

Diagnosis and management planning for root-filled teeth with persisting or new apical pathosis

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Teeth may require further management following root canal treatment because of persisting or new apical pathosis. Management must be based on the diagnosis of the presenting condition and the history of the previous treatment, particularly in relation to when it was completed. Most root-filled teeth with periapical pathosis should be re-treated in the first instance via a conventional orthograde approach since most disease is related to an infected root canal system. However, this approach to treatment should only be followed if the tooth is suitable for further restoration and when the restoration has a good long-term prognosis. Assessment of whether a tooth is suitable for treatment may not be possible until after restorations, caries, and cracks have been removed so that the remaining tooth structure can be visualized and assessed. Periapical surgery should be reserved for teeth with persistent symptoms and/or apical radiolucency following root canal re-treatment and where the differential diagnosis suggests an ongoing periapical condition such as a true cyst, extra-radicular infection, or foreign body reaction which cannot be addressed via an orthograde approach. If a tooth has to be extracted, it can be replaced with one of several forms of prostheses; implant-supported prostheses are gaining popularity and have a proven track record, especially for single tooth replacements. The use of implants should be restricted to cases where teeth are already missing or where a tooth cannot be retained because it is not suitable for further restoration due to insufficient tooth structure.

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Introduction

The first, and most important, stage of managing disease is to diagnose the presenting disease process. This requires the clinician to have a thorough knowledge and understanding of the disease processes. When assessing a patient who presents with symptoms and/or a periapical radiolucency associated with a root-filled tooth a number of factors must be considered. In the past, the focus has often been placed on the radiographic appearance of the root filling, which has led to a mechanical approach to managing the disease. In this article, a biological approach will be outlined with emphasis on the diagnosis and then treating the cause in order to improve the predictability of the treatment outcome. In other words, the diagnosis should dictate the management options for the tooth. It

is then a matter for the clinician and the patient to jointly decide which management option to choose.

In order to diagnose any condition, it is necessary to have a classification of the various diseases and/or conditions which can occur. Classifications are important because they:

- allow clear and accurate communication between professionals;
- allow clear and accurate education of students and colleagues;
- help clinicians to categorize the presenting condition—that is, diagnose the condition—which should then indicate the appropriate management options;
- allow clear communication during scientific writing; and
- avoid confusion between clinicians.

An ideal classification should be:

- possible to use clinically, based on information which can be obtained via the clinical and radiographic examination procedures;
- meaningful—that is, based on the changes which occur in the tissues;
- able to be used to determine the management options for the patient; and
- used universally within the profession.

Throughout this article, the terminology and classifications proposed by Abbott & Yu (1) for pulp and root canal conditions, and by Abbott (2) for periradicular conditions, will be used. Although the latter classification is not solely related to root-filled teeth, the periradicular disease processes associated with root-filled teeth are the same as those which occur with teeth that have not had any previous endodontic treatment (except in the case of foreign body reactions to materials which have been extruded into the periapical region). The classification of pulp and root canal conditions includes a section for teeth that have had previous endodontic treatment.

Terminology and definitions

An important aspect of communicating concepts is to define the various terms to be used. It is also essential to have a clear and concise classification of the diseases and conditions to be diagnosed. In order to comply with this, the following terms and meanings will be used in this review.

Treatment

This term is defined as “administration or application of remedies to a patient for a disease or an injury” (3). Treatment is a systematic course of medical or surgical care and hence it implies that some form of “active” therapy is required. This could be non-invasive (such as prescribing an appropriate medication) or it could be invasive (such as root canal re-treatment, periapical surgery, etc.). This term does not include an appointment to review or reassess the tooth since this is not a medical or surgical form of care, nor is it a form of “active” therapy.

Management

In a medical sense, this term is defined as “the whole system of care and treatment of a disease” (4). Thus, it

can be considered as the manner of handling a patient including treatment. Hence, this term includes all aspects of dealing with a patient which, following appropriate diagnosis, could include reviewing and reassessing the tooth as well as active treatment (such as root canal re-treatment, periapical surgery, etc.). Therefore, the term “management” is an all-encompassing term that includes the entire patient journey rather than just indicating that active treatment is required.

Success and failure of treatment

Many authors refer to “success rates” when discussing treatment outcomes but these terms are misleading and ambiguous (5). Friedman & Mor (5) proposed alternate terms which are more accurate and more useful for clinical practice—they recommended the terms “favorable” or “unfavorable” with an additional category of “uncertain” to be used when the healing response is not clear. Other terms suggested by Friedman & Mor (5) are “healing”, “healed” and “not healed”—these are used to describe the radiographic appearance of the periapical region following treatment. Apart from the reasons discussed by Friedman & Mor (5), if a case is initially classified as a “success” but subsequently “fails”, then it was clearly not a “success” even at the early reviews. Therefore, where a percentage “success rate” is claimed for a review period, this should be considered as meaning that that percentage of the cases had bone repair evident on the radiograph but only at that specific time interval. If the review period was a short time after treatment, then this should be further considered as an *indication of healing* in the specified number of cases rather than indicating true “success”, since success can only be determined over a long period of time.

Post-treatment disease

Although the term “post-treatment disease” has gained popularity within the endodontic community in recent years, it is a poor term which does not meet the criteria required to be included in a diagnostic classification since it does not indicate what is occurring within the periapical tissues. In addition, and because of its vague meaning, it does not lead the clinician to a management plan or a series of management options. The term is vague and misleading since it does not

define or consider what is really meant by the words used in the phrase, as follows:

- “treatment” – the treatment could be a restoration, periodontal treatment, a root canal filling, periapical surgery, etc.; that is, any possible treatment;
- “post-treatment” – this could mean after instrumentation of the root canal system, after placing the root filling, after periapical surgery, etc.; this term also does not indicate the time frame after the original treatment—if it is assumed that the problem has occurred after root canal treatment (see above), then how long after the treatment was completed does this term become relevant (for example: is it 1 month, 6 months, 1, year, 2 years, 5 years, 10 years, etc.); and
- “disease” – it can be assumed that this implies a periapical radiolucency but periapical conditions can also present as radiopacities; in addition, a radiolucency could be a periapical true cyst, a foreign body reaction, an extraradicular infection, or some other pathosis unrelated to the pulp or root canal system; a radiolucency could also be a periapical scar which is not a disease but a “condition” or a normal physiological response.

It is well known and accepted within the dental profession that it is not possible to use radiographs to differentiate between the various periapical conditions which can be associated with root-filled teeth—that is, a granuloma, true cyst, pocket cyst, extraradicular infection, foreign body reaction, or a scar. Hence, in order to address this diagnostic problem and to overcome the deficiencies of the term “*post-treatment disease*”, the following three terms are recommended as being more appropriate alternatives. They are based on the time interval between when the root canal filling was completed and when the diagnosis of the current condition is being made.

• **Persistent periapical radiolucency following root canal treatment**

This term is used for teeth that have periapical regions which do not have radiographic signs of bone healing within four or five years following routine orthograde root canal treatment. The various conditions that constitute the differential diagnosis for root-filled teeth in this category are listed in Table 1.

Four to five years is considered to be the time frame required for assessment of the periapical healing response as some lesions can take this long to heal

Table 1. Differential diagnosis for a root-filled tooth with a persistent periapical radiolucency

Periapical conditions that could present as a persistent periapical radiolucency following root canal treatment
A Chronic apical periodontitis due to an infected root canal system
B An extraradicular infection
C A periapical true cyst
D A foreign body reaction
E A periapical scar

(6, 7). If radiographic signs of complete healing are evident before 4–5 years, then the case has had a favorable outcome. However, if there are no radiographic signs of repair and there are no symptoms or other signs, then such cases should be reviewed for at least 4–5 years to determine whether the radiolucency will reduce in size before considering that there has been an unfavorable outcome—that is, a persistent radiolucency. If the radiolucency has reduced in size, then it may indicate a periapical scar (condition E in Table 1) or it may indicate that the canal is still infected (condition A in Table 1). Where the radiolucency remains the same size or increases in size, then it usually indicates one of the four conditions listed as A-D in Table 1—that is, there is a periapical problem.

