatory reaction in a constricted space; this reaction is best relieved by

![Figure 11-24 Overextended gutta-percha and extracted tooth with gutta-percha intact.](image-url)
retrieval. If retrieval fails, a decortication procedure with an oral surgeon is indicated at the earliest possible time (preferably within the first 24 to 36 hours).

Inflammatory edema that compresses and compromises blood supply to soft tissues and nerves in limited spaces with resulting ischemia is termed compartment syndrome. Compartment syndromes are a group of conditions that result from increased pressure within a limited anatomic space, acutely compromising the circulation and ultimately threatening the function of the tissue within that space. Compartment syndrome occurs from an elevation of the interstitial pressure in a closed osseofascial compartment that results in microvascular compromise. The pathophysiology of compartment syndrome is an insult to normal local tissue homeostasis that results in increased tissue pressure, decreased capillary blood flow, and local tissue necrosis caused by oxygen deprivation. Compartment syndrome is caused by localized hemorrhage or postischemic swelling. The pathophysiology of compartment syndrome is a consequence of closure of small vessels. Increased compartment pressure increases the pressure on the walls of arterioles within the compartment. Increased local pressure also occludes small veins, resulting in venous hypertension within the compartment. The arteriovenous gradient in the region of the pressurized tissue becomes insufficient for tissue perfusion.

The clinician should have a high index of suspicion whenever a closed bony nerve compartment has the potential for bleeding or swelling. Compartment syndromes are characterized by pain beyond what should be experienced from the initial injury. Also, diminished sensation may be noted in the distribution of the nerve within a compartment that is being compressed, such as the inferior alveolar nerve canal enclosed by bone on all sides. Elevation of compartment pressure to more than 30 mm Hg for more than 8 hours can cause irreversible tissue death.

Current Use of Silver Points

Based on what has been known for more than 3 decades, use of silver points in lieu of gutta-percha or other conventional endodontic filling materials represents a departure from the current standard of care. This is because silver points corrode in time and a tight three-dimensional apical seal is lost. Fig. 11–25 represents gross overextension with a silver point that ultimately caused the loss of tooth #14 as a result of endodontic failure.
Use of N-2 (Sargenti Paste) and Related Sealers

Dental literature reports that permanent paresthesias are associated with gross overfilling with paraformaldehyde sealant (N-2) that are not usually associated or reported with conventional sealants (Fig. 11-26). Current use of paraformaldehyde-containing endodontic sealants is not merely the result of a philosophic difference between two respectable schools of thought. Rather, the distinction is between the reasonable and prudent school of thought that advocates conservative conventional endodontics and the imprudent and radical school of paraformaldehyde providers who unreasonably risk permanent, deleterious injury with N-2 overextensions. Regardless of the number of clinicians using this latter technique and cytotoxic material, it is unsafe and should be avoided. A customary negligent practice is no defense.

Figure 11-25 Gross overfill into sinus with a silver point, which ultimately caused sinusitis and loss of tooth #14 as a result of endodontic failure.
Clinicians may be liable for fraudulent concealment, intentional misrepresentation, or co-conspiracy if they discovered that a previous clinician’s negligence is the cause of dental disease and both the prior clinician and subsequent treater concealed the prior clinician’s negligence. For instance, if a gross overextension of a paraformaldehyde packing or sealant is evident radiographically and the patient reports that another clinician caused the overextension (that resulted in permanent lip anesthesia), subsequent treating clinicians may be liable for fraudulent concealment if they tell the patient that the anesthesia will probably disappear shortly and that using N-2 merely reflects a philosophic difference, rather than substandard practice. Likewise, if the radiographs indicate sealant is inside the inferior alveolar nerve canal and the patient complains of persistent anesthesia, the patient should not be told to wait for return of sensation. Rather, the clinician should refer the patient immediately for microsurgical consultation regarding decortication and decompression surgery.

The Federal Food, Drug, and Cosmetic Act of 1938 (amended in 1962) prohibits interstate shipment of an unapproved drug or individual components used to compound the drug. On February 12, 1993, the FDA dental advisory panel confirmed that N-2’s safety and effectiveness remain unproven. N-2 may not be shipped interstate or distributed intrastate if any of the N-2 ingredients were acquired interstate. Mail order shipments of N-2 from out-of-state pharmacies in quantities greater than for single-patient use are considered a bulk sales order rather than a prescription, thus violating FDA regulations. A San Francisco jury awarded punitive damages against the N-2-distributing New York pharmacy for knowingly shipping N-2 in violation of FDA regulations done with deliberate disregard for patient safety.

