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THE ACE REPORT

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Frederic Barnett, DMD


Gary D. Glassman, DDS


Gerald N. Glickman, DDS, MS


Garry J. Nervo, BDSc, MDSc


Alvaro Cruz G., MSc, DDS

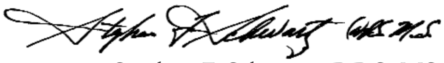
Adhesive Dentistry and Endodontics

- Has adhesive dentistry come to endodontics?
- Do bonded resins belong in the root canal?
- Is gutta percha on the way out?
- When do we adopt new technology?

These are indeed provocative and important questions. *The ACE Report* has promised its readers practical and cutting-edge information to make your endodontic treatment outcomes more successful and predictable. In that spirit, *The ACE Report* is presenting in this issue not only the importance of an often-overlooked cause of endodontic failure—the postendodontic coronal restoration—but also a "resin substitute" for gutta percha. The two articles are accompanied by an update on fourth-generation apex locators, along with a review of their accuracy and troubleshooting tips to enhance their value to your endodontic treatment. Additionally, a new section will include some interesting endodontic case presentations. The purpose of this section is not to showcase clinicians' artistry, but rather to show the varieties of canal morphology and treatment approaches to unusual and difficult cases.

There is an adage that seems especially pertinent to dentistry: Never be the first nor the last to adopt new technology or treatment modalities. We all have drawers and cabinets full of "stuff" that just didn't quite work out. Endodontics has been spared the anguish of many of these changes because most of the materials and methods have remained constant for the last 50 years. It is only in the last 5 to 10 years that we have seen changes such as nickel-titanium rotary instruments, electronic apex locators, and single-visit treatments take their place in everyday practice. The technologies and treatment recommendations described in this issue of *The ACE Report* will hopefully contribute to your evidence-based decision making as this trend of advancement continues in endodontics. The opinions expressed in this issue have met the test of being well researched and FDA approved (Resilon™), and they embrace concepts and goals for optimal endodontic treatment outcomes. Having said that, there are many techniques and materials that fall within the standard of care in endodontics and are supported by well-respected clinical and basic science research. Endodontic procedures performed well with a variety of techniques enjoy a high degree of success. The decision to adopt new materials or methods should be contemplative and thorough. It is our hope that this issue will stimulate you to investigate whether this information can help you better meet the needs of your patients and make the practice of endodontics an important and successful part of your practice.

Sincerely,



Stephen F. Schwartz, DDS, MS
Editor-in-Chief
The ACE Report

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Jeffrey W. Hutter, DMD, MEd


Joseph D. Maggio, DDS


Lynda Elliot, DDS


Joseph S. Dovgan, DDS


David Brown, DDS, MS

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Accurate Working-length Determination Using a Fourth-generation Apex Locator

Jorge Vera, DDS
Professor of Endodontics
University of Tlaxcala, Mexico

Monica Gutierrez, DDS
Private Practice in Endodontics
Mexico City, Mexico

Abstract

The purpose of this article is to review, based on clinical observations, the accuracy of a fourth-generation electronic apex locator. Electronic root canal length was recorded in 30 maxillary second molars that were to be extracted. Files were cemented in place after negotiation of the canals in the following manner: one file to the 0.5-mm mark, one file in another canal after reaching the 0.0-mm mark and then withdrawing it to the 0.5-mm mark, and finally a third file in the third canal when the negative numbers (indicating the file had reached the periodontal ligament) were displayed on the screen. All of the teeth were extracted and cleared, and the distance of the file to the external foramen on the root surface was measured. Taking the file to the 0.0-mm mark on the display and then withdrawing it to the 0.5-mm mark seems to be the most accurate way to use the electronic apex locator under the conditions of this study.

Establishing working length at the apical constriction, or the minor diameter, of the canal is considered ideal when attempting to create a small wound site and conditions for satisfactory healing. The distance to this anatomical landmark from the external foramen on the root surface ranges from 0.5 mm to 1 mm.[1-3]

When attempting to determine working length, radiographic methods do not allow for an accurate determination of the position of the apical constriction. In fact, the apparent radiographic distance of the file from the radiographic apex was determined to be 0.7 mm shorter than the actual position of the file.[4]

Electronic root canal–length measuring devices have been widely studied in vitro using different mediums, such as agar, gelatin, or alginate,[5-8] and in the presence of various canal fluids.[9] In a study by Huang,[10] it was concluded that the principle of electronic root canal measurement is purely a physical phenomenon; when the electrode passes through the narrow apical foramen, the foramen produces a significant electrical-resistant gradient that is constant except when the canal is filled with electrolytes or the apical foramen is too large. First-generation apex locators were the resistance type, which measured resistance between the two electrodes to determine location within a canal. The second generation was the single-frequency impedance type, which used impedance measurements instead of resistance to measure location within a canal. The improvements of the second over the first generation were essentially that the second gathered more information and that the frequency of an impedance-based unit could be varied to compensate for canal conditions. The third generation was similar to the second, but it used multiple frequencies to determine distance from the end of the canal. This provided even more information that could be used to compensate automatically for various canal conditions. Research performed on third-generation devices has shown that accurate measurements could be obtained even in the presence of electrolytes with an accuracy between 85% and 95%.[11-14] The Elements™ Diagnostic Unit[a] is a fourth-generation apex locator. Impedance, in fourth-generation units, is broken down into its primary components (resistance and capacitance) and measured directly and independently during use. This eliminates erroneous readings from different combinations of these properties that can provide the same impedance reading. In other words, there has to be two combinations of resistance and capacitance giving the same impedance, so that there are two

[a]SybronEndo, a division of Sybron Dental Specialties, Orange, CA 92867; 800-346-3636

Figure 1—Elements™ Diagnostic Unit reading of 0.5 mm.

Figure 2—Instruments cemented in each canal before extraction.

Figure 3—Instruments in each canal after extraction.

Figure 4—Cleared tooth showing the location of the three files in the canals.

different situations that would give the same feedback (and, thus, the same location reading within the canal). The Elements™ Diagnostic Unit also uses multiple frequencies to compensate for canal conditions and does not make any calculations internally, as in third-generation units. Instead, all combinations of capacitance and resistance are calculated and loaded into a matrix database within the unit, making the displayed information much more stable.

Materials and Methods

Thirty maxillary molars that were to be extracted for various reasons were selected for study in making clinical observations with the Elements™ Diagnostic Unit. All of the patients included in the study accepted the proposed treatment and signed an informed consent form. After appropriate rubber dam isolation and access were performed, the root canals were located, and the access cavity was rinsed with sodium hypochlorite (5.25%) and dried. With the hand files, an endodontist performed the following procedures while negotiating the root canals. In one canal picked arbitrarily on each molar, a file was cemented with composite resin once the display on the Elements™ Diagnostic Unit reached the 0.5-mm reading without going to the 0.0-mm mark. Another canal in the same tooth was selected and another file was cemented once the device reached a –0.2-mm to –0.5-mm reading on the display (indicating that the file had gone through the apical constriction and reached the periodontal ligament). In the third canal, after reaching the 0.0-mm mark, the file was withdrawn until the 0.5-mm mark was obtained according to the manufacturer's recommendations for use of the Elements™ Diagnostic Unit (Figure 1). Immediately after all of the files were cemented, all of the teeth were radiographed before and after extraction (Figures 2 and 3). Six teeth that were damaged during this procedure were discarded. All specimens were cleared (Figures 4 and 5), and the distance from the file tip to the foramen on the external root surface was determined using a microscope and a calibrating device.

Results

After extracting all of the teeth, those that appeared to be damaged from the extraction or where the position of the file could not be determined accurately were discarded. In the canals where the file

Figure 5—Cleared tooth showing the location of the three files in the canals.

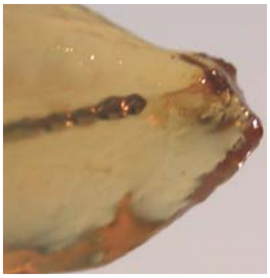

Figure 6—Position of the file after going down to the 0.5-mm mark.

Figure 7—File location after withdrawing the instrument from the 0.0-mm mark to the 0.5-mm mark.