The first four conditions (A-D) listed in Table 1 will generally require further treatment—such as root canal re-treatment and/or periapical surgery, or extraction. However, the last condition (E, a periapical scar) does not require any active treatment but should be managed by arranging further reviews to monitor the region since it is not possible to definitively diagnose a periapical scar during a clinical and radiographic examination. Its assessment is generally based on a lack of any symptoms and/or signs that would suggest any of the first four conditions (A-D) listed above, and either a reduction or no change in the size of the radiolucency when compared to the immediate post-operative radiograph.

• **New periapical pathosis associated with a root-filled tooth**

This term is used for a tooth which had root canal treatment many years ago and early reviews of the

tooth and its periapical tissues indicated that the periapical region had healed following treatment but a new radiolucency has developed later. The new radiolucency indicates that the root canal system has become infected again (excluding root fracture etc.). Typically, this assessment would not be made until more than five years after the previous root canal treatment was completed in order to allow time for those cases which are slow to display radiographic signs of periapical tissue healing (see above).

This term can also be used if there was no radiolucency present at the time of the original root canal treatment and the periapical region maintained normal radiographic appearance during the initial follow-up period (i.e. up to five years) but the radiolucency developed later. This radiolucency indicates that the root canal system has become infected subsequent to the root canal treatment.

A tooth in this category has a new disease that has no connection with the original condition — it just happens to be in a tooth which has previously been root-filled. Apart from the presence of the root filling, and notwithstanding that there may be a different microbial flora present in infected root-

filled teeth (8, 9) in terms of the diagnosis and management options, these cases are no different than teeth which have not been endodontically treated. The various conditions that should be included in the differential diagnosis for root-filled teeth in this category are listed in Table 2.

If the clinician does not have access to the radiographs and clinical records concerning the previous diagnosis and root canal treatment, and when there are no symptoms or clinical signs of active disease in addition to the conditions listed in Table 2, the clinician should also consider that the periapical radiolucency could indicate the presence of a periapical scar. However, this should only be a provisional diagnosis and further reviews should be arranged over time in order to monitor the region for radiographic signs of changes in the status of the periapical tissues.

All of the periapical conditions listed in Table 2 develop as a result of, or as a sequel to, the presence of micro-organisms in the root canal system. Hence, these teeth should initially be managed with root canal re-treatment (see below) followed by regular clinical and radiographic reviews to monitor the healing response. If the periapical region does not show radiographic signs of healing following re-treatment of the root canal system, then the tooth subsequently would be diagnosed as having a “persistent periapical radiolucency following root canal treatment” (as above) and therefore will require further treatment or further reviews. If further treatment was indicated, then this would typically be a periapical curettage since the micro-organisms should have been removed from the root canal system when the root canal re-treatment was performed and therefore the persistent periapical radiolucency is likely to be a periapical (or an extraradicular) problem rather than an intra-canal problem. Some cases may also be managed with apical root-end resection and root-end filling in conjunction with periapical curettage if the operator suspects that there may be residual organisms in the apical portion of the root canal system.

- **Another condition which mimics a periapical radiolucency**

There are many radiolucencies and radiopacities of the jaws which can mimic periapical diseases of pulp/root canal origin by being superimposed over the periapical region on a radiographic image or by

Table 2. Differential diagnosis for a root-filled tooth with a new periapical radiolucency

Periapical conditions that could present as new periapical pathosis associated with a root-filled tooth

A Primary acute apical periodontitis due to an infected root canal system

B Primary acute apical abscess due to an infected root canal system

C Secondary acute apical periodontitis due to an infected root canal system

D Secondary acute apical abscess due to an infected root canal system

E Chronic apical periodontitis due to an infected root canal system

F A chronic apical abscess due to an infected root canal system

G Facial cellulitis associated with an infected root canal system

H An extra-radicular infection

I A periapical pocket cyst

J A periapical true cyst

K A foreign body reaction

Table 3. Radiolucent lesions of the jaws that may mimic “periapical” pathosis and should be considered to be part of the differential diagnosis of a radiolucency in the periapical region (Reproduced and adapted from Abbott (2, 10) with permission)

<i>EPITHELIAL CYSTS</i>	
Developmental Odontogenic Odontogenic keratocyst Dentigerous cyst Lateral periodontal cyst Glandular odontogenic cyst	Non-Odontogenic Nasopalatine duct cyst Nasolabial cyst
<i>NEOPLASMS AND OTHER TUMORS</i>	
Odontogenic <i>BENIGN</i> Ameloblastoma Squamous odontogenic tumor Calcifying epithelial odontogenic tumor Clear cell odontogenic tumor Ameloblastic fibroma Ameloblastic fibrodentinoma Odontoameloblastoma Adenomatoid odontogenic tumor Calcifying odontogenic cyst Odontogenic fibroma Odontogenic myxoma Benign cementoblastoma <i>MALIGNANT</i> Malignant ameloblastoma Primary intraosseous carcinoma Malignant variants of other odontogenic tumors Malignant changes in odontogenic cysts Ameloblastic fibrosarcoma Ameloblastic fibrodentinosa sarcoma Odontogenic carcinosarcoma	Non-Odontogenic <i>BENIGN</i> Cemento-ossifying fibroma Neurofibroma Neurilemoma Osteoid osteoma Osteoblastoma Chondroma Idiopathic histiocytosis <i>MALIGNANT</i> Ewing’s sarcoma Chondrosarcoma Osteosarcoma Neurogenic sarcoma Carcinoma of the maxillary sinus Malignant neural tumors Burkitt’s lymphoma Metastatic carcinoma Primary lymphoma of bone Plasma cell neoplasms - Solitary plasmacytoma - Multiple myeloma Malignant salivary gland tumors
<i>NON-NEOPLASTIC BONE LESIONS</i>	<i>INFLAMMATORY LESIONS</i>
Fibrous dysplasia Cemento-osseous fibroma and cemento-osseous dysplasias (including periapical cemental dysplasia and florid osseous dysplasia) Cherubism Central giant cell lesions Central haemangioma of bone Aneurysmal bone cyst Simple (traumatic/solitary/haemorrhagic) bone cyst Osteomyelitis Tuberculosis	Radicular cysts (of pulpal origin) - Apical: true, pocket - Lateral - Residual Paradental cysts - including: - Inflammatory collateral cyst - Mandibular infected buccal cyst Periapical granuloma Periapical abscess
<i>METABOLIC DISEASES</i>	
Paget’s disease (initial phase) Hyperparathyroidism	

being located within the periapical region. Some of these may be anatomical structures (such as the mental foramen, incisive foramen, maxillary sinus, etc.) or they may be various pathological conditions (such as cysts, tumors, bone diseases, etc.). Hence, clinicians should always consider “non-endodontic” conditions as part of their differential diagnosis of all radiolucencies and radiopacities of the jaws. A list of possible conditions has been presented by Abbott (2, 10) and this is reproduced in Table 3.

Examination

In order to arrive at a diagnosis and management plan, it is essential to examine the patient thoroughly. The examination forms part of the diagnostic process which begins with a comprehensive medical and dental history, with special emphasis on the presenting problem. Information provided by the dental history should enable the clinician to form a provisional diagnosis before examining the patient. The clinical examination can then be targeted in an appropriate manner towards confirming this provisional diagnosis while also being aware that any findings or test results which are not consistent with that provisional diagnosis could indicate an alternate diagnosis.

When taking the dental history from a patient who has a root-filled tooth, the clinician should endeavor to obtain as much information as possible about the previous diagnosis and treatment. This should include asking when the treatment was done, since this information is important in determining whether the current periapical condition is a new condition or a persistent one, as outlined above. This in turn can affect the management and treatment of the patient. It is also advantageous to question the patient about who did the previous treatment so that that particular dentist can be contacted to request details (including radiographs) of the diagnosis, treatment, and any subsequent reviews which were completed.

Root-filled teeth or teeth which have had other forms of endodontic treatment (including root canal treatment that has not been completed) will not normally present with symptoms or signs of pulp disease, since the pulp has been removed. Hence, in such cases, it is the condition of the root canal system which needs to be diagnosed and this typically means determining whether or not the root canal system is infected (1).