Defective Restorations

Marginal gaps greater than 50 µm lead to cement dissolution and cause 10% of crown failures within 7 years after cementation. Dull or worn explorers substantially increase the likelihood of nondetection of open margins. A sharp explorer can detect margin defects as small as a 35 µm opening. Accordingly, a sharp clinician should utilize a sharp explorer to detect open margins. Open crown margins contribute to endodontic failure and should be avoided (see Chapter 21).
PROPHYLACTIC ENDODONTIC PRACTICE

Malpractice Prophylaxis

Most negligently injured patients do not sue. Nonetheless, litigation serves a prophylactic purpose since litigation fears make some clinicians more careful and help promote professional guidelines. For example, after the American Society of Anesthesiologists adopted practice guidelines to reduce patient harm, deaths and professional liability premiums decreased dramatically.

Disclosure Errors

Should dental negligence harm a patient, then full disclosure, including accepting the clinician responsibility along with providing an apology and explanation, results in the best outcome for the clinician and patient. Also, assurance of efforts to prevent a recurrence results in greater patient satisfaction and retains trust with the disclosing clinician to sustain a continuing clinician-patient relationship. Patients want to be told of treatment errors regardless of whether the error can be corrected. One study in which there was full disclosure of negligently caused therapeutic errors resulted in only one patient thereafter seeking legal advice. In the same study patients paradoxically acknowledged, “It is realistic to expect that doctors will make errors” along with, “Patients have a right to expect that their doctors will not make errors.” Nonetheless, virtually all patients concluded, “Patients should be able to trust their doctors to give them the right care.” Apologetic expressions of sorrow or empathy for a patient’s injuries are barred in evidence from being construed as admissions of fault in California, Oregon, and Colorado. In sum, doing right for the patient includes telling the patient when negligent errors occur.

Periodontal Examination

Competent endodontic treatment begins with adequate diagnostic procedures, as discussed in Chapters 1 and 3. An adequate periodontal evaluation must accompany each endodontic diagnosis, which requires a diagnostic radiograph, clinical visualization, mobility recordings, evaluation of the periodontal tissues, and probing for periodontal pockets with a calibrated periodontal probe, particularly in furcation areas.

Although endodontic treatment may be successful, tooth loss may result from progression of any residual, untreated periodontitis. Consequently, periodontal evaluation and prognosis are mandatory so that the patient and clinician can make an informed and intelligent choice about whether to proceed with endodontics, a combination of periodontal and endodontic treatment, or extraction.

Each tooth undergoing endodontic therapy (and adjacent teeth) should be probed with a calibrated periodontal instrument to obtain six measurements per tooth. Pockets of 4 mm or greater should be recorded on the patient’s chart. If no pockets exist, WNL (within normal limits) or a similar abbreviation should be noted. Mobility should also be charted and classified class I, II, or III. Gingival recession, furcations, and mucogingival deficiencies should also be recorded.

A clinician who treats with endodontic success but ignores loss of periodontal attachment may misdiagnose or fail to appreciate the risk of failure because of poor periodontal prognosis. The endodontic treating clinician should not assume that an adequate periodontal evaluation has been performed by another clinician or the referring clinician. Instead, an independent periodontal evaluation should be done with a calibrated periodontal probe and results recorded before initiating endodontics including absence of pockets or within normal limits.

If clinically significant periodontal disease is present, the endodontic treating clinician should consult with the restorative clinician to determine whether the periodontal disease will be properly treated or referred to a periodontist in conjunction with endodontic treatment. A patient should be advised of any compromise of the endodontically treated tooth’s periodontal status to comply with required informed consent disclosure.
**Temporomandibular Disorders**

Occlusal prematurities can trigger temporomandibular disorders (TMDs) in patients with a prior TMD history. Therefore, during or following endodontic therapy for a patient with a history of a prior TMD, it is essential that temporary and final restorations not open the bite or significantly alter existing occlusion.\[79\]

**Preoperative and Postoperative Radiographs**

Pretreatment, midtreatment, and posttreatment radiographs or digital images are essential for endodontic diagnosis and treatment.

1. A current, pretreatment, interpretable periapical radiograph is mandatory.
2. Measurement films or digital images are necessary to verify canal length (if an electronic canal-measuring device is not used) and the apical extent of the gutta-percha fill to the radiographic apex.
3. Posttreatment radiographs are essential for determining the adequacy of the endodontic seal or if further treatment is necessary (see Chapter 10).

**Digital Radiography**

Digital radiographic endodontic applications are ever increasing, as described in Chapter 26. The standard of care does not currently require digital imaging because traditional silver halide radiographic film is a reasonable alternative. When there is more than one reasonably acceptable practice modality, a clinician who chooses either modality meets the standard of care. Fig. 11–27 represents a distal open margin on tooth #30 (shown digitally) that is not evident in Fig. 11–28 with plain-film radiography.

![Figure 11-27](http://home.mdconsult.com.eproxy1.lib.hku.hk/das/book/body/0/1357/8...)

**Figure 11-27** Distal open margin on tooth #30 (shown digitally).

![Figure 11-28](http://home.mdconsult.com.eproxy1.lib.hku.hk/das/book/body/0/1357/8...)