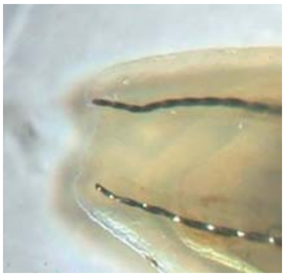

Figure 8—File location after withdrawing the instrument from the 0.0-mm mark to the 0.5-mm mark.

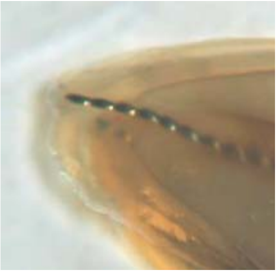

Figure 9—File location after withdrawing the instrument from the 0.0-mm mark to the 0.5-mm mark.

Figure 10—Elements Diagnostic Unit™ reading on the negative numbers.

Figure 11—File location after registering in negative numbers (–0.2 mm to –0.5 mm) on the Elements™ Diagnostic Unit.

Figure 12—Tooth No. 18 demonstrating accurate working-length determination.

was cemented after going down to the 0.5-mm mark (Figure 6), 20 out of 24 were 0.5 mm from the external foramen and 4 canals were more than 0.5 mm from the external foramen. In two of those, the file appeared to be at the apical constriction, which was more than 1 mm from the external foramen. In the canals where the file was withdrawn from the 0.0-mm mark to the 0.5-mm mark, 22 out of 22 were at 0.5 mm, which seemed to be consistent with the position of the apical constriction as visible under magnification (Figures 7 through 9). In those canals where the file went to the negative numbers (–0.2 mm to –0.5 mm), the file was out of the canal in all 23 cases (Figures 10 and 11).

Discussion

Accurate determination of root canal length is crucial to achieve successful root canal treatment (Figures 12 and 13).[15] Radiographic methods to determine working length have shortcomings and often can be inaccurate.[4] A working length that is erroneously established long of the apical constriction may cause irreversible damage to the root structure, leading to perforation and overfilling. In contrast, determining working length short of the constriction may lead to inadequate debridement and/or disinfection of the root canal system, resulting in delayed or impaired healing.[16]

The instruction manual for the Elements™ Diagnostic Unit states that when the file reaches the periodontal ligament, the numeric display will read 0.0. From that point, the file should be withdrawn to the 0.5-mm mark to achieve the most accurate reading. When observing our specimens, the Elements™ Diagnostic Unit performed best when these instructions were followed (22 out of 22 were within 0.5 mm of the external foramen). Another interesting finding was that when the device displayed a negative number, the file was always beyond the apical constriction and, in most cases, out of the root structure. Therefore, once the device has detected that the file is "long," withdrawing the file to the 0.5-mm reading seems to be a very efficient way to determine the final working length. It has been the authors' observation that the Elements™ Diagnostic Unit performs better when the access cavity is dried before introducing the file into the canal. Ideally, "crown down" instrumentation is preferred, and a file big

Figure 13—Tooth No. 19 demonstrating accurate working-length determination.

Figure 14—The DynaTorq® electric motor with external port for the Elements™ Diagnostic Unit.

enough to be worked down into the apical constriction is preferred to using a small file that does not approximate the apical diameter of the constriction, as this may lead to erroneous readings.[10]

A shortening of working length occurs when instrumenting curved canals. This shortening can vary from 0.22 mm to 0.5 mm.[17] However, once coronal flaring is done, little change in length occurs.[18] Moreover, it has been found that flaring the canal before determining working length with an electronic apex locator increases the accuracy with which the device is able to identify the apical constriction. The present study did not attempt to compare the Elements™ Diagnostic Unit with any other apex locators, but it was designed to make some clinical observations as to the way the device functioned when following the manufacturer's guidelines. Clearing teeth may destroy some tooth structure during the decalcification process. This may make the file look closer to the root end than it originally was; therefore, more studies comparing the Elements™ Diagnostic Unit to other apex locators should be done using different technologies to determine if fourth-generation apex locators are more accurate than those of the third generation.

Troubleshooting Incorrect Readings

1. Keep the access cavity dry. If fluid is present in the canal, it should have the least value of conductivity. The most common irrigants are listed below in descending order of conductivity:
   a. Sodium hypochlorite (5.25%)
   b. Ethylenediaminetetraacetic acid (EDTA 14%)
   c. Saline
   d. RC Prep®,[c]
   e. Isopropyl alcohol
2. An EDTA lubricant can be used when attempting to negotiate the root canal.
3. Whenever possible, use a "crown down" technique and take the electronic measurement with the Elements™ Diagnostic Unit using a file that is approximately big enough to bind at the apical constriction.
4. Make sure the batteries are fully charged. Do not use the device if the batteries are low.
5. Eliminate contact with metallic coronal restorations. If the file touches the restoration, a false reading will occur. This contact also can be created from transmission through a fluid medium between the file and any metallic restoration.
6. When working on curved canals, a second working-length measurement is advisable after flaring the middle and coronal thirds.

[c]Premier Dental Products Co, Plymouth Meeting, PA 19462; 888-670-6100

New Integrated Technology

Recent technology has combined the advantages of a fourth-generation apex locator with an electric motor for use with nickel-titanium rotary instruments. This has made continual observation of the position of the file in the canal possible throughout the instrumentation phase of canal preparation. The DynaTorq®,[b] electric motor has an external port (Figure 14) that allows a fourth-generation apex locator to be attached to the motor. A contact in the handpiece completes the circuit to the instrument in the canal, allowing for continuous monitoring of the file position as the instrument is advanced down the canal.

Conclusion

Under the conditions of the present study, it was concluded that the Elements™ Diagnostic Unit performs very well when the file is taken down to the 0.0-mm mark and then withdrawn to the 0.5-mm mark. It also is very important that when the device indicates that the file is long with a negative reading, it is probably beyond the apical constriction irrespective of the radiographic appearance.

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[b]Micro Motors, Inc, a Pro-Dex Company, Santa Ana, CA 92707; 800-562-6204

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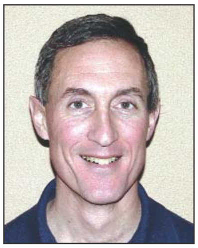
The Role of the Restorative Dentist in the Success or Failure of Endodontics

Richard Schwartz, DDS
Private Practice Limited
to Endodontics
San Antonio, Texas

Clinical Assistant Professor
Graduate Endodontics
University of Texas Health
Science Center
at San Antonio
San Antonio, Texas



Abstract

Endodontics and restorative dentistry are a continuum. Endodontic treatment cannot be successful without careful planning and timely execution of the restorative treatment. Restorative dentistry encompasses diagnosis and treatment planning, clinical treatment, and maintenance. Each of these phases influences the outcome of endodontic treatment. This article describes the relationship between endodontics and restorative dentistry and discusses how the restorative process affects the long-term success or failure of endodontics.

Bacteria are widely accepted as the primary cause of apical periodontitis[1] and endodontic failure.[2] The primary goal of endodontic treatment is to eliminate bacteria from the root canal system. One of our basic goals in restoring endodontically treated teeth should be to prevent reinfection of the root canal system.[3] The root canal procedure is not complete until the tooth has been restored and bacterial contamination has been prevented.

Numerous studies have reported on success and failure rates for endodontics. The one that is perhaps the most often quoted is the Washington Study, which reported 94% success.[4] However, some cross-sectional, longitudinal population studies have reported success rates in the 40% to 60% range.[5,6] Why is there such a large variation of reported success rates? Many variables go into the equation, such as case selection, preoperative diagnosis, isolation, and technique issues.[7] One variable that is sometimes overlooked, but is very important, is the timing and execution of the restorative dentistry once the endodontic treatment is complete. This article will discuss the philosophy and critical steps in the endodontic/restorative process and describe the role the restorative dentist plays in determining the success or failure of endodontic treatment.