This decision will be based largely on the status of the periapical tissues which in turn is based on the radiographic appearance of the periapical region and the presence of pain or tenderness to biting/percussion on the tooth. If there is evidence of periapical disease, then the root canal system is very likely to be infected. However, if there are no signs of periapical disease, then the root canal system may or may not be infected since a periapical radiolucency will not be evident until some time (possibly many months) after the root canal system becomes infected (11). Likewise, the absence of symptoms does not necessarily imply the absence of disease since a tooth with an infected root canal system and chronic apical periodontitis typically has no symptoms (2). In addition, periapical true cysts, extraradicular infections, and foreign body reactions may have no symptoms for much of their existence and will only have symptoms if there is an acute exacerbation of the chronic inflammation associated with them. This typically only occurs when bacteria from the associated infected root canal system and/or their byproducts have exited through the apical foramina into the periapical tissues and the conditions in the periapical tissues are conducive for an acute inflammatory reaction to occur. This usually requires that the host's defense system is compromised, possibly for some unrelated reason (12).

The essential aspects of a clinical examination include:

- visual examination of the hard and soft tissues;
- examination of the teeth and restorations;
- periodontal assessment;
- mobility testing;
- percussion;
- palpation;
- transillumination;
- bite testing; and
- pulp sensibility testing of adjacent teeth.

A radiographic examination is also essential with periapical radiographs being the most common and generally the most useful images. Periapical radiographs from varying angles may be required and other images—such as bitewing radiographs, panoramic radiographs, computed tomography, cone beam scanning, etc.—can be useful for some cases. More details about the examination procedures and typical findings for the various pulp/root canal conditions and periradicular conditions associated with infected root canal systems have been outlined by Abbott & Yu (1) and Abbott (2), respectively.

In summary, the diagnostic process should be considered as an “information-gathering exercise.” Once the information has been gathered, it must be processed and organized in order to provide the diagnosis. The final diagnosis should consist of the following four aspects:

- a) identification of the tooth in question;
- b) assessment of the status of the root canal system;
- c) assessment of the status of the periradicular tissues; and
- d) identification of the cause(s) of the disease(s).

There are five main stages in the diagnostic process, namely:

- a) history-taking (includes both medical and dental histories);
- b) clinical examination and tests (e.g. pulp sensibility tests, percussion, mobility, palpation, periodontal assessment, etc.);
- c) radiographic examination (including other imaging techniques if required);
- d) investigation of the tooth; and
- e) recording of the findings and diagnosis.

The first three have been discussed above. The term “investigation of the tooth” is used for the initial stages of managing the disease—it involves the removal of all restorations, caries, cracks, and fractured portions of the tooth (13). This removes the most common causes of the disease, or more accurately, it removes the potential pathways of penetration into the tooth for the bacteria which are causing the disease. This procedure also forms an essential part of the diagnostic process (14) since it allows the clinician to confirm the diagnosis of the status of the root canal system through direct visualization. Furthermore, it then allows the clinician to assess the prognosis of the tooth in more detail by inspecting the remaining tooth structure in order to determine whether the tooth is suitable for further treatment and especially for further restoration once the root canal treatment has been completed (see below). It is only at this stage of the process that the clinician can provide the patient with a reasonable estimate of the prognosis of the tooth and the overall treatment needs (13, 14).

Cause(s) of the disease(s)

As mentioned above, an essential part of the diagnostic process is to determine the cause(s) of the disease(s). Once the cause(s) has/have been identified then the approach to, and the options for, managing the

disease(s) should become obvious since the first stage of treating any disease is to remove the cause (13). For example, if a tooth has an infected root canal system as a result of the presence of caries, then the caries must be removed before any other treatment is undertaken; if this is not done, then bacteria will be left in the tooth and the disease process is likely to continue even though the symptoms may have been resolved and the signs may not be immediately obvious. However, over time the effect of having left caries (that is, bacteria) in the tooth will become evident as the periapical disease will not resolve and the radiolucency will persist and enlarge. Alternatively, symptoms may develop and cause the patient to seek further treatment.

Apart from the non-endodontic conditions listed in Table 3, periapical diseases are a direct result of pulp/root canal diseases and, in particular, infections of the root canal system. Therefore, consideration of how the micro-organisms have entered the root canal system is essential. The possible pathways of penetration into teeth for micro-organisms are:

- via caries or exposed dentin;
- through cracks;
- through gaps at restoration margins such as when the restorations are breaking down or have been poorly placed;
- via fractures of the tooth or a restoration;
- through apical or lateral root canal foramina which have been exposed to organisms as a result of trauma; and
- through apical or lateral root canal foramina which have been exposed to organisms by deep periodontal pockets as a result of advanced periodontal disease.

Of the above, the three most common pathways are via caries, cracks, and through restoration margins. While these problems can sometimes be noted during a clinical and radiographic examination, one study (13) has shown that there was only a 56.1% chance (with a 95% Confidence Interval) of finding that one or more of these problems were present when there was a restoration present in the tooth. In some teeth, these problems may be recognized as being present, but it is difficult, or even impossible, to determine the extent of these problems in a restored tooth. Hence, removal of all restorations from teeth with pulp/root canal or periapical diseases is advocated to increase the possibility of identifying the cause(s) of the disease(s) as well as removing it/them and thereby increasing the likelihood of a favorable treatment outcome. Once the

restoration has been removed, any caries, cracks, or fractured portions of the tooth should also be removed as these are all potential pathways of entry and penetration for micro-organisms to reach the root canal system. Further major advantages that follow removal of the restorations include allowing the clinician to more accurately assess the suitability of the remaining tooth structure for further restoration, to determine what type of restoration should be undertaken, the design of the restoration, and whether any adjunctive treatment (e.g. post-retained core, periodontal crown lengthening surgery, etc.) is required. The overall prognosis can be greatly improved as the ability to select appropriate cases for endodontic treatment (including re-treatment) is vastly improved by this approach. This essential process of investigation of the tooth has been largely neglected by many clinicians even though it has been advocated by several authors and for many years (14).

Management options

There are several management options available for clinicians when faced with a root-filled tooth which has persistent or new disease. In general, these options are:

- 1) review and reassess;
- 2) root canal re-treatment;
- 3) periapical surgery; or
- 4) extraction (with or without prosthetic replacement).

In some cases, a combination of these options may be used—for example, review and reassess followed by root canal re-treatment if the radiolucency increases in size. Another example would be to perform root canal re-treatment initially but, if the periapical problem persists, then periapical surgery may be required. When deciding which option or options to follow, consideration must be given to the patient's age, general health, oral health, willingness to proceed, finances, etc. It is also necessary to consider the options in view of any complications that the proposed treatment may involve—such as when the problematic tooth is an integral part of a complex prosthesis and its removal has major implications for the patient's overall oral status, their ability to function, their finances, etc. In all cases, fully-informed consent must also be obtained from the patient and this implies that a full explanation of all options, details of treatment, likely outcomes, possible complications, costs, etc. must be provided.

The decision regarding which option, or options, to present to the patient will depend on the diagnosis and the cause of the disease(s). Hence, it is essential to determine whether the periapical radiolucency is:

- a persistent periapical radiolucency following root canal treatment (Table 1) and, if so, is it due to—
 - the root canal system being infected
 - an extraradicular infection, a periapical true cyst, a foreign body reaction, or
 - a periapical scar;
- a new periapical disease associated with a root-filled tooth (Table 2); or
- another condition mimicking a periapical radiolucency (Table 3).

Once a diagnosis has been made according to the above possibilities, then the management options outlined in Figures 1–3 can be followed. If the diagnostic process indicates that the radiolucency is not of pulp/root canal origin, then none of the above management options apply and the patient should be referred to an appropriate dental and/or medical specialist for further assessment and appropriate management (Fig. 1). However, in general, if the periapical radiolucency is believed to be a periapical scar (Figs. 4 and 5) or if the diagnosis is not definitive enough, then the first option listed above (i.e. to review and reassess) would be the logical choice.