**Figure 11-28** Distal open margin on tooth #30 not evident with plain-film radiography.

Advertised claims of 80% reduction in radiation with direct digital radiography (rather than film) assume the
A digital x-ray image should never be modified in order to “enhance” the radiographic appearance of the original image. X-ray modification can be detected and, in litigation, can be devastating to the clinician’s defense. See further discussion on x-ray alteration in Chapter 26.

**Dental Fear**

Dental fear may result in patients delaying or avoiding dental care. Frequent cancellations and missed appointments are characteristic of patients with dental phobia. Although it is ordinary a defense of contributory negligence if patients do not follow a clinician’s treatment recommendations, the patient’s advocate may contend that the defendant dentist negligently failed to diagnose a fearful patient. Fearful patients tend to avoid dental treatment because they believe it may exacerbate a prior traumatic dental experience. Referral to clinicians who specialize in treating fearful patients should be considered to facilitate comprehensive dental treatment and to avoid future emergency endodontic care because of repeatedly cancelled treatment visits.

Dental anxiety and finances are the two most important barriers to patients obtaining regular dental care. Fearful dental patients avoid necessary treatment, delay recalls, and are reluctant to undergo painful procedures. Therefore it is essential that such patients be identified for proper management or referral for fear-reduction therapy. A patient who experiences a highly intense anxiety in the dental chair, together with a history of avoiding dental care, suggests a diagnosis of dental phobia. Fearful dental patients fear loss of control during dental treatment and require reassurance and reaffirmation that they have the power to halt the procedure by raising a hand or another appropriate gesture. After trust is gained, additional procedures may be performed.

In addition to desensitizing techniques, the use of proven topical-anesthesia delivery systems helps to ensure a relatively painless injection of local anesthetics. Topical-anesthetic patches and oral-anesthetic rinses may prove a valuable aid for pain management of the fearful patient.

The use of psychologic questionnaires, such as the *Dental Anxiety Scale* or the *Modified Dental Anxiety Scale*, may be helpful in identifying such individuals. These simple questionnaires are short, quick, and easy to complete, and users are provided with cutoff scores that help the clinician to identify patients who have psychologic special needs. In this way the clinician will be in a position to assist the dentally anxious or dentally phobic patient in accessing dental health care.

**Patient Rapport**

Good patient relations are 15% dependent on the clinician’s competency to cure and 85% dependent on the clinician’s ability to assure the patient that the treatment being given will be done with the clinician’s best judgment and care.

Rapport between clinician and patient reduces the likelihood the patient will sue despite an adverse result. The clinician can develop rapport by demonstrating genuine interest in the patient and making the patient feel valued. Patients feel important if they are seated in the operator within a reasonable time after arriving. The longer a patient is kept waiting, the more frustration and animosity build. If the patient cannot be seen within a reasonable time, a staff member should communicate the reason and, if appropriate, offer to reschedule the appointment. Staff or clinician should telephone the patient at the end of the day after any difficult procedure or surgery to check on the patient’s status and remind the patient to follow postoperative instructions. The clinician should record any patient complaints, symptoms, and noncompliance with instructions. The latter can be used as evidence of patient contributory negligence if litigation occurs.

The clinician should remember that the patient lacks the information and expertise to evaluate quality and performance. Patients have their own experiences and perceptions and often rely on lay information when...
gathering facts about dental procedures and treatment options. However, clinicians should expect some patients (especially those with access to the Internet) to ask technical questions and expect sophisticated responses.

**Rapport-Building Blocks**

Sir William Osler advised, “Listen to the patient. He is trying to tell you what’s wrong with him.” The best communicators listen more than they speak. When they do speak, it is mostly to clarify what the patient has said. Difficult clinician-patient relationships create poor communications. Improved understanding of the patient’s complaints fosters better rapport, aids treatment, and reduces the likelihood of litigation.

In discussing the patient’s complaints the clinician should ask, “What do you think is causing the problem?” Otherwise, the clinician may solve the patient’s dental problem while failing to solve the patient’s perceived problem. Failing to clarify the patient’s expectations about diagnoses and recommended treatment leaves the patient with unresolved worries and concerns. For instance, a patient may fear that a retained endodontic file is carcinogenic unless this fear is allayed with a careful explanation that it is not.

**Unhurried Visits**

Full attention to the patient’s complaints, good eye contact, and respectful addressing of the patient gain rapport, improve communication, and prevent lawsuits. The clinician should avoid questions that require a yes-or-no answer. Instead, the clinician should ask what the patient perceives as the problem, rephrase the patient’s complaints to prevent miscommunication, and ask if the patient’s complaints have been summarized accurately. Summarizing clarifies understanding by repeating important points. The clinician should also inquire if there are any remaining questions. Nonverbal communication is a powerful tool; therefore the clinician should shake hands initially or comfort with an outstretched hand if pain is provoked.