Diagnosis and Prognosis

Careful clinical and radiographic evaluation should be performed before any clinical procedures are initiated. The evaluation should include an assessment of the pulpal status of the teeth. Studies have reported that 3% to 22% of teeth with existing crowns have necrotic pulps.[6-8] Undoubtedly, some of these pulps were necrotic before restorative treatment was initiated. It is advisable to pulp-test all teeth with large restorations or questionable vitality during the initial examination. A cold test provides a simple, effective test of pulpal responsiveness for the vast majority of patients. The teeth also should be tested for tenderness to pressure, percussion, and apical palpation. Occasionally, an asymptomatic tooth in need of endodontic treatment can be identified. Karlsson[9] estimated that the percentage of teeth with crowns and necrotic pulps rises by about 1% each year after the crown is placed. For this reason, periodic pulp testing of teeth with crowns or large restorations also is advisable.[6]

Endodontics usually is performed through existing restorations. A study by Abbott[10] showed that problems such as caries or cracks can be evaluated more effectively if all existing restorations are removed first. The study compared teeth that received root canal treatment with and without removal of the existing restorations and found that a significantly higher percentage of teeth with potential problems were identified when the existing restorations were removed. If possible, it is advisable to remove all existing restorations, such as amalgam or composite, before initiation of endodontics. When this is not possible, a caries detector should be applied to all exposed tooth structure in the access cavity to aid visualization of leakage, caries, or cracks (Figure 1).

Crown-root fractures are a particular problem in endodontics and must be identified early in the process. Most significant crown-root fractures start in the mesial or distal marginal ridge and extend apically. Many root canal failures result from undiagnosed fractures that were present when the root canal treatment was performed. Before root canal treatment, posterior teeth should be viewed carefully with magnification, good lighting, and transillumination (Figures 2 and 3). If a vertical fracture is seen, a dye (such as methylene blue) may help to determine the apical extent of the fracture. If a crack extends apically beyond the cementoenamel junction, or across the floor of the pulp chamber, the long-term prognosis is guarded. If there is bone loss adjacent to the crack, detected by probing or visible on radiographs, the prognosis is poor.[11] The key is early diagnosis, determining the prognosis, and, with the patient's input, deciding between endodontic treatment and extraction.

It is important to distinguish between crown-root fractures that extend apically onto the root and horizontal fractures that extend across the base of a cusp. Both may look the same when viewing the marginal ridge, but with good light and magnification it is easy to distinguish them from each other once the existing restorations have been removed (Figure 4). A tooth with a horizontal fracture has a good prognosis and, in many cases, has a normal pulp that does not require root canal treatment. The clinician should be suspicious of a crown-root fracture when a tooth presents with signs or symptoms of pulpitis or apical periodontitis without any obvious reason for the associated pathosis (Figure 5).

Treatment Planning

It is the restorative dentist's responsibility to develop an overall treatment plan before initiating endodontic treatment or referring a case to an endodontist. This includes evaluating restorability, periodontal status, any need for crown lengthening, and where the tooth fits into the overall treatment plan. Sometimes restorability cannot be determined until all caries is removed and/or crown lengthening is performed. It is important for the restorative dentist to carefully evaluate these factors before starting treatment. Too often, root canal treatment is performed and the tooth is later extracted because of periodontal concerns or problems with restorability.

If restorability is not an issue, and the tooth can be isolated adequately, it is advisable to perform the endodontics early in the treatment plan. With good illumination and magnification, fractures can be identified and their extent and significance can be determined. Caries can be identified and completely removed. The likelihood of successful endodontic treatment can be accurately assessed. If a poor prognosis is determined, the treatment plan can be modified before additional expensive procedures, such as crown lengthening or bone grafts, are performed. Apical periodontitis can cause the failure of periodontal procedures. It can cause bone grafts to fail, affect the integration of implants, or, once integrated, cause the implants to fail. In most cases, endodontics should be completed before these procedures are performed.

The best method to restore endodontically treated teeth has been a subject of debate for many years, and the debate continues to this day. Several principles are generally accepted, however, and should be considered in the treatment plan.

1. Sound natural tooth structure should be retained whenever possible.[12,13] There should be minimal removal of radicular dentin for posts,[14] and an external ferrule is highly desirable.[15]

2. Posterior teeth should receive cuspal coverage. A classic study by Sorensen and Martinoff[16] in-

Figure 1—Caries is seen adjacent to the composite buildup. (Photo courtesy of Dr. Gary Carr, San Diego, California.)

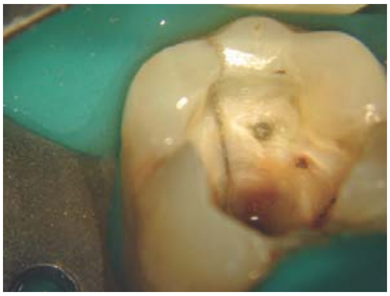


Figure 2—Vertical fractures can affect the prognosis of treatment. (Photo courtesy of Dr. Sashi Nallapati, Ocho Rios, Jamaica.)

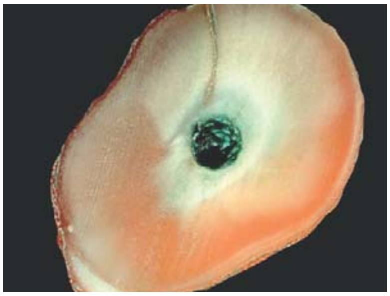


Figure 3—A tooth with a vertical fracture that tracks down a canal has a poor prognosis. In most cases, extraction is indicated. (Photo courtesy of Dr. Carr.)

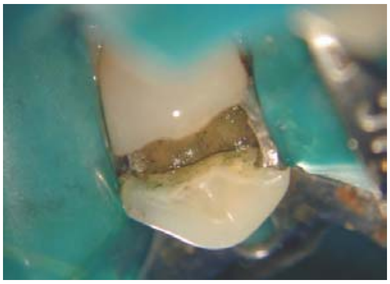


Figure 4—Here, a horizontal fracture is highlighted that extends across the base of the cusp. (Photo courtesy of Dr. Nallapati.)

Figure 5—A vertical fracture was suspected in the symptomatic lower left second molar. A root canal was started, and the crack could be visualized extending into one of the canals. The distal bone loss provided a clue that the tooth would be nonrestorable. The tooth was sectioned and extracted.

Figure 6—When sealing the canal orifices, excess gutta percha is removed and the floor of the chamber is cleaned. (Photo courtesy of Dr. Bill Watson, Wichita, Kansas.)

vestigated the effects of many restorative variables on the survival of teeth after root canal treatment. The only variable that made a difference was cuspal coverage. A retrospective study by Cheung and Chan[12] reported similar results. A retrospective study by Aquilino and Caplan[17] reported that the survival rate of endodontically treated teeth was six times greater with cuspal coverage than without.

3. From a structural and functional standpoint, a sound anterior tooth with minimal restorations and a conservative access opening requires only restoration of the access opening.[14] These teeth may be restored with crowns or veneers for other reasons, however.

It is very helpful to the dentist performing the root canal treatment to know the restorative treatment plan. When referring a patient for endodontic treatment, or to any specialist for that matter, the restorative dentist should send a copy of the treatment plan. At the very least, it provides the specialist with a better understanding of the patient, and it helps in decision making for the specialist's portion of the treatment. In many cases, the specialist may have suggestions or input into the overall treatment plan and may be able to help in the patient's decision-making process.

Coronal Leakage

Contamination of the root canal space by saliva, often referred to as "coronal leakage" or "coronal microleakage," is a well-accepted cause of endodontic failure.[18] Recurrent caries or fractured restorations may lead to recontamination of the root canal space. Under the best of conditions, the oral environment is harsh, and dental restorations must withstand physical, chemical, and thermal stresses. It is a difficult environment in which to maintain a leak-free system. In vitro studies have shown that exposure of coronal gutta percha to bacterial contamination can lead to the migration of bacteria to the apex in a matter of days.[19,20] Bacterial by-products and endotoxins can penetrate to the apex in an even shorter time than bacteria.[21] When the root canal space has been grossly contaminated, retreatment should be considered. This is especially true if there has been persistent contamination for more than a few days.[3] Recent studies by Ricucci and coworkers[22,23] in a clinical setting have questioned the importance of coronal microleakage as a cause of endodontic failure. Nonetheless, there are no benefits—but there are potential negative effects—from coronal microleakage.