If the radiolucency is considered to be a result of an infected root canal system (whether it is persistent disease or a new disease), then root canal re-treatment would be the treatment of choice (Fig. 6) provided the investigation phase indicates that the tooth is suitable for further root canal treatment and a new restoration and that the new restoration is likely to have a good long-term prognosis. In some cases, the examination and/or pre-operative radiograph (Fig. 7) may suggest that there will be insufficient tooth structure remaining following root canal re-treatment to enable the tooth to be restored adequately, in which case extraction should be recommended. However, in most cases, the restorations, caries, and cracks will all need to be removed to allow full assessment of the remaining tooth structure (Fig. 8). If comprehensive and effective root canal treatment had been provided recently (i.e. within the last five years), the history is known, previous radiographs are available, and the radiolucency was an indication of a persistent periapical problem (such as an extraradicular infection, true cyst,

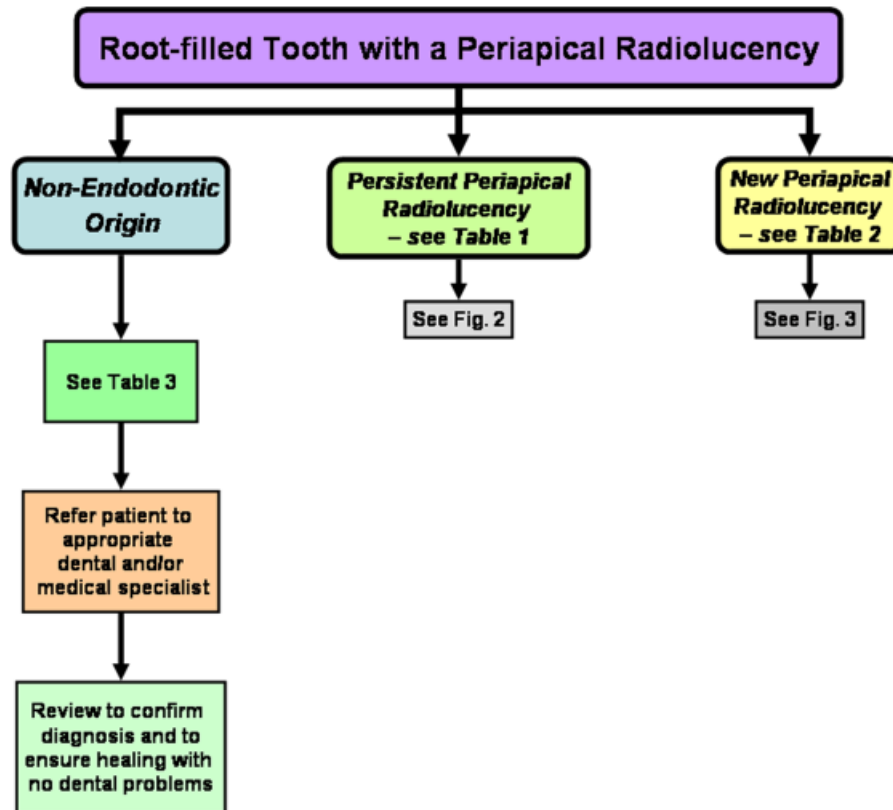


Fig. 1. Management options for a root-filled tooth with a periapical radiolucency which is not the result of a root canal infection.

or foreign body reaction), then periapical surgery would be indicated. Figures 2 and 3 summarize these approaches to management.

It is believed that the vast majority of periapical radiolucencies (whether they are persistent diseases or new diseases) are a result of the presence of bacteria within the root canal system—that is, an intra-radicular infection. Several studies support this belief (12, 15–18). Ricucci et al. (15) examined periapical biopsies from 12 symptomatic and 12 asymptomatic root-filled teeth which had periapical radiolucencies. They reported that all of the teeth had periapical inflammation and bacteria were identified in all but one of the roots. The one case with no bacteria in the root had a foreign body reaction to the root filling material which had been extruded into the periapical tissues. Interestingly, they also reported that this case had originally been treated because it had pulpitis rather than an infected root canal system. The teeth had been root-filled for a mean time of 7.5 years in the asymptomatic group and for a mean of 2.2 years in the symptomatic cases. In the asymptomatic cases, the bacteria were reported to be

present in “small numbers” whereas the symptomatic group had “large numbers” of bacteria. Most bacteria were located within the root canal system—that is, within the main canal, apical ramifications, lateral canals, isthmus and/or dentinal tubules. Most of the symptomatic cases had a dense biofilm filling the entire lumen of the apical canal and ramifications. Finally, four of the symptomatic and one asymptomatic case had bacteria located in the periapical region as well as inside the root canal system. This study clearly demonstrated that the primary reason for persistent periapical radiolucencies is the presence of bacteria within the root canal system and the radiolucency was an indication of periapical inflammation.

Studies of biopsies taken from periapical regions indicate that the most common finding is a periapical granuloma with reports ranging from 35% to 87.1% (17–21). Some of these studies are summarized in Table 4. In other words, the most common finding is inflammatory tissue within the periapical region. As outlined above, the most likely reason for the presence of a granuloma is an intraradicular infection. The

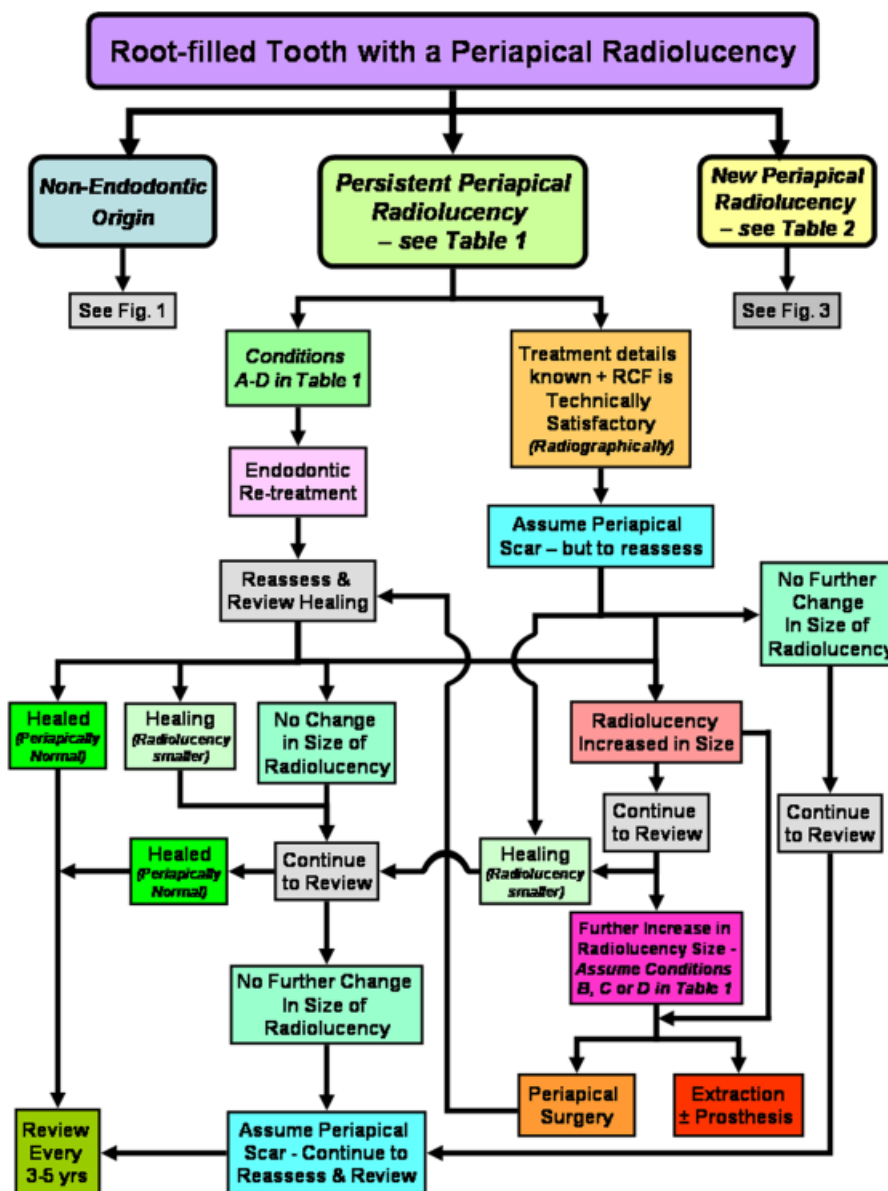


Fig. 2. Management options for a root-filled tooth with a persistent periapical radiolucency following root canal treatment.

incidence of other conditions is generally much lower (Table 4) and to date no study has been able to estimate the true incidence of periapical true cysts, extraradicular infections, foreign body reactions, and periapical scars. Studies have reported a wide range of incidences of these conditions and these ranges are likely to be a result of variations in the samples included in the study, surgical biopsy techniques, histological processing, and interpretation. As examples, Nair et al. (12) reported that 35% of their cases were abscesses whereas Schulz et al. (17) reported only 5% of their cases were abscesses. The cases examined by Nair et al. (12) were all

extracted teeth and they were obtained from patients who had presented with pain or other symptoms, whereas the samples in the Schulz et al. study (17) were obtained during periapical surgical procedures and none of the patients had symptoms at the time of surgery. All cases with acute inflammation or secreting abscesses were treated immediately except to control their symptoms through antimicrobial therapy. In addition, in order to be included in the Nair et al. (12) study, every sample had to have the soft tissue lesion attached to the root apex whereas only 21% of the cases in the Schulz et al. (17) study satisfied this



Fig. 3. Management options for a root-filled tooth with a new periapical radiolucency.

criterion. Hence, different sample cohorts and different criteria are likely to have led to the differing results. A review article by García et al. (16) has discussed this in detail.