Emotions are the dominant force behind most malpractice claims. Patients who feel misled, betrayed, or abandoned become angry and may seek vindication instead of simply seeking financial compensation. Thus the clinician should maintain a tactful and courteous approach and be attentive to the patient’s needs and complaints. In addition, the clinician should always make sure that communications with the patient are clear, even to the point of being repetitious, by asking if the patient has any questions. The patient should never be abandoned in the middle of a course of treatment. Also the clinician should always be available to provide follow-up care. Clinicians should avoid making a diagnosis over the telephone. Instead, one can suggest an office exam to assess treatment needs.

Good telephone communication is a matter of asking the right questions, such as asking a patient complaining of postoperative swelling if there is difficulty breathing or swallowing, as well as the degree and location of swelling. In cases of suspected infection, clinicians should ask the patient or family member to call back with a temperature reading to verify the patient is afebrile.

**Off-the-Cuff Diagnoses**

One clinician misdiagnosed a patient’s party guest’s endodontic problem as “sensitivity caused by gum recession” and recommended a desensitizing toothpaste. Although the conversation took place in a social setting, a lawsuit resulted based upon an inadequate diagnosis.

**Keeping Conversations Professional**

Making light of a minor occurrence, such as the dropping of an instrument, with a quip about the clinician’s “one drink too many” at lunch, may seem funny at the time. However, it may not sound so funny if the patient soberly reiterates the quip to a jury.

The clinician must not let a patient’s flattery of the clinician’s abilities undermine one’s best professional judgment. Heroic measures usually result in treatment failures, dissatisfied patients, and, ultimately, lawsuits for uninformed consent.

A patient dissatisfied with prior treatment that appears adequately performed should prompt the clinician to stop treatment. Young clinicians are more apt to walk into traps involving a patient’s request for
unreasonable treatment. A compassionate clinician who is able to communicate conscientious concern avoids many malpractice actions. Thus when an iatrogenic mishap occurs, it behooves the clinician to be frank and forthright with the patient. Moreover, negligence concealment may extend the statute of limitations. Most states with discovery statutes construe discovery as the date on which the patient discovered the negligent cause of the injury and not the date of the injury itself. Further, belated discovery of injury from another clinician evokes a feeling of betrayal in the patient and destroys rapport that would otherwise dissuade the patient from instituting litigation. Beginning in July 2001, the Joint Commission on Accreditation of Health Care Organizations required hospitals to provide an honest explanation to patients regarding medical mishaps. These standards are designed to prevent errors and to reduce medical negligence claim payouts. In 1999 the *Annals of Internal Medicine* concluded that “extreme honesty may be the best policy.” A full-disclosure policy in a study involving a hospital in Lexington, Kentucky showed that this hospital was in the top 25% of claim incidence, but it was also in the bottom 25% of claim payouts ($1.3 million over 7 years).

**Fees**

Clinicians should clarify fees and payment procedures before initiating treatment. If the dental treatment becomes more extensive than originally planned, the clinician should discuss any increased charges and reasons for those charges with the patient before continuing treatment. Charging for untoward complications, such as extended postoperative visits or retrieving broken instruments, should be resisted.

An overzealous receptionist who places payment pressure on a dissatisfied patient or a clinician who sues to collect a fee from an already displeased patient may invite a countersuit for malpractice. Refunding fees or paying for the treatment fee of the subsequent treating clinician is usually much less expensive than 1 week in court and a jury award for a patient’s pain and suffering. If clinicians must sue for a fee, they should do so only if treatment is beyond reproach and records substantiate proper diagnosis, treatment, and informed consent options.

Suing for unpaid fees continues to be a proven method for getting countersued for dental malpractice. The client who has paid fees in the past but who stops at some point is either unhappy with the dental service received or short of funds. Dealing with a patient’s countersuit takes time, and collection of unpaid fees may prove difficult. The patient being sued may seek an attorney, who will scrutinize the clinician’s handling of the patient and use 20/20 hindsight to second-guess the clinician’s treatment.

Some cross complaints for dental malpractice lack merit, whereas others have genuine merit. Whenever possible, clinicians should avoid suing patients for unpaid fees. Before ever considering suing, the clinician should discuss the fee situation with the patient and consider either a payment schedule or fee reduction.

The amount of money being awarded by juries is increasing. In 1999 a New York City jury awarded $3.5 million against a clinician who had replaced three amalgams with composites. To relieve postoperative sensitivity, endodontics was performed and subsequently failed. A chronic TMD followed the extraction, from which the patient was likely to suffer lifetime pain.

**Incidence of Negligence**

Medical errors or adverse events are estimated to occur in almost one out of four patient visits to a family practitioner. A U.S. government study of the Institute of Medicine found that 98,000 avoidable deaths occur annually because of medical negligence. In this study, injury from medical care occurred in 3.7% of hospital admissions. Some 58% of these injuries were concluded to be preventable, and 13.6% were fatal injuries. The actual fatality numbers may be underestimated since calculations were based solely on hospital chart review.