Contamination should be prevented during the endodontic treatment by employing strict aseptic clinical techniques, which should always include the use of a rubber dam. Using a rubber dam also is highly desirable for restorative procedures. Once root canal treatment is completed, immediate restoration of the tooth is recommended whenever possible, because permanent restorations leak less than temporary restorations.[24] When this is not possible, the root canal space should be protected with intracoronal barriers and adequate temporization. Bonded restorations should be used to seal the root canal space.[25] The quality of the restorative dentistry performed after root canal treatment has a direct effect on the success of the endodontics.[26-28]

Orifice Barriers

Immediate restoration of the tooth after completion of the root canal procedure is the best approach to prevent contamination. When restoration of the tooth must be delayed, the canal orifices and floor of the pulp chamber should be sealed as a separate step of temporization, especially when most of the chamber is filled with a cotton pellet. A bonded orifice barrier is preferred, either composite resin[29] or a glass ionomer material.[30] If a composite is used, standard bonding procedures should be performed and a clear resin material is preferable, so that the gutta percha is visible through the resin. This allows the restorative dentist to visualize the gutta percha and use it as a guide if entry is needed into the canals for restorative purposes. If a glass ionomer material is used, a shade should be selected that is easily distinguishable from dentin in the floor of the pulp chamber. Concerns have been expressed about bonding resin to dentin that has been exposed to a eugenol-containing sealer. However, this is not a problem if the total-etch technique is used.[29] Sealing the floor of the pulp chamber provides an extra measure of protection to the root canal system in the period of temporization and during restorative procedures, particularly if they are performed without the rubber dam. It adds very little cost or time to the procedure.

After completion of the root canal treatment, the orifices should be countersunk slightly with a round bur and the chamber thoroughly cleaned with a combination of air abrasion, detergent, and/or alcohol to remove debris and excess sealer (Figure 6). If resin is to be used, the dentin should be etched and prepared with a dentin adhesive system (some are self-etching) and a clear resin placed and light-cured (Figure 7). There are several clear flowable composite resins available. Clear sealants also may be used.

Temporization

A superficial search of the literature yielded 29 articles that evaluated the sealing properties of temporary restorative materials for endodontic access openings. Studies were done with dyes, radioactive isotopes, fluid filtration, bacteria, or an electrochemical technique. They were done in vitro and in vivo on previously restored teeth and unrestored teeth. Materials tested included zinc oxide and eugenol preparations, zinc phosphate cements, glass ionomer cements, and composite resins. Based on the literature search, it may be fair to say that any of these materials can be used successfully for temporization. Whatever material is used for temporization, some guidelines should be followed.

1. If a cotton pellet or small sponge is placed in the chamber to make reentry easier, it should be of minimal thickness, and the temporary material should be of maximum thickness.[31]

2. If intermediate-term temporization is planned—for example, 1 to 2 months—consider placing temporary material in each orifice in addition to the access opening to provide a double barrier.

3. If a long-term seal is needed—for example, during apexification procedures with calcium hydroxide—consider using a permanent restorative material, such as bonded composite or resin-modified glass ionomer.

Teeth that require a post can present special challenges for temporization. Fox and Gutteridge[32] showed that the degree of contamination of a post space was approximately equal whether it contained a temporary post and crown or was left open. Demarchi and Sato reported similar results.[33] Therefore, when a post space is not restored immediately, an extra step is needed before temporization. If adequate root length is present, several millimeters of self-curing barrier

Figure 7—The floor of the chamber is then etched, bonded, and sealed with a layer of clear resin. Note how the gutta percha is clearly visible through the resin. (Photo courtesy of Dr. Watson.)

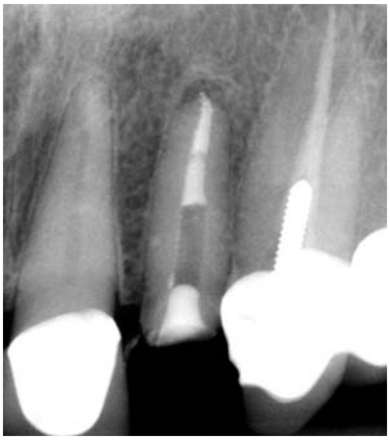


Figure 8—Temporary posts and crowns do a poor job of protecting the root canal system from contamination. A barrier may be placed over the obturating material to protect it.

Figure 9—Immature roots with thin dentin walls should be restored with bonded composite, extending apically beyond the crestal bone. This imparts additional resistance to fracture. (Endodontics by Dr. Gary Glassman, Toronto, Ontario.)

material may be placed over the gutta percha (Figure 8). Self-curing glass ionomer materials or traditional temporary cements may be used. If there is not adequate root length and a post is needed to retain the temporary crown, another alternative is to pack the apical 3 mm to 4 mm with mineral trioxide aggregate (a cement that seals well) rather than gutta percha. The tooth should be restored with a post and core as soon as possible.

Studies have shown that bacteria multiply rapidly in empty spaces within a tooth after endodontic treatment.[34] Therefore, when a post space is created but not restored immediately, it is advisable to fill that space with calcium hydroxide paste or some other antimicrobial material before temporization. The post space should then be irrigated with an antimicrobial solution before cementation of the post.[3]

Restoring Access Openings

The best time to restore the access opening is immediately after completion of the root canal. In most cases, a bonded restoration should be used to minimize the potential for leakage. Trautmann et al[35] showed that a perfect seal is not achieved with any of the current materials, although in their study the results might have been better if the occlusal porcelain had been etched before bonding procedures. They also showed that leakage occurred at the crown margins, particularly with all-ceramic crowns. Their studies emphasize the importance of careful evaluation of existing restorations when doing endodontics as well as the benefit of removing existing restorations whenever possible before endodontic procedures.

When access openings are restored, all available tooth structure should be etched and restored with a bonded material. Existing restorative materials should be roughened and cleaned, and etched if possible. Ceramic materials should be etched with hydrofluoric acid or other suitable etchant. In teeth with thin dentin walls, a bonded restorative material should be extended apically beyond the crestal bone if possible, in an attempt to lend strength and support to the remaining tooth structure[36] (Figure 9).

Post Placement and Removal

The topic of posts has been hotly debated for years and is a lengthy, complex topic. For the purposes of this article, the discussion will be limited to the endodontic perspective.

It is generally agreed that the primary purpose of a post is to retain a core.[37] If the core can be retained by coronal tooth structure or by anatomic features in the pulp chamber or canals, there is no need for a post.[38] Placement of a post adds risk to a restorative procedure. In most cases, the canal is enlarged to accommodate the post, and with many post systems a parallel channel is created in a tapered root. This creates the risk of perforation at the apical extent of the post or a "strip" perforation in the root concavities. Sound dentin also is removed, which weakens the root. For these reasons, posts should only be used when they are needed to retain the core.

From an endodontic standpoint, the most important question about posts is, "Do they allow the root canal to be retreated if necessary?" Posts made of ceramic materials, for example, should be avoided because they often are impossible to retrieve. However, most metal and fiber posts can be removed.

The best time to prepare a post space is at the time the root canal procedure is performed. The clinician who performed the root canal treatment is intimately familiar with the anatomy of the root canal space, and one recent study[39] showed that more leakage occurs around gutta percha if post space preparation is delayed.

Conclusion

Endodontics and restorative dentistry are a continuum. Endodontic treatment cannot be consistently successful without proper planning and follow-up care by the restorative dentist. Success is achieved through effective endodontic procedures, effective temporization and isolation, and timely restorative treatment. With existing endodontic materials, contamination of the root canal space may result in the failure of endodontic treatment and the need for retreatment, surgery, or extraction.

New materials with improved sealing properties are entering the market that may replace traditional gutta percha and sealers in the next few years. Several hydrophilic resin sealers are currently available, and others are in development. Some of these sealers provide adhesion to dentin, something that is not possible with traditional sealers. None of the new sealers will provide a perfect, leakproof system, but they may prove to be better than traditional zinc oxide and eugenol or calcium hydroxide sealers. Resin-based obturating materials allow at least some adhesion between the dentin, sealer, and obturating material. Resin-based obturating materials need to be soft or dissolvable in solvents to allow retreatment. Even with improved materials and better sealing properties, however, adequate preparation and disinfection of the root canal system will still be critical, and prevention of coronal leakage will still be important.

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Resilon™: A Novel Material to Replace Gutta Percha

Frederic Barnett, DMD
Associate Professor of Endodontics
Albert Einstein Medical Center
Philadelphia, Pennsylvania

Martin Trope, DMD
J.B. Freedland Professor of Endodontics
Department of Endodontics
University of North Carolina at Chapel Hill
Chapel Hill, North Carolina

University and specialty-based studies on endodontic outcomes have demonstrated a high degree of clinical success.[1,2] However, cross-sectional, retrospective population studies have revealed success rates in approximately 50% of cases.[3-5] As such, significant improvements in clinical treatments (debridement, disinfection, and root filling) and/or materials are required.