Other studies provide further evidence to support root canal re-treatment as the first choice of treatment of teeth with periapical radiolucencies. Grung et al. (22) reviewed the outcome of surgical management of 477 teeth with periapical pathosis over follow-up periods varying from 1 to 8 years, depending on when healing could be confirmed. The average observation period was 2.3 years, although those reviewed for more than one year had an average review period of 4.4 years.

They reported that the outcome of surgical treatment was closely related to the standard of treatment of the root canal system and that orthograde endodontic treatment should be the preferred treatment wherever possible. When there had been orthograde treatment of the canals prior to, or in conjunction with, the surgery, then 20% more cases healed than those managed merely with a surgical approach (85.3% compared to 65.2%). There was a negative influence associated with the type of endodontic treatment performed, with 28% of the cases which failed to heal being in the apical root-end filling group compared to only 4% of the cases which had orthograde root fillings.

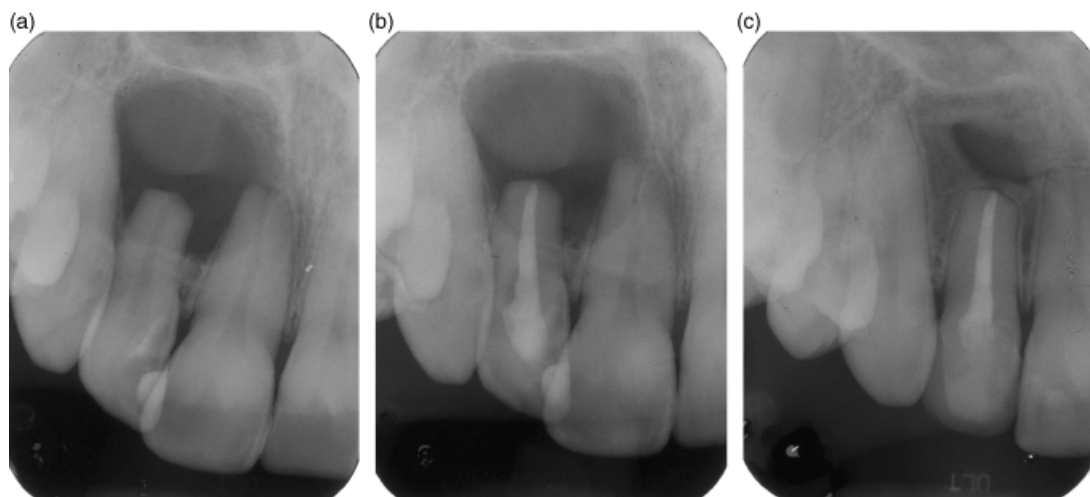


Fig. 4. A possible periapical scar following periapical surgery of the maxillary right lateral incisor which had a pulpless, infected root canal system and a secondary acute apical abscess. (a) Pre-operative radiograph showing a well-defined large periapical radiolucency. The lesion could be palpated from both the labial and palatal aspects. (b) Post-operative radiograph following conventional root canal treatment and periapical curettage. The surgery was required because the tooth continued to have palatal swellings and symptoms following canal preparation and several intra-canal dressings. (c) Follow-up radiograph after two years.

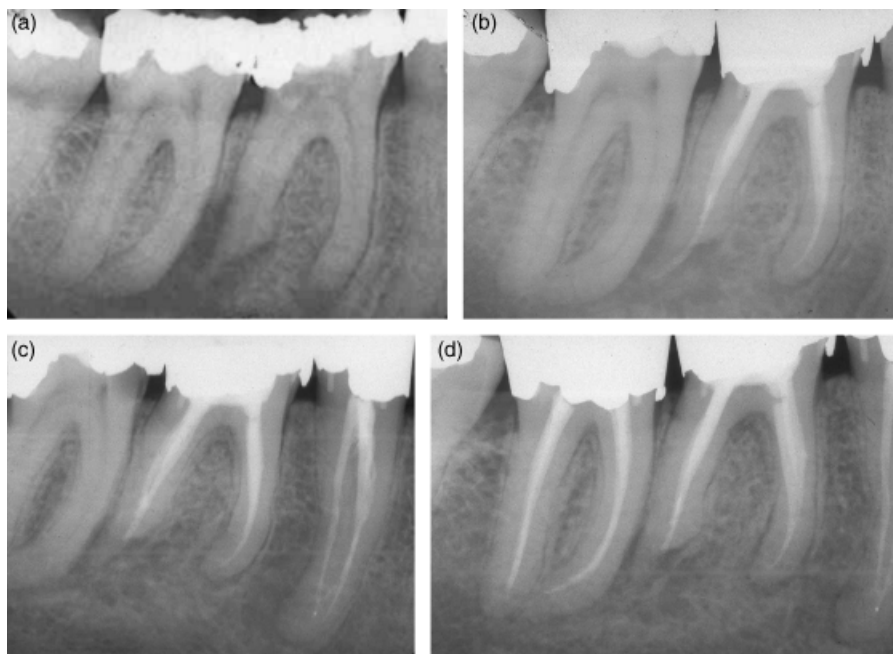


Fig. 5. A possible periapical scar following orthograde endodontic treatment of a mandibular right first molar tooth. (a) Pre-operative radiograph of the tooth which had a pulpless, infected root canal system with chronic apical periodontitis and external apical inflammatory root resorption. (b) Post-operative radiograph following conventional root canal treatment with several intra-canal dressings over a nine-month period to control the resorption and achieve apexification of the open apical foramina. (c) Follow-up radiograph after 3 years. (d) Follow-up radiograph after 6 years.

This was attributed to the less effective anti-infection methods available to the clinician when surgically treating cases (22).

More recently, systematic reviews (23, 24) have been performed to determine whether there are any differences in treatment outcome for surgical and

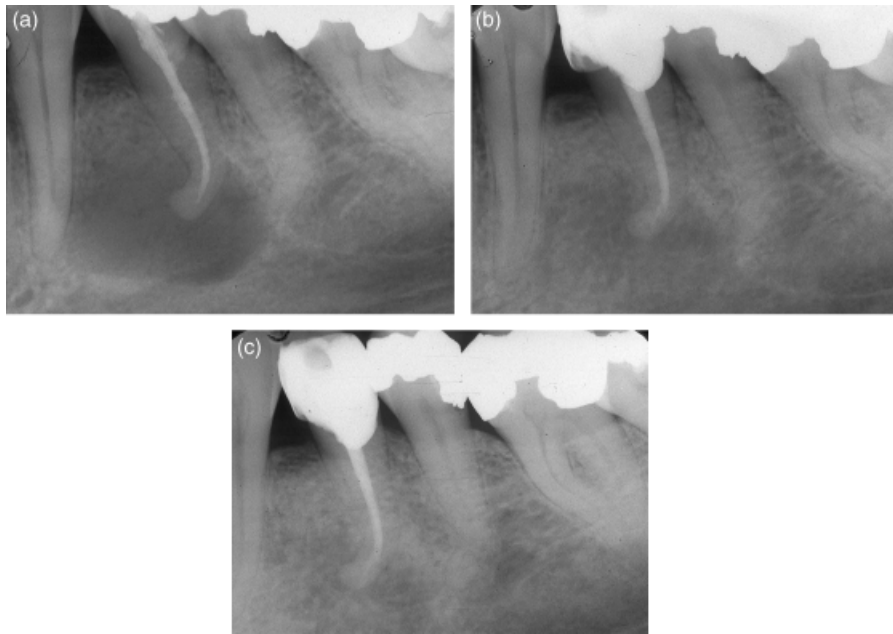


Fig. 6. (a) Pre-operative radiograph of a mandibular left first premolar tooth which had an infected root canal system with chronic apical periodontitis that persisted despite previous endodontic treatment one year earlier. (b) Post-operative radiograph following conventional root canal re-treatment with several intra-canal dressings over a 10 month period while waiting for signs of periapical healing. (c) Follow-up radiograph after 2 years.