**Alcohol**

Excessive alcohol consumption can contribute to a higher incidence of corrosion from chronic regurgitation and vomiting from gastritis associated with alcohol abuse. Corrosion can lead to coronal marginal leakage predisposing to endodontic failure. Accordingly, medical histories should include histories of gastric reflux disease, bulimia with associated habitual vomiting, gastritis, and excessive alcohol intake.

**Post Perforation**
Post selection is important for minimizing the risk of perforations. Generally posts should not exceed one third of the mesiodistal width of a tooth, should follow the canal anatomy, and should leave 4 to 5 mm for sealant in the opened post space; this is described more thoroughly in Chapter 21. Excessively large posts violate these guidelines and unreasonably increase the risk of perforation or tooth fracture. Root fracture risks are increased with short posts, large-diameter posts, and threaded posts. Large posts not only weaken roots but also increase perforation potentials. Short posts predispose to root stress and post loosening. Posts should extend three quarters the root length for maximum retention, provided 5 mm of gutta-percha apical seal is achievable. For shorter-than-average roots, maintain 4 mm of apical seal. When a tooth is already crowned, access to the root canal entrance surface should be located before rubber dam placement. This will aid in orienting the root’s long axis, which may vary from the prosthetic crown’s long axis. Fig. 11-29 represents an endodontist’s perforation of tooth #7 because of difficulty in locating the entrance into the root canal apical to the pulp chamber.

Ordinarily, a careful clinician performing endodontic therapy should be able to avoid post perforations. If post perforation occurs, early diagnosis and treatment are important. Belated diagnosis and treatment substantially increase the risk of endodontic failure. If perforation is relatively small in size (i.e., 1 mm or less) and promptly diagnosed at the time of the post perforation, immediate treatment with intracanal sealants (MTA) in the area of the perforation will probably succeed. However, delayed diagnosis and treatment (beyond 24 to 72 hours) result in bacterial contamination in the area surrounding the perforation. Delayed perforation repair therapy can cause periodontal or endodontic lesions and lateral periodontal abscesses occurring secondary to...

Figure 11-29 Avoidable perforation. (Courtesy Stephen Cohen, MA, DDS.)
delayed diagnosis, which usually prognosticates a high failure risk.

**Perforation Prevention**

Irreversible endodontic complication such as furcation perforation during pulpal chamber access is usually preventable with due care. Furcation perforations are avoided by adhering to basic principles of pulpal chamber removal such as cleaning and shaping in a coronal rather than an apical direction. Innovative bur designs can access the pulp chamber without risking furcation perforation by preventing cutting or ditching of the pulp chamber by use of a non - end-cutting bur.

**Cores**

Incorrect choice of cores can contribute to failure, including fractures. For instance, some manufacturers (e.g., ESPE Premier [Norristown, PA] for Ketac silver) recommend against use of their core material unless at least two thirds of the tooth remains before buildup. Failure to follow the manufacturer’s directions can be considered when an expert determines whether the standard of care was met.

Resin-reinforced post-and-core systems show promise for structurally weakened incisors, but long-term longevity has not been reported. A ferrule or other counter-rotational core design is an important consideration for fracture resistance and retention, although it has not been proved as statistically significant for the resin-reinforced core systems.

**Absorbable Hemostatic Agents**

Absorbable collagen hemostatic agents should not be placed on or adjacent to peripheral nerves because of the potential for neural injuries, particularly in bony nerve canals. Also, as such material is absorbed, its chemotactic properties promote collagen formation and scarring. Compression injuries of peripheral nerves in bony canals can result from expanding scar tissue. FDA adverse incident reports list 11 patients with severe neural defects including paraplegia secondary to absorbable collagen products placed in the spinal canal for hemorrhage control. Thus the FDA has warned of paralysis from absorbable hemostatic agents. Accordingly, after hemorrhage is controlled with hemostatic agents, absorbable collagen agents should not be left in situ or near bony neural spaces. This will avoid having remaining hemostatic material cause swelling, pressure, or migration to adjacent neural tissues. The minimum amount of collagen agents necessary to achieve hemostasis should be used.

**Pneumomediastinum (Air Embolus)**

When performing endodontic surgery a surgical handpiece should be used that ventilates air through the back of the handpiece rather than an air turbine that directs air into open tissue spaces. Pneumomediastinum, also known as mediastinal emphysema, may result from air embolisms dissecting down the neck facial planes from air forced into the submandibular or sublingual spaces contiguous with neck spaces.

**Broken Needle**

Scanning electron microscopy (SEM) with an energy dispersive x-ray spectrometer attachment can analyze whether a broken instrument is due to excessive operator trauma or manufacturing defect. Fig. 11 - 30 represents a combination of low-cycle bending fatigue and tensile overload. Accordingly, the local anesthetic needle likely fractured because of bending deformation as it struck the ramus.
Ductile rupture in metals results from shearing along planes that are oriented at 45 degrees to the tensile stress. Tensile "necking" results from multiple slipping deformations in all the 45-degree planes to the needle axis because of significant overload. Final rupture resulted from a combination of bending and tension. Fig. 11–31 shows the needle tip bent and blunted as it hit a hard object. No manufacturing defects were found. Fig. 11–32, A and B, shows SEM views of the fracture. Fig. 11–32, C, is an SEM view of the needle fracture taken at the hub side of the fracture. These illustrations demonstrate why longer 25-gauge needles should be used for mandibular blocks rather than shorter 30-gauge needles.[81]

Figure 11-30  Tensile overload shown elongated ductile dimple voids.