After the "cleaning and shaping" or chemomechanical instrumentation procedures of endodontic treatment, obturation of the root canal system is required. Ideally, obturation of the root canal system should entomb persisting microorganisms that remain within infected dentinal tubules or within fins, cul-de-sacs, etc. Additionally, the root filling should completely seal the canal system from reinfection from the oral cavity and from apical penetration of tissue fluids.[6] However, although gutta percha and conventional sealers have been considered the gold standard of endodontic obturation, these materials cannot be relied on when there is coronal leakage.[7-9] In fact, the quality of the coronal seal has been shown to be of significance relative to the periradicular status of root-filled teeth in several studies.[10,11]

A new material, Resilon™,[a] (Epiphany™,[a] and RealSeal™,[b] are representative brand names), has been developed to replace gutta percha and traditional sealers for root canal obturation (Figure 1). This system is comprised of:

1. Resilon™ primer[a]: a self-etch primer, which contains a sulfonic-acid–terminated functional monomer, hydroxyethylmethacrylate, water, and a polymerization initiator.
2. Resilon™ sealer[a]: a dual-curing, resin-based composite sealer. The resin matrix is comprised of BisGMA, ethoxylated BisGMA, urethane dimethacrylate, and hydrophilic difunctional methacrylates. It contains fillers of calcium hydroxide, barium sulfate, barium glass, bismuth oxychloride, and silica. The total filler content is approximately 70% by weight.
3. Resilon™ core material[a]: a thermoplastic, synthetic, polymer-based (polyester) root canal core material that contains bioactive glass, bismuth oxychloride, and barium sulfate. The filler's content is approximately 65% by weight. The Resilon™ core materials, similar to gutta percha cones, are available in ISO sizes in 0.02, 0.04, and 0.06 tapers, as well as in accessory sizes. Additionally, pellets of this material are available for use with the Obtura II[c] delivery system.[12]

These new materials have been shown to be biocompatible, noncytotoxic, and nonmutagenic and have been approved for endodontic use by the US Food and Drug Administration.

The concept of adhesive dentin bonding procedures for endodontic treatment has been previously investigated.[13-16] It was found that resin-based adhesive materials may have the potential to reduce the degree of microleakage from both apical and coronal directions of the root canal system. Removal of the smear layer with 17% ethylenediaminetetraacetic acid (EDTA) is required for the use of resin-containing root filling materials. It has been shown that by removing the smear layer, a decrease in coronal leakage will occur[17] and higher bond strengths will be obtained.[18]

Shipper et al[9] evaluated the microbial leakage in roots filled with Resilon™ and Resilon™ sealer in vitro using lateral and warm vertical condensation. These

[a] Pentron Clinical Technologies, Wallingford, CT 06492; 800-243-3969
[b] SybronEndo, a division of Sybron Dental Specialties, Orange, CA 92867; 800-346-3636
[c] Obtura/Spartan, Fenton, MO 63026; 800-344-1321

Figure 1— RealSeal™ kit containing Resilon™ primer, Resilon™ sealer, and Resilon™ cones.

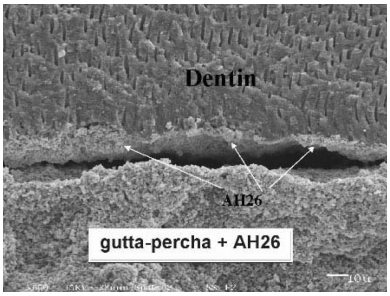

Figure 2— Scanning electron microscopy of sectioned root filled with gutta percha and AH-26 sealer. A 10-µm-wide gap is observed.

results were compared to gutta percha with AH-26 sealer and gutta percha with Resilon™ sealer, using both lateral and warm vertical obturation methods. A dual-chamber, in vitro method was used,[19] and *Streptococcus mutans* and *Enterococcus faecalis* were selected as the test microorganisms. The results indicated that all of the gutta percha groups had significantly ($P < .005$) more leakage (more teeth), and that the leakage occurred at a faster rate than when Resilon™ with Resilon™ sealer was used. These results may be of great significance in clinical endodontic practice.

At the completion of this leakage study, one Resilon™-filled and one gutta-percha–filled specimen were randomly selected for scanning electron microscopy (SEM) evaluation. These teeth were longitudinally sectioned so that the dentin–root filling material interface could be observed. The SEM sections of the root filled with gutta percha/AH-26 showed a uniform gap (Figure 2). This gap was approximately 10 µm wide and was between the sealer and the gutta percha. No gaps were observed in the root that was obturated with Resilon™ with Resilon™ sealer (Figure 3).

The excellent sealing ability of the Resilon™ system may be attributed to the "monoblock" that is created by the adhesion of the Resilon™ cone to the Resilon™ sealer, which adheres and penetrates into the dentin walls of the root canal system (Figure 4). In contrast, the gap between the gutta percha cone and the AH-26 sealer may allow an avenue for leakage, as was seen in the in vitro experiment.

These in vitro results were confirmed in an in vivo investigation by Shipper et al.[20] A dog model was used to assess and compare in vivo the efficacy of gutta percha and AH-26 sealer vs Resilon™ and Resilon™ primer and sealer [Resilon™ "Monoblock" System (RMS)] in preventing apical periodontitis subsequent to coronal inoculation with oral microorganisms. Fifty-six vital roots in the premolars of seven adult beagle dogs were aseptically instrumented, filled, and temporized. The roots were randomly divided into 4 experimental groups and 1 negative control group and filled as follows: group 1 (n = 12)—lateral condensation of gutta percha + AH-26 sealer; group 2 (n = 12)—vertical condensation of gutta percha + AH-26 sealer; group 3 (n = 12)—lateral condensation of RMS; group 4 (n = 10)—vertical condensation of RMS; negative control (n = 10)—gutta percha + AH-26 or RMS root fillings using lateral or vertical condensation techniques as in groups 1 through 4. In the positive

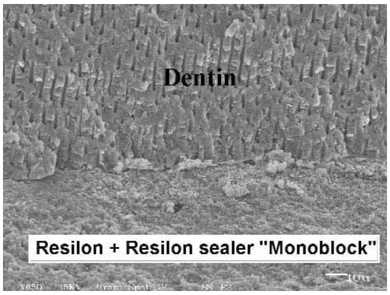

Figure 3—SEM of sectioned root filled with the Resilon™ system. No apparent gaps are observed.

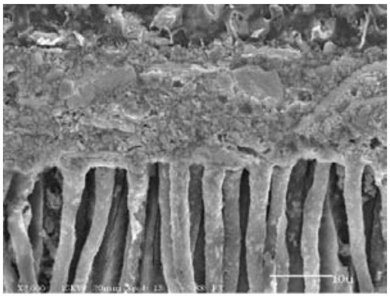

Figure 4—SEM at higher magnification of root filled with the Resilon™ system. Penetration of Resilon™ into the dentinal tubules is observed.

Figure 5—A mandibular first molar instrumented with the K3 Variable Tip Variable Taper sequence and obturated with RealSeal™ using warm vertical compaction.

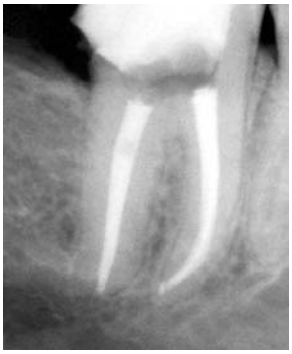

Figure 6—A mandibular molar instrumented with the K3 Variable Tip Variable Taper sequence and obturated with RealSeal™ using warm vertical compaction.

Figure 7—A mandibular molar instrumented with the K3 Variable Tip Variable Taper sequence and obturated with RealSeal™ using warm vertical compaction.