conventional re-treatment cases. However, there are insufficient high-level randomized clinical trials which have been published to allow adequate assessment of this. Del Frabbro et al. (23) identified only three studies, with two of those reporting different data from the same clinical study. Follow-up times were relatively short and overall there was little difference in treatment approaches in the short term, although they noted a slightly higher rate of healing for the surgical cases. Torabinejad et al. (24) also performed a systematic review and found a higher rate of healing after surgery if the outcome was assessed after 2–4 years (77.8% compared to 70.9% for non-surgical re-treatment). However, they also reported a higher rate of healing for root canal re-treatment cases if the outcome was assessed after 4–6 years (83.0% compared to 71.8% for surgery). There were insufficient articles describing outcomes of more than six years to be able to make a comparison, but it was noted that the number of surgical cases with healing had fallen even further to 62.9% when reviewed for more than six years. Unfortunately, the authors of these studies referred to “success rates” when discussing the treatment outcomes; this term is misleading, as discussed above. The misleading nature of this term is exemplified by

those surgical cases which were categorized as being “successful” in the early review periods but later had signs of further periapical pathosis at subsequent reviews—these cases clearly cannot be classified as being successful even in the early time periods once their longer term results are considered.

The above studies suggest that healing after surgery may be quicker but better outcome rates are not sustained over time. This finding is in agreement with Kvist & Reit (25) who reported slower healing dynamics in root canal re-treatment cases. The faster healing following surgery might possibly be due to the creation of a “clean wound” without any irritants within the alveolar bone during surgery, whereas non-surgical treatment does not remove the inflamed tissue which the body subsequently has to remove as part of the healing response once the irritants have been removed from the root canal system. Furthermore, the longer term results suggest that the surgical approach provides a short-term solution, at best. Although the reasons for this have not been investigated, it is likely to be due to two factors: first, the inability to disinfect the entire root canal system when working from an apical approach as noted by Grung et al. (22), and second, the failure to identify and remove the original cause of the



Fig. 7. Example of a tooth which is unlikely to be suitable for further restoration, based on the radiographic appearance. The maxillary right canine tooth has a fiber-type post in the canal and this post has fractured at a sub-gingival level. Several pins were used within the root to help retain a large, temporary composite resin restoration. The amount of tooth structure which would remain after root canal re-treatment is unlikely to be sufficient to enable a new restoration to be placed; hence the long-term prognosis of this tooth is poor and it should be considered for extraction and prosthetic replacement.

disease—that is, the pathway(s) by which bacteria and their nutrients have been entering the tooth to establish the infection within the root canal system, as discussed above.

Since most persistent radiolucencies following root canal treatment are likely to be periapical inflammatory responses (i.e. granuloma) as a result of an infected root canal system, the first choice for managing these cases is root canal re-treatment, and this should be followed by a period of review to determine whether there are clinical and radiographic signs of healing (see Figs. 2 and 3). If there are early signs of healing, then the tooth should be monitored further until the radiolucency has



Fig. 8. Example of a tooth that is not suitable for further restoration. The mandibular third molar had a full coverage crown which was an abutment for a four-unit bridge placed one year prior to the patient developing acute irreversible pulpitis as a result of further caries on the buccal aspect. The caries was several millimeters sub-gingival on the buccal surface and the patient was unable to maintain adequate oral hygiene measures in this area. The extent of the caries could not be determined until after the tooth had been investigated by removing the restoration and the caries. The investigation indicated that the tooth was not suitable for further restoration and hence extraction was advised.

completely healed or until it appears as though there is some scar tissue remaining (i.e. the radiolucency is smaller but not completely gone). Regular and long-term follow-up every 3–5 years is also advisable even after healing is complete since a new disease could develop once the restoration breaks down and allows further bacterial entry into the tooth and its root canal system (Fig. 9). It is well-recognized by the dental profession that all restorations have a finite life span and that they may break down at some stage in the future. In general, the older the restoration, the greater the possibility that it may break down and lead to further infection of the root canal system, and thus new periapical pathosis.

Alternatively, if the radiolucency does not show evidence of healing following root canal re-treatment and instead increases in size, then this is likely to indicate that the presenting problem was not merely bacteria in the canal but was also due to a periapical problem—such as a true cyst, an extraradicular

Table 4. Diagnoses reported from the histological examination of biopsies taken from the periapical regions during surgical management or extraction of root-filled teeth in five representative studies (12, 17, 19–21)

Diagnosis reported from biopsy	Nair et al. 1996 (12)	Abbott 1999 (20)	Wang et al. 2004 (21)	Schultz et al. 2009 (17)	Love & Firth 2009 (19)
Periapical granuloma	35%	60.6%	83%	70%	77%
Periapical abscess	50%	3.8%	N/R	5%	3%
Periapical cyst	6% - pocket 9% - true	13.6%	14%	23%	18%
Periapical scar	N/R	0.8%	3%	1%	2%
Foreign body reaction	N/R	19.7%	N/R	N/R	25% in a granuloma; 2% in cysts; 1% in a scar
Extraradicular infection	N/R	1.5% (reported as Actinomycosis)	N/R	N/R	N/R
Keratocyst	N/R	N/R	N/R	1%	N/R

Note: N/R = No cases reported with this diagnosis

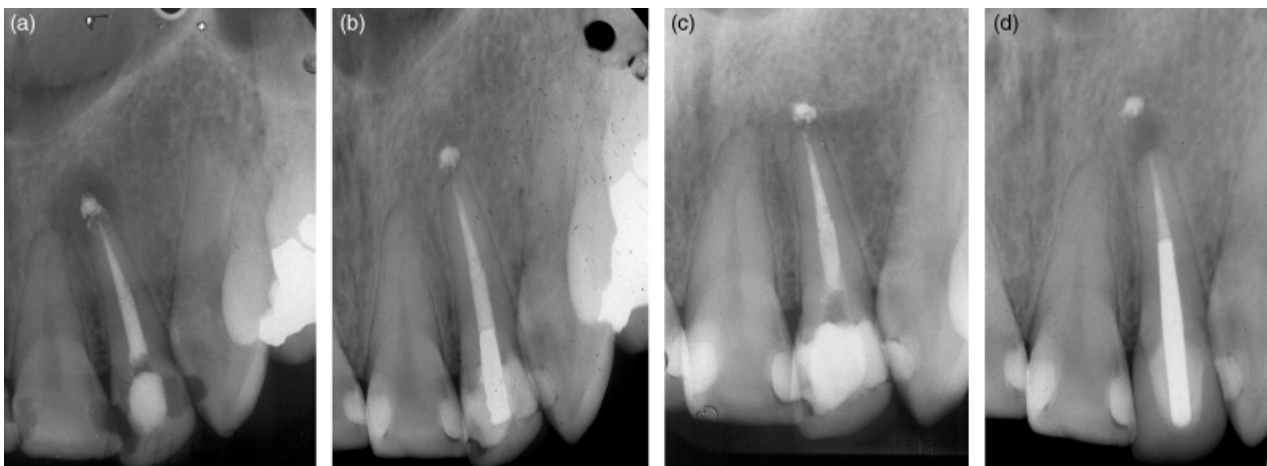


Fig. 9. (a) The post-operative radiograph of a maxillary left lateral incisor tooth taken after completion of conventional root canal treatment in 1993. Some of the root filling material has been extruded into the periapical tissues. (b) The two-year review radiograph taken in 1995 shows considerable reduction in the size of the radiolucency, indicating healing of the periapical bone. (c) A four-year review radiograph taken in 1998 shows further reduction in the size of the radiolucency. (d) The ten-year review radiograph taken in 2003 shows that a new periapical radiolucency has developed subsequent to the placement of a post-retained coronal restoration.

infection, or a foreign body reaction. Hence these cases will require periapical surgery to remove the lesion. This also allows the opportunity for histological examination of the biopsy specimen in order to determine the true diagnosis and, in particular, to rule out the possibility of the lesion being some other pathosis which is mimicking a periapical radiolucency (see Table 3). Following surgery, the tooth should be

monitored at regular intervals until healing is observed, and then long-term follow-up should also be arranged as described above.