Figure 11-31  Needle blunting of broken needle tip demonstrating striking hard object (ramus).
Sterilization

Nonsurgical use of the dental unit water supply should comply with the Environmental Protection Agency regulatory standard of less than 500 colony-forming units (CFU)/ml.

CDC guidelines require sterile water or sterile solutions for all surgical procedures. Disinfected water from handpieces or ultrasonic devices is no longer acceptable as a water coolant during surgery. Instead an ultrasonic handpiece that can deliver a sterile irrigant during surgery should be used. Dental unit water lines are available with tubing that can be autoclaved for surgery. Some ultrasonic devices are also available with disposable tubing to maintain a sterile water coolant delivery system.

Digital radiographic devices that contact the oral mucosa region require a combination of barrier protective sheath and chemical disinfection in accordance with prudent manufacturers’ directions.

Rotary NiTi files likely contain bioburden material that after sterilization may act as a foreign body. Efficiency degradation after sterilization should suggest to the prudent clinician a single use per patient philosophy.

Posttrauma Therapy

The reader is referred to Chapter 16 for a full discussion of how to treat and manage patients who have sustained a traumatic injury.

Continuing Education

A clinician is legally obligated to maintain current knowledge in the field of endodontics. If not, the clinician may have only 1 year of knowledge (repeated 30 times) during the span of a 30-year career.

Examples of recent endodontic improvements include improved cleansing, shaping, filling, and obturation techniques. Microscopes, variable tapered file systems, heat pluggers, noneugenol resin cements, new
irrigants and medicaments, and NiTi instruments are but some examples of improved technology.

By not maintaining continuing education knowledge and updating clinical skills, a clinician may unreasonably condemn otherwise salvageable teeth because of inadequate diagnosis or treatment.

Millennium Management of Endodontic Advances

Technologic advances are touted as ideal endodontics. However, the standard of care is a minimal standard of reasonably acceptable practice, rather than the perfect ideal. Thus the reasonable and prudent clinician is not required to know and use all the latest technologic advances in endodontics. On the other hand, the reasonable and prudent clinician must keep current with available advances that are generally accepted and proved by research. Microsurgical endodontics is an example of improved endodontics technology; use of magnifying loupes or similar devices may prove inadequate for apical surgery or fractured instrument retrieval compared with microscopes. Therefore the clinician should adopt proven improvements in the endodontic field. Three-dimensional reconstruction of mandibles can be accomplished with volumetric tomography to accurately locate the inferior alveolar nerve or mental foramen. See Figure 11-33 for an example of volumetric tomography usage for implant placement and/or apical surgery.

Figure 11-33  Volumetric tomography usage for implant placement and/or apical surgery.

If studies demonstrate significantly superior results for some alternative to surgical endodontics, the informed consent standard of care may require that the patient be advised of the alternative technique, even if it is more expensive. There may be more than one path to success. So long as the clinician uses reasonably acceptable techniques and informs the patient of reasonable alternatives, the standard of care is met. However, clinicians should remember that today’s surgical advance may be tomorrow’s re-treat. For example, breast and temporomandibular joint (TMJ) implants were inadequately tested technology and proved disastrous. Microscopic apical surgery has gained general acceptance, is performed by the majority of endodontists, and represents the current standard of care.

Clinicians should evaluate the quality of peer-reviewed research articles for new products rather than accepting them at face value. For instance, a case report amounts to no more than the author’s personal experience with one patient. Some authors report a series of patients if there are only two patients. Finally, a brash conclusion is to state something has occurred time and time again if similar findings were observed with only three patients. Valid scientific principles mandate that a test result can be replicated by other competent scientists duplicating a particular research protocol. If research cannot be duplicated, sweeping conclusions should not be made.

Statistical Research

Statistical research conclusions may vary since research protocols may not similarly control variables of population groups studied. Discrepancies occur even within trials or among large trials. Meta-analyses of multicenter randomized controlled trials aim to reduce bias by estimating the effect size for outcomes and adverse effects after pooling all qualified research studies. This approach will not assist if the supporting randomized controlled trials are derived from confounded data from heterogeneous trials. Such research results represent an estimate of the average difference in the responses of the tested treatment groups. These differences in results of different centers from various test groups may reflect important distinctions in the clinical conditions of enrolled research subjects. Such distinctions may help identify subgroups of patients harmed by the researched product, although on average treatment has an overall benefit.
Since most research is currently controlled and sponsored by companies marketing a product, only favorable studies are usually submitted for publication. Literature reviews are prone to publication bias because journal editors are more likely to publish favorable rather than unfavorable conclusions. The most important use of literature review articles is to develop research questions that ultimately must be tested using a randomized controlled trial. Studies other than randomized controlled trials were the basis for prescribing hormone replacement therapy to millions of women to prevent cardiovascular disease. A randomized controlled trial of this therapy was terminated early because increases in cardiovascular disease and breast cancer were discovered.