Figure 8—A mandibular molar instrumented with the K3 Variable Tip Variable Taper sequence and obturated with RealSeal™ using warm vertical compaction. The excellent flow of RealSeal™ can be visualized within the accessory apical anatomy.

control, 57 additional premolar roots were instrumented and infected but not filled. The premolars in groups 1 through 4 were accessed again, inoculated with dental plaque scaled from the dogs' teeth, and temporized. This fresh inoculum of microorganisms was repeated on two more occasions at monthly intervals. The teeth in the negative control group were not accessed again and remained undisturbed. At 14 weeks postcoronal inoculation, the dogs were euthanized, and jaw blocks were prepared for histologic evaluation under a light microscope. Periapical inflammation was observed in 82% (18 of 22) of roots filled with gutta percha + AH-26, which was statistically more than the roots filled with RMS (19%, or 4 of 21) and the roots in the negative control (22%, or 2 of 9) (McNemar paired analysis, $P < .05$). The RMS was associated with significantly less periapical inflammation, which may be because of its superior resistance to coronal leakage.

Figure 9—A maxillary first premolar with three root canals instrumented using the K3 Variable Tip Variable Taper sequence and obturated with RealSeal™ using warm vertical compaction.

Figure 10—A maxillary first molar instrumented with the K3 Variable Tip Variable Taper sequence and obturated with RealSeal™ using warm vertical compaction.

All methods of root canal obturation may be used with the Resilon™ system. These are the clinical steps for using the Resilon™ system following the routine cleaning and shaping and cone-fitting protocols:

1) Smear layer removal: Sodium hypochlorite should not be the last irrigant used within the root canal system because of compatibility issues with resins.[21,22] Rather, liquid EDTA or SmearClear™,[b] can be used as a final canal rinse or soak for 1 minute. SmearClear™ contains surfactants that enhance the wetting of the canal walls and provide for optimal smear layer removal (J. Jantarat, K. Yanpiset, C. Harnirattisai, unpublished data).

2) Placement of the primer: After the canal is dried with paper points, the self-etch primer is placed into the root canal system to the working length with paper points. Dry paper points are then used to wick out the excess primer from the canal.

3) Placement of the sealer: Next, the dual syringe (containing the sealer) with the automixing tip attached is used to express the sealer onto a mixing pad. The sealer can then be placed into the root canal system using a lentulo spiral, the PacMac[b] (at low rpm), or by generously coating the master cone.

4) Obturation: The root canal system is then obturated by your preferred method (lateral, warm vertical, or PacMac). Resilon™ pellets for the Obtura II delivery system are available for backfilling techniques.

5) Immediate cure: The Resilon™ root filling material can be cured immediately with a halogen curing light for 40 seconds. The use of a curing light is not required, however, as the material will self-cure within 1 hour.

6) Coronal restoration: A coronal temporary or permanent restoration should then be placed to properly seal the access cavity. The use of glass ionomer or composite resin to seal the floor of the pulp chamber also should be considered.

Clinically, the material is highly radiopaque and handles well with both cold lateral condensation and heated root canal filling techniques (Figures 5 through 10). In fact, the clinician does not need to change his or her obturation technique, as there is essentially no learning curve. The material appears to be biocompatible, and the sealer has considerable flow through accessory canals. No untoward postoperative pain has been reported by clinicians using the system, and some cases have demonstrated healing within a short period of time.

Conclusion

The aim of this article was to present the characteristics of a new resin-based endodontic root filling material. Despite the fact that gutta percha and sealer have been used for many years for root canal obturation, new materials and techniques have been developed that may increase the potential for successful outcomes by creating a better interface between root canal walls and filling material that decreases bacterial leakage. Further studies are necessary to confirm the clinical performance of these techniques to replace gutta percha.

Disclosure

Dr. Trope is a consultant for Pentron Clinical Technologies.

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The Elements™ Obturation Unit: New Product Preview

Gary D. Glassman, DDS
Private Practice
Toronto, Ontario

The current continuous wave of condensation techniques in the past required two separate devices: an electric heat source (such as the System-B™[,a] or the Touch 'n Heat™[,a]) for down packing, and an injection system (such as the Obtura II[b] or the E & Q Plus™[,c]) for three-dimensional backfilling. Incorporating advanced technologies in software, metallurgy, and electronics in a compact industrial design, the Elements™ Obturation Unit[a] has combined both an electric heat source and backfilling injection system in a single state-of-the-art unit. It is a multifunctional, multitasking achievement of modern engineering. It seamlessly integrates down packing, backfilling, hot-pulp testing, and heat cauterization in a single dynamic unit that takes up only one third of the space of two separate machines (Figure 1).

The left side of the unit houses the System-B™ controls and handpiece while the right side houses the extruder system and its controls (Figure 2). Both the System-B™ and extruder handpieces have autoclavable aluminum sheaths with silicone coatings at the "active end" that prevent heat transfer to the clinician's fingertips and protect the patient's soft tissues. The sheaths are installed by lining up the index marking and sliding them into place until a click is felt and heard. The activation switches are easy to reach, smooth to the touch, and signal with an audible tone when deployed. Two sheaths are provided for each handpiece so that one can be in use while the other is being autoclaved.

The digital/graphical display for the System-B™ controls incorporates four functions, each with its own preset default temperatures and durations (Figure 3). If a temperature setting other than the preset is desired for any of the functional modes, the temperature function can be used to change the temperature in 5-degree increments. Pressing and holding the "current mode" buttons for 4 seconds will set that temperature for that particular function. This new temperature preset is retained until manually changed or the defaults are renewed. The preset for the down-pack control function is 200°C, the backfill function is 100°C, the heat-cautery function is 600°C, and the hot-pulp test function is 200°C.

The System-B™ handpiece is activated by depressing the button with a gloved finger. The tip will heat instantly and the LED indicator on the handpiece will illuminate. The tip will remain heated only as long as the button is depressed. A "time-out" feature assists the clinician by shutting off the energy to the tip after an appropriate amount of time for each of the four functions. This avoids overheating the tooth and/or tissue. The "time-outs" are 4 seconds for the down-pack function, 15 seconds for the backfill function, 60 seconds for the hot-pulp test function, and 5 seconds for the heat-cautery function. During activation, the tip temperature is continuously maintained and displayed. The handpiece will need to be reactivated to resume heating beyond the preset duration. During down packing, the unit emits an automatic timer beep at 5 seconds and 10 seconds after the time-out to indicate readiness for the separation burst.

The pluggers are available in 0.04 (0.3-mm round end), 0.06, 0.08, 0.10, and 0.12 (all 0.5-mm round

[a]SybronEndo, a division of Sybron Dental Specialties, Orange, CA 92867; 800-346-3636
[b]Obtura/Spartan, Fenton, MO 63026; 800-344-1321
[c]Meta Dental Company, Elmhurst, NY 11373; 718-639-7460

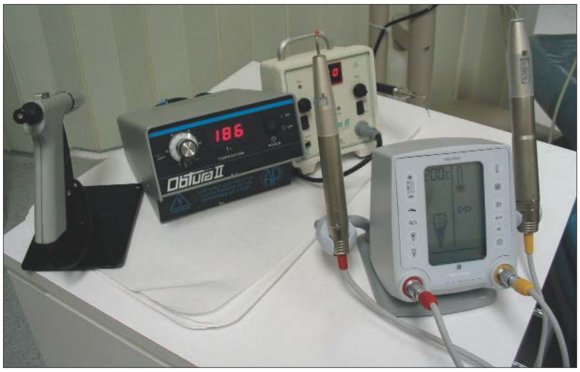


Figure 1—The Elements™ Obturation Unit saves counter space versus the Obtura II and System-B™ devices.