When a patient presents with a root-filled tooth which has a new radiolucency (see Table 2), the most likely diagnosis will be an infected root canal system that has occurred as a result of breakdown of the restoration over time, or due to the presence of caries or

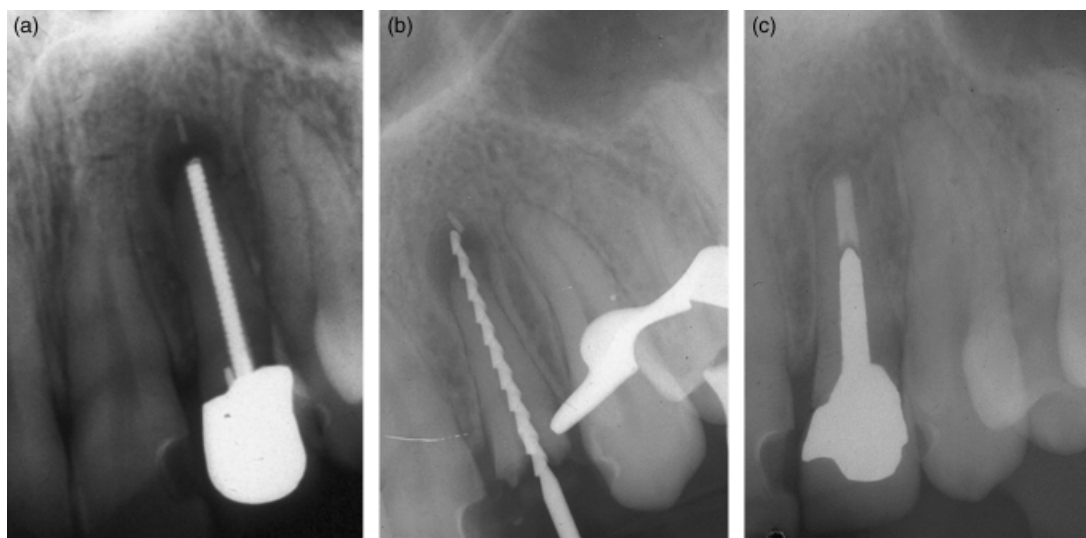


Fig. 10. (a) Pre-operative radiograph of a maxillary left lateral incisor tooth that had an infected root canal system with chronic apical periodontitis which developed 10 years after previous root canal treatment and restoration with a post-retained crown. There may also have been a foreign body reaction to the extruded root filling material which can be seen in the periapical tissues. (b) Working length radiograph after removing the crown, post and root filling material. (c) Follow-up radiograph taken one year after conventional root canal re-treatment followed by periapical surgery to curette the lesion. The tooth has also had a new post-retained crown restoration placed.

cracks in the tooth. Fractures of the tooth or restoration, trauma, or deep periodontal pockets may also cause such problems. In essence, these cases should be treated as a new disease—which they are—and the presence of the root filling should not change the overall approach to management. Once these cases have been endodontically re-treated from an orthograde approach, they should then be reviewed regularly to monitor the periapical healing response (see Fig. 3). If the radiolucency persists following this re-treatment, then at this stage it can be considered to be a persistent radiolucency associated with a root-filled tooth (see Table 1) and it should be managed according to the principles outlined above and in Figure 2—except that the persistence of the radiolucency is not likely to be the result of an intraradicular infection (since the root canal system has just been re-treated), it is more likely to be the result of a periapical problem (such as a true cyst, an extraradicular infection, or a foreign body reaction). Hence, further orthograde root canal re-treatment will not normally be required at this stage and periapical surgery should be considered. In such a situation, it is usually only necessary to undertake periapical curettage without any root-end resection since the root canal system has recently been re-treated.

Some teeth will need to be managed with both root canal re-treatment and periapical surgery concurrently for technical reasons such as when the post extends all the way to the apical foramen (Fig. 10), when the examination suggests that there is a foreign body within the periapical tissues in addition to an infected root canal system, where previous surgery has been performed and the root-end filling material is hindering further treatment, or where an apical abscess persists despite initial cleaning and disinfection of the root canal system (Fig. 4).

Extraction is always an option to be considered. An extraction may be chosen by the patient or it may be recommended by the attending clinician. Some patients may choose to have their tooth extracted rather than proceed with what they may perceive as being complicated and/or expensive treatment which typically includes root canal re-treatment and a new restoration with a possibility that surgery may also be required. If the patient chooses to have an extraction, then they should ideally consider the various prosthetic options for dealing with the resultant space created in the dental arch. However, some teeth may be recommended by the dental practitioner for extraction since they have been deemed to be unsuitable for

further endodontic treatment and restoration—the assessment of the tooth’s suitability for further treatment is sometimes possible during the clinical and radiographic examination (Fig. 7) but in many cases this is not fully possible until the tooth has been investigated (as above) by removing the restorations, caries, cracks, etc. (Fig. 8).

Case selection

The most important aspect of managing any disease process is to choose the most appropriate treatment option for each case (5). Case selection is important for the patient since patients desire predictable treatment outcomes and typically want to minimize the amount and extent of treatment required and the associated costs. Hence, there is little point in offering uncertain treatment options unless the patient is fully aware of the risks involved and the possible outcomes. Case selection is also important for the individual practitioner in order to obtain a high rate of favorable treatment outcomes as this reflects the reputation of the practitioner.

When considering the management of root-filled teeth which require further treatment, there are many factors to be considered. Some of these are related to the technical aspects of the root canal re-treatment and/or periapical surgery, while other factors that must be considered are related to the further restoration of the tooth, as mentioned above. The tooth must be suitable for further restoration and the restoration should last for many years without further complications. The prognosis from a restorative dental perspective is the most important factor when deciding whether to retain or extract a tooth (26). If a tooth is not deemed to be suitable for further restoration, then the patient should be advised to have the tooth extracted. Replacement with a prosthesis can then be discussed.

Whether or not a tooth is suitable for further restoration is largely a subjective assessment undertaken by the dentist at the time of investigation of the tooth and further assessment while actually performing the restoration. Some authors have attempted to provide guidelines for dentists to assess the volume of remaining coronal tooth structure (27) prior to restoring teeth and these guidelines may be helpful in some cases. However, these guidelines do not provide

any assistance for assessing the quality of the remaining tooth structure and whether or not the tooth is likely to fracture in the future. In practice, most dentists tend to subjectively assess the tooth by visual examination. The decision will be affected by the individual dentist’s clinical experience, his/her preferences for materials, and their availability. Inevitably, some teeth will be assessed as being suitable for further restoration but then the new restoration does not last long or the tooth fractures. Conversely, some teeth may be assessed as being unsuitable by one dentist whereas another dentist may consider them to be suitable. Unfortunately, there are no definitive or accurate means to assess teeth for their suitability for restoration and dentists must be careful in their case selection process. Despite the uncertainties that can exist in case selection, studies have shown that root-filled teeth can survive for many years. A systematic review (28) has reported that 98–99% of root-filled teeth with full coverage crowns survived for up to three years, 94% survived for five years, and 81% survived for 10 years. However, although 94% of root-filled teeth restored with direct restorations (such as amalgam and composite resins) survived for one year, the number then decreased to 84% by three years and 63% at both five and 10 years. Hence, the type of restoration provided after root canal filling appears to be a critical factor that determines the longevity of root-filled teeth.

Other factors which play an important role in the longevity of root-filled teeth include periodontal disease and subsequent fracture of the tooth. Vire (29) reported that almost 60% of root-filled teeth which required extractions were extracted because of “prosthetic reasons” (mainly fractures) and 32% were due to periodontal reasons, while pure endodontic problems were rare (8%). Vire (29) also reported that the endodontic problems manifested within an average of two years following treatment whereas the prosthetic and periodontal problems typically occurred after 5–5½ years. Similarly, Chen et al. (30) reported that 40% of root-filled teeth requiring extraction were extracted because of extensive decay or because they were unsuitable for restoration, 28% because of fractures, 23% due to periodontal disease, and only 9% for endodontic reasons.