Prudent clinicians do not adopt every new technology. Before adoption, such technology must have demonstrated benefits with acceptable levels of risk. It must also be adequately tested, with sufficient numbers of test subjects, over a significant length of time. Because manufacturers too often rush their products to market, newer products may not meet this criterion. Therefore except for breakthrough technologic changes, a clinician will not likely be judged negligent for failure to adopt each latest device or technique. However, clinicians must keep in mind that in the information technology industry, 1 year is considered several generations, if not an eternity.

The standard of care usually does not mandate incorporation of every new technology. However, in those states with informed consent laws that are based on what a prudent patient would want to know, rather than what prudent clinicians should do, the patient may argue that an alternative technology or technique used by a different clinician would have been chosen had the clinician provided the patient with such information. For instance, even if the majority of clinicians have not yet adopted microsurgery to aid surgically grafting gingival recession areas, should graft failure occur, the patient may claim that the clinician failed to provide the option of microsurgical periodontal grafting before obtaining the patient’s informed consent.

Thorough instrumentation and obturation of the entire root canal system, using generally accepted instruments, materials, and devices, remain the best means of ensuring endodontic success.

**Other Clinicians’ Substandard Treatment**

Clinicians should not be overly protective of blatant examples of another clinician’s substandard dental treatment. On discovery of apparent negligent treatment by a previous clinician, the clinician should consider investigation. Begin by obtaining the patient’s written authorization for transfer of a copy of the previous clinician’s records, including radiographs. If the negligence is still suspected after reviewing the records, the clinician should consider talking with the previous clinician to learn the circumstances of what occurred during the patient’s past treatment (after obtaining the patient’s consent pursuant to HIPAA).

On discovery of a gross violation of the standard of care, a clinician has an ethical responsibility to report the matter to the local dental society, peer review, or dental licensing board or agency. In addition to informing the patient if this is not done and the patient later discovers negligent treatment that is patently obvious, the clinician could arguably be sued as a co-conspirator to fraudulent concealment of another clinician’s neglect.

**Peer Review**

If despite good rapport, candid disclosure, and an offer to pay corrective medical or surgical bills the patient is still unsatisfied, the clinician should consider referring the patient to peer review. Peer review committees award damages for out-of-pocket losses, but not for pain and suffering or lost wages. Consequently, even if the committee’s decision is adverse to the clinician, the damage award will probably be less than a jury’s verdict. If peer review finds for the clinician, the patient may be discouraged from proceeding further with litigation. Peer review proceedings, including the committee’s decision, are not admissible in court.

Insurance carriers usually honor and pay a peer review committee award, because a fair adjudication of the merits has been determined. The award is usually less than a jury would award. However, defense costs, including attorney’s fees, are saved.

**Human Immunodeficiency Virus and Endodontics**

A clinician may not ethically refuse to treat an HIV-seropositive patient solely because of such diagnosis. Although in the 1980s no federal law had clearly extended the protection of the handicapped laws to patients with AIDS, federal congressional action in 1990 extended this protection to the dental office setting with the
passage of the Americans with Disabilities Act. Many states already offer additional protection under state law.

Confidentiality for patients disclosing their HIV status is important, because an inadvertent disclosure to an insurance carrier or to other third parties, without any need to know, may result in cancellation of the patient’s health, disability, or life insurance.

This cancellation could result in a claim against the clinician whose office disclosed such information without authorization. Therefore employees should sign the confidentiality agreement shown in Fig. 11–34. In signing this agreement the staff may be alerted to the seriousness and importance of maintaining the confidentiality of patient health histories, because these histories may document AIDS, venereal disease, or other socially stigmatizing diseases.

If a patient requests that the clinician not inform the staff of the patient’s HIV status, the clinician should refuse to treat that patient. This information is essential to staff members who may come in contact with the infection. For example, an accidental needle stick with HIV-infected blood, which carries a risk of approximately 1 in 250 chances of seroconversion, may occur. Current medical protocol includes prophylactic administration of zidovudine (AZT), either to prevent or to slow the manifestation of AIDS from a deep, penetrating, accidental needle stick exposure.