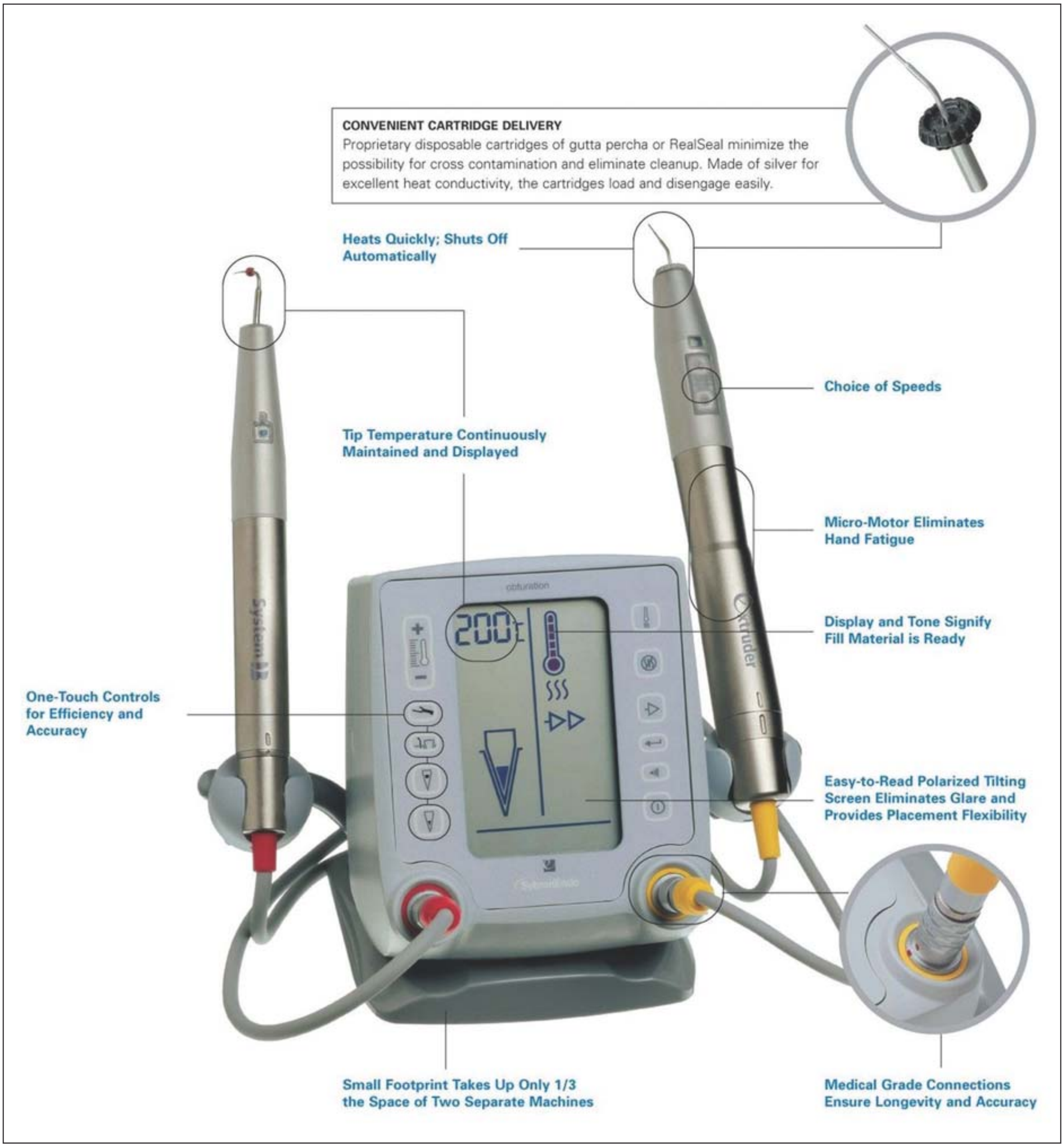


Figure 2—Overview of the Elements™ Obturation Unit.

end) tapers. They replicate the canal shape and maximize condensation forces to move the filling material and sealer into all areas of the root canal system, including lateral and accessory canals, to ensure a complete and homogeneous fill. They have a new "hex-nut" attachment that allows quick insert and release, thereby eliminating the need for a pinvise nut that is found in both the original System-B™ and the Touch 'n Heat™. The new 0.04 taper has a 40% smaller tip diameter that allows access into smaller canals and provides the same thermo-feedback as the other System-B™ pluggers, but it is closer to the size of a Touch 'n Heat™ tip.

The extruder system is micromotor driven and automates the backfill process, eliminating the fatiguing manual action required by other thermo-softening injection units. Its advanced insulation technology allows the extruder to stay dramatically cooler than other units throughout treatment.

Proprietary disposable cartridges of gutta percha

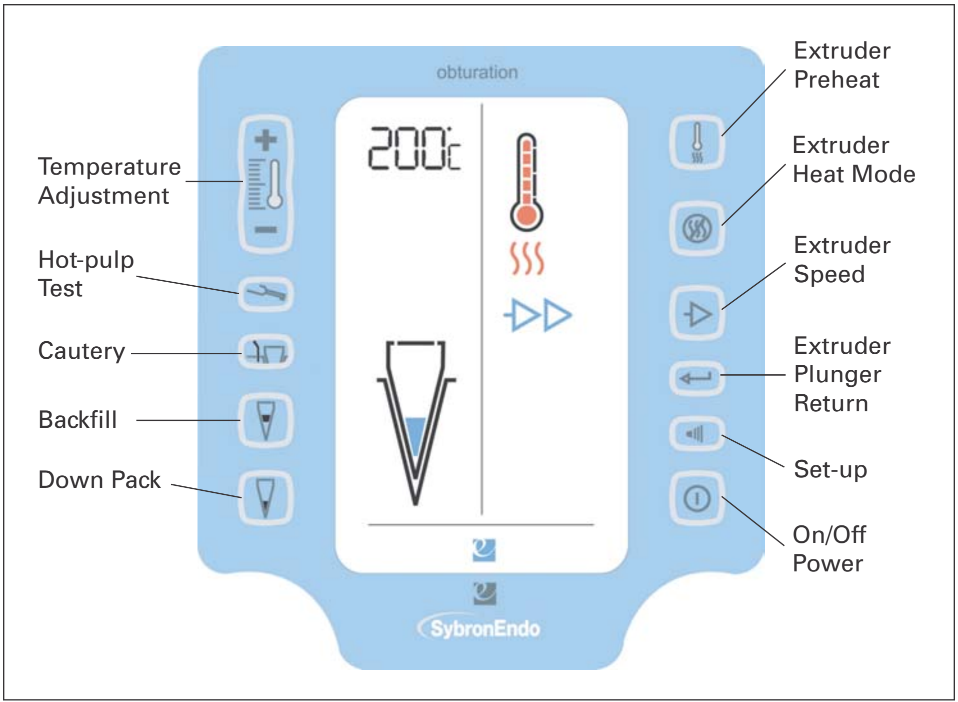


Figure 3—The front panel of the Elements™ Obturation Unit illustrating the function of each button.

or RealSeal™,[a] make the messy cleanup of plungers and bushings found in other units a thing of the past, and the needles are extra long (by 4 mm), facilitating access to posterior teeth with unprecedented visibility and greater control and accuracy. The cartridges are offered in 20-, 23-, and 25-gauge sizes that have plastic locknuts color-coded gray for RealSeal™ and black for gutta percha. Made of silver for excellent heat conductivity, the cartridges load and disengage easily from the handpiece with the specialized tool provided with the unit.

The extruder handpiece has a mechanical indicator on the opposite side of the activation buttons that shows the amount of material remaining in the cartridge. If the extruder is deactivated before the cartridge is empty, the plunger will retract slightly to prevent excess filling material from discharging. When the heat-select and heat-activated buttons are deployed, the preset temperature is reached in approximately 45 seconds and shuts off automatically (in 15 minutes for gutta percha and 5 minutes for RealSeal™) to prevent overheating of the filling material. There are two activation buttons on the extruder handpiece that allow the clinician to choose between two speeds for the extrusion of filling material.

Conclusion

There are several advantages of the new System-B™ electric heat source in the Elements™ Obturation Unit over the previous stand-alone System-B™ unit and Touch 'n Heat™ unit. Autoclavable removable sheaths, multifunctional preset heat settings, an audible "time-out" feature to prevent overheating of tooth structure, a detachable cord for servicing, and a "hex-nut" attachment for the pluggers are several examples. The extruder system has several feature

Figure 4A—Preoperative view.

Figure 4B—Down pack with RealSeal™.

Figure 4C—Backfill with RealSeal™.

Figure 5A—Preoperative view.

Figure 5B—Down pack with RealSeal™.

Figure 5C—Backfill with RealSeal™.

enhancements compared to the Obtura II and the E & Q Plus™: disposable color-coded cartridges of either RealSeal™ or gutta percha, available with different gauged tips (no messy cleanup), preset one-touch heat settings for RealSeal™ and gutta percha, audible "heat ready" tones, a dual-speed feature, a fatigue-free activation button, automatic plunger retraction, and autoclavable/removable shields/sleeves.