Two epidemiological studies have followed a large number of teeth to determine survival rates and the number of teeth requiring other treatment following initial non-surgical root canal treatment. Chen et al.

(30, 31) reported that 93% of over 1.5 million teeth survived for five years and that approximately 10% of teeth had an “untoward event” during this period which required further treatment such as extraction (6.9%), root canal re-treatment (2.3%), or periapical surgery (0.5%). Salehrabi & Rotstein (32) also followed a large population who had 1.46 million teeth endodontically treated and they reported that 96% were retained over eight years without an “untoward event.” Extraction was required for 2.9% of the teeth, root canal re-treatment for 0.4%, and periapical surgery for 0.6%. The vast majority (85%) of the extractions were required within three years of the initial treatment. While these two studies have reported follow-up events after initial non-surgical root canal treatment as opposed to re-treatment, the results are still very relevant to the discussion in two ways. Firstly, they demonstrate that case selection is an important aspect as it could be argued that teeth requiring extraction within such short time periods following root canal treatment probably should not have been treated but should have been extracted. In stating this, it is also recognized that fractures may have occurred after the endodontic treatment as a result of trauma or other factors which cannot be predicted or controlled by the dentist. However, it is likely that many of these fractures occurred because the teeth were not ideally suited to the treatment provided. Secondly, these two studies demonstrate that some teeth will require further treatment—either due to the persistence of bacteria within the root canal system (i.e. root canal re-treatment required) or due to a periapical problem (i.e. periapical surgery required), as discussed above. Hence, it is important for dentists to understand that there is an upper limit to the rate of favorable outcomes which can be achieved with endodontic treatment, even with the highest quality treatment and with the best case selection criteria. The small number of cases which do not heal following root canal treatment, or re-treatment, require further treatment—such as periapical surgery—to deal with the periapical problem. The overall rate of favorable outcomes can be increased if these procedures are considered together.

Alternatives to tooth retention

Over the last decade, there have been many comparisons made between the outcomes of root canal

treatment and the outcomes of implant-retained restorations (26, 33–39). Proponents of one form of treatment tend to favor their preferred approach and often the claims are supported by references from the literature. However, a comparison of two entirely different treatment options is unlikely to be valid since different criteria are used to assess their outcomes. In more recent years, the survival of the tooth has been compared to survival of the implant. This is a more realistic approach than in earlier reports where harsh criteria may have been applied to one form of treatment but not to the other. However, even survival criteria are open to criticism since mere survival of the tooth or implant does not account for further treatment which may have been required, repairs to restorations, discomfort noted by the patient, restorations dislodging, etc. Goodacre et al. (33) have compared the rate of complications associated with implant-retained prostheses and conventional fixed prosthodontic treatment and they reported a greater incidence with the former as well as a comparatively low rate of complications associated with root-filled teeth restored with post-retained crowns. The complexity of the implant-retained prosthesis also plays a role as lower complication rates with implant-supported single crowns were reported than with implant-supported bridges, which in turn had lower complication rates than combined tooth-implant supported bridges over 10 years of follow-up (40).

While a detailed analysis of the many reviews comparing implants with root canal treatment (including root canal re-treatment and surgery) could be undertaken, this is unlikely to produce a universal approach to treatment decisions by all practitioners. Treatment decisions should be based on a prediction of the long-term prognosis for each treatment option available. It is also essential to understand that the so-called “success rates” or rates of favorable outcomes reported in a study (whether it be a retrospective or a prospective study) are not figures which can be used as a predictor of the outcome of treatment in any given case. That is, reported success rates should not be considered to be the probability of a successful or favorable outcome in each new case which is about to be treated. Success rates are a report of what has happened in a group of cases whereas the probability of a successful outcome is a prediction of what might occur in one particular case. There are many factors which must be considered when discussing prognosis with a patient.

If practitioners base their decision to endodontically re-treat a tooth or to extract it and replace it with an implant (or other prosthesis) solely on the rates of survival of teeth and implants, then this approach suggests that adequate assessments of the particular tooth in question, the rest of the dentition, and the patient overall have not been done. Many factors need to be considered before recommending any form of treatment. In the best interests of the patient, the retention of a tooth is usually preferred over extraction and replacement, even though an implant-retained restoration may have an excellent prognosis.

The costs and benefits should also be considered when discussing treatment options with a patient. A cost : benefit analysis reported by Moiseiwitsch & Caplan (41) indicated that root canal treatment and restoration of a single tooth with a crown was less expensive, it involved fewer appointments, and it could be completed more quickly than doing an extraction, placing an implant, and restoring the implant with a crown.

Instead of basing decisions on outcome studies, it is recommended by this author that the decision as to whether to retain or extract a tooth should be based on its suitability for further restoration after the root canal filling. In simple terms, if the tooth is suitable to restore, then the ideal, least expensive, and most expedient treatment option is root canal treatment plus restoration. Alternatively, if the tooth is not suitable for restoration, then it should be extracted and replaced with a prosthesis. In the latter situation, the use of an implant-retained restoration is one of the prosthetic options, with the other general options being removable partial dentures and fixed bridges (each of these having various designs, materials, and procedures). The choice for the patient must then be based on information and recommendations provided by the dentist and the patient's own research and expectations. The use of an implant is generally preferred because of the reported longevity, comfort, aesthetics, and lack of involvement of adjacent teeth.

Interestingly, a survey of treatment preferences amongst dental faculty and dental students from the New York University College of Dentistry (42) revealed that both groups significantly more frequently chose endodontic and restorative treatment over extraction and implant placement when given a choice for specific clinical situations: 87.9% for faculty and 74.4% for students. Students tended to select implants

more often than faculty and the more recent graduates on the faculty chose implants slightly more frequently than the less recent graduates (85.5% compared to 89.4%). As the complexities of the endodontic and prosthetic situations increased, implants were more likely to be chosen by all participant groups. The medical condition of the patient also affected treatment decisions with endodontics and restorative treatment being favored over implants for medically-compromised patients by all participants (96.2% for faculty and 88.2% for students). When questioned about their preferred treatment modality for replacing a single tooth, all participants favored using a single-tooth implant (89.1% of faculty and 92.3% of students) rather than a three-unit fixed bridge. This study suggests that despite advances in techniques and the perceived popularity of implants, the majority of dental educators and students still favor tooth retention over extraction and implants, although there was a trend for younger people to be somewhat more in favor of implants. This may indicate that the experience level of the dentist in providing complex treatment plays a role in treatment planning decisions.

The above survey also highlights that implants are becoming the favored option for replacing a single missing tooth rather than using a fixed bridge. The value of implants in replacing missing teeth should not be underestimated as many studies have shown very high implant survival rates. Implants should be considered to be an integral part of the dentist's range of treatment options whenever a tooth is missing as well as when a tooth is no longer deemed suitable for further endodontic and/or restorative dental treatment.

Conclusions

The management of a root-filled tooth with periapical radiolucency must be based on the diagnosis of the presenting condition. The history will help to establish the diagnosis because the time since the previous treatment was performed is an important factor. In general, the majority of root-filled teeth with a periapical radiolucency should be root canal re-treated provided that the tooth is suitable for further restoration and that such restoration will have a reasonable to good long-term prognosis. Periapical surgery should be reserved for teeth which have a persistent radiolucency following root canal re-treatment and where

the differential diagnosis at that stage suggests that there is an ongoing periapical condition such as a true cyst, an extraradicular infection, or a foreign body reaction which requires surgical removal. Some teeth will not be suitable for further restoration and therefore should be extracted. Missing teeth can be replaced with several forms of prostheses, although the use of implant-supported prostheses is gaining popularity and they have a proven track record, especially for single-tooth replacements. However, the use of implants should be restricted to cases where teeth are already missing or where they are not suitable for retention because of a lack of tooth structure and hence there is a poor prognosis for endodontics and restoration. The ultimate decision as to which treatment option to follow will depend upon many factors, not the least of which is the patient's desires.

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