Although a treating clinician risks devastating a dental practice by informing patients that the clinician has contracted AIDS, the legal risk of not informing patients is much greater. The health care provider may be required to advise patients of positive HIV test results under the doctrine of informed consent (i.e., advising of a known risk of harm from accidental exposure). Even if an uninformed patient never contracts AIDS, in those states that use a reasonable patient standard for disclosure of material risks of treatment (which could include accidental direct contact such as an unintended cut or needle stick), the patient may decide to bring an action for intentional concealment as a variant of informed consent and seek to recover emotional distress and punitive damages. Conversely, patients may be legally liable for intentionally misrepresenting their health history regarding their HIV status.

**Infective Endocarditis**

If a patient’s medical history shows valvular heart defects with regurgitation, the clinician should consult with the patient’s physician to determine the necessity of antibiotic prophylaxis against infective endocarditis in accordance with current American Heart Association (AHA) guidelines. If the physician does not appear knowledgeable about those guidelines, the clinician should provide a copy of the guidelines to the physician. If the physician advises deviation from AHA guidelines, the clinician should inquire why the physician feels that this is appropriate. The clinician should also record any discussions with the physician in the patient’s chart and confirm the discussion and the physician’s recommendation in writing (by fax and letter to the physician).

Communications with the physician should be specific, because the physician may not appreciate dental treatment risks, such as overextension of files or filling material sealants that occur nonsurgically and may enter the bloodstream. The following format might be used:

**Dear Physician:**

Your patient requires potentially invasive dental treatment that will likely result in a transient bacteremia. Does the patient have a heart valve defect that increases the risk of infective endocarditis? If so, please advise of the diagnosed defect and recommended prophylactic antibiotics and dose for endodontic treatment or surgery with potential to invade the bloodstream. If you require the patient to have a current cardiac evaluation or echocardiogram to provide an answer, please advise both me and the patient, preferably in writing.

Please also advise if your recommendation is in accordance with the enclosed American Heart Association current guidelines concerning bacterial endocarditis relating to dental treatment.

Thank you for your anticipated cooperation.

(Enclosure: current AHA guidelines)
Individuals who have undergone total-joint replacement surgery may arguably be at increased risk for bacterial infection to the artificial joint. Late joint infections (i.e., less than 6 months) may potentially occur as the result of bacteria introduced into the oral cavity. Antibiotic prophylaxis may be recommended for certain individuals with total joint replacements before specific dental procedures (as recommended by the AHA). The drugs (e.g., cephalexin, cefradine, amoxicillin) used to prevent the late infection of prosthetic joints differ slightly from those recommended by the AHA. The treating orthopedist’s recommendation is the guidepost clinicians should consider during the first 6 months after joint replacement surgery.
CONCLUSION

If the clinician performs endodontics within the standard of care as described in this chapter, there should be little concern that a lawsuit for professional negligence will be successful. Prophylactic measures suggested in this chapter should help lessen the likelihood of litigation by reducing, if not eliminating, avoidable risks associated with endodontic care.

Both the patient and clinician benefit from risk reduction. To do it wrong does not take long, but it is far better for the clinician to take the extra precautionary time to do it right. We are a profession that deserves the public’s trust but only if that trust is earned. Clinicians earn public trust by providing safe and excellent quality patient care. The best prophylaxis against being sued is to do it right the first time rather than defending a clinician’s wrongs before a jury.
Legal References


f. California Business and Professions Code, § 1683.

g. California Health and Safety Code, § 123110(j).


k. California Business and Professions Code, § 1680(s).


o. California Business and Professions Code, § 2056.


s. 18 A.L.R.4th 603.

t. Sheeley v Memorial Hospital, 710 A.2d 161, 1998.


v. Flowers v Torrence Memorial Hospital Medical Center, 8 Cal.4th 992, 1994.

w. Restatement 2d Torts, §§ 283, 289.
x. Restatement 2d Torts, § 299A (comment e).

aa. Seneris v Haas, 45 Cal.2d 811, 1955; see also 53 A.L.R.2d 124.


ff. Glover v Dentsply International, Los Angeles County Superior Court (California), Case No. BC279973.


ii. California Evidence Code, § 669.

jj. Restatement 2d Torts, §§ 282 et seq.


mm. Tunkl v The Regents of University of California, 60 Cal.2d 92, 1963.


rr. Simone v Sabo, 37 Cal.2d 253, 1951.

ss. Restatement 2d, Agency §§ 228 – 237.


vv. Restatement 2d, Torts § 402A. (See Fig. 10 – 18.)


iii. He v Michaelian, San Francisco Superior Court (California), Case No. 315630, 2000.

jjj. 21 U.S.C. §§ 301 et seq.

kkk. Cedars North Towers Pharmacy, Inc. v U.S.A., District Court, Fla, Case No. 77 – 4965 (8/18/78, summary judgment).

LLL. Irshheid v Elbee Chemists and Available Products, Inc., San Francisco Superior Court (California), Case No. 908373, 1992.


ppp. Flores v Michaelian, San Mateo County Superior Court (California), Case No. CIV430666, 2003.


www. Boulais v Lustig, Los Angeles Superior Court (California), Case No. BC038105 ($102,500 jury verdict to an ungloved surgical technician).