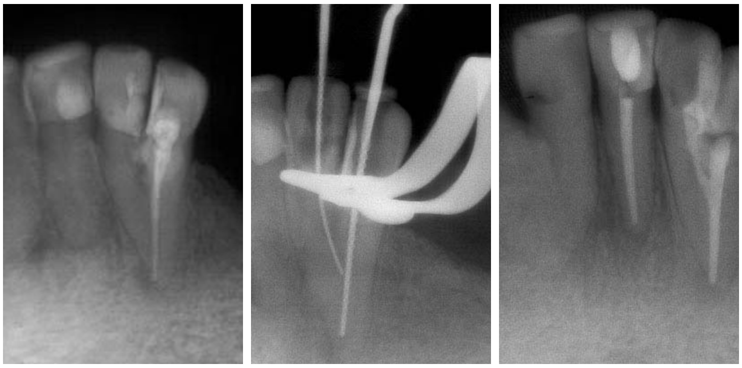
For practitioners who are first-time users of electric heat sources and thermo-softened injection delivery systems, or for those who are purchasing additional equipment, it would be beneficial to consider acquiring the one unit that incorporates both devices to take advantage of the multitude of features and small footprint (ie, minimal use of counter space). For those who possess two independent devices already, as maintenance and repair costs become formidable it may be more economically prudent to replace them with the single Elements™ Obturation Unit.

The Elements™ Obturation Unit represents the next generation in thermo-softened filling material delivery devices, incorporating the latest in technology, ergonomics, and ease of compliance with Occupational Safety and Health Administration standards to facilitate a more thorough three-dimensional obturation of the root canal systems (Figures 4A through 5C).

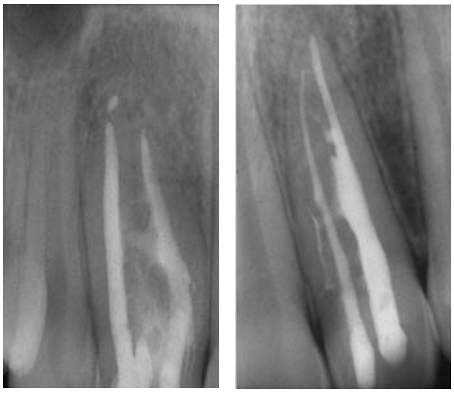
Endodontic Oddities

Just a little fun to show a few examples of less than "routine" cases by members of the ACE Group.

Fusion or Confusion???



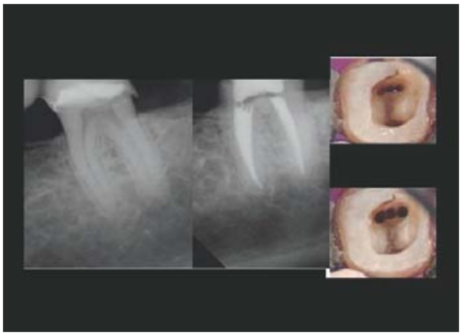
Fused mandibular lateral and cuspid courtesy of Dr. Alvaro Cruz and Dr. Mario Uribe.



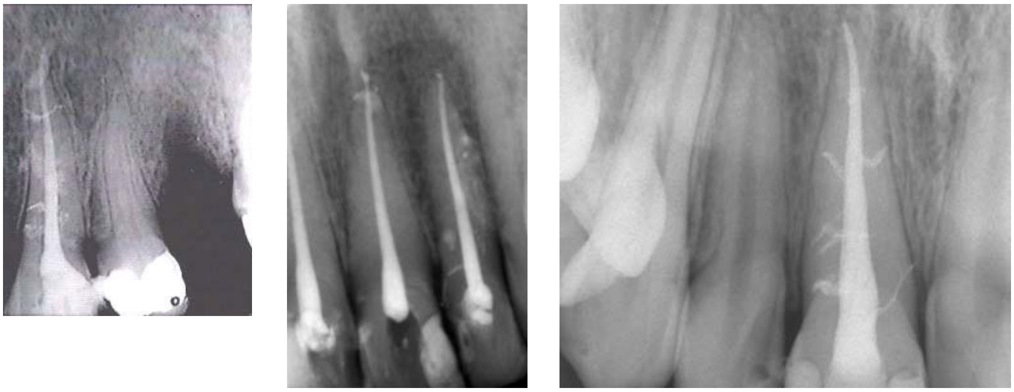
Fused maxillary lateral incisors courtesy of Dr. Stephen F. Schwartz.

Canals Galore

Four-canal mandibular bicuspid courtesy of Dr. Richard Mounce.

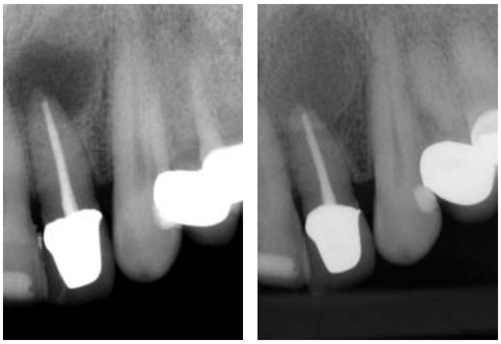


Three mesials courtesy of Dr. Fred Barnett.



Multiple accessory canals courtesy of Dr. Philippe Sleiman.

Resolution with Resilon™



Courtesy of Dr. Joseph Maggio.

Persistence Yields Perfection

Broken post.

Post and root canal filling retrieval.

Retreatment.

New restoration.

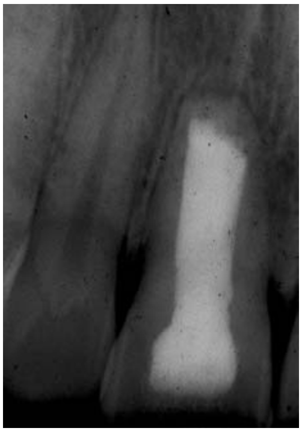
New smile.

Courtesy of Dr. Jantarta Jeeraphat.

It's So Hard to Say Goodbye

Avulsed incisor.

1-year postreplant/periapical lesion. Endodontic treatment was never initiated.



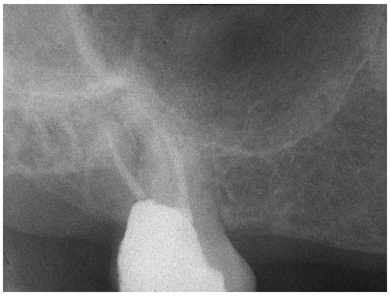
Apical closure after calcium-hydroxide apexification and warm vertical condensation of gutta percha.

Courtesy of Dr. Stephen F. Schwartz.

This One Cracks Me Up

Vertical fracture of tooth No. 15.

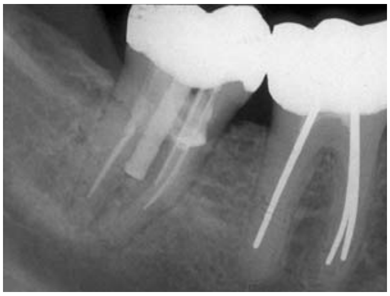
Removal of fractured crown and palatal root.



1 year after completed root canal therapy on remaining buccal roots.

Courtesy of Dr. Stephen F. Schwartz.

When All Else Fails

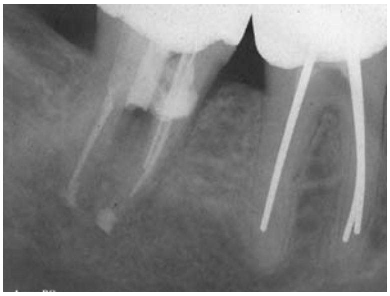


Pretreatment radiograph.

Clinical evidence of post perforation.

Courtesy of
Dr. Stephen F. Schwartz.

Immediately after repair and intentional replantation.



1-year follow-up of replantation.

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the ultimate filling machine

The Elements Obturation Unit™ combines System B™ technology with a motor-driven extruder handpiece to make obturation predictable, efficient and accurate. From downpack to backfill, the Elements Obturation Unit puts the Continuous Wave of Condensation™* technique into one simple-to-operate device that takes up only 1/3 the space of two separate machines. For more information on the ultimate filling machine, call your authorized distributor or SybronEndo at **800.346.ENDO**. Visit us online at **www.SybronEndo.com.**

*The phrase "Continuous Wave of Condensation" is a trademark of Dr. L. Stephen Buchanan.

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