

Quality Resource Guide

A Guide to Contemporary Endodontic Technology

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The following commentary highlights fundamental and commonly accepted practices on the subject matter. The information is intended as a general overview and is for educational purposes only. This information does not constitute legal advice, which can only be provided by an attorney.

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The content of this Guide is subject to change as new scientific information becomes available.

Educational Objectives

Following this unit of instruction, the learner should be able to:

1. Learn of the importance of evidence-based practice in endodontics.
2. Understand recent advances as well as contemporary concepts and technologies used in endodontic practice.
3. Learn about outcome studies in which the effectiveness of these technologies has been evaluated.
4. Learn about some promising newer concepts and technologies for which insufficient evidence currently exists.

Introduction

The discipline of Endodontics is experiencing continuous change and innovation. Dentists are now able to perform endodontic treatment more effectively and efficiently, while the patients are more comfortable. Conceptual and technological advances allow the dentist to achieve the basic objectives of endodontic therapy in less time and with more precision, while still conforming to fundamental principles of patient comfort and long-term success of treatment. This guide will outline a number of recent procedural and technological advances, explaining the basic concepts and procedures involved, and describing the results of clinical outcomes studies wherever these are available. The technologies that will be reviewed include: Diagnostic instruments, cone beam computed tomography (CBCT), local anesthesia, preemptive analgesia, magnification and imaging,

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electronic apex locators, rotary instrumentation, root canal disinfection, and endodontic obturation. This guide is not necessarily intended to recommend a particular product or technology, rather it describes the rationale for making a change in the dentist's practice, and the principles involved in making a selection among available technologies.

Endodontic Diagnosis, Treatment Planning and Prognosis

In any health care discipline, an accurate diagnosis based on the health history, clinical examination and diagnostic testing is essential prior to initiation of treatment. In endodontics, this fact is not only true but it is becoming even more important in contemporary practice due to many reasons. Many dental patients are older and present in the dental office with significant medical conditions that can influence the presentation or prognosis of disease, and the choice of the most appropriate treatment for them. Patients also have much better access to dental care, and retain many more teeth on average than they did in the past. Therefore, patients have on average a more extensive and involved dental treatment history that may complicate the diagnosis and the treatment plan. Patients are much better educated about their rights as patients, and about selecting the most appropriate treatment, based on the best available evidence and their own values and priorities. Patients expect the dentist to present them with treatment alternatives, risks involved, specific outcome expectations and the option to see specialists, so that they are able to make educated decisions. Finally, patients are more interested in improving their quality of life, including an interest in painless dental procedures and preservation of natural dentition whenever possible, while keeping their expenses to a reasonable minimum. Therefore, it is essential that the dentist is sensitive to these issues, and knowledgeable enough to be able to provide accurate feedback to common patient concerns and queries.

For optimal endodontic treatment, it is essential that the dentist be able to establish an accurate pulpal and periapical diagnosis for the tooth or teeth to be treated. This allows correct identification of the source of a patient's complaint, and provision of

effective treatment, including emergency treatment if necessary. Proper diagnosis also allows the provider to recognize non-endodontic pathosis that may mimic endodontic disease, and make an appropriate and timely referral to other health care providers and avoid medico-legal problems.

In addition, it is now well established that the preoperative diagnosis significantly influences the prognosis of treatment. Studies of endodontic treatment outcomes have shown that the prognosis of cases with vital/inflamed pulp with no infection is generally over 90%. However, cases with pulp necrosis with periapical lesions (established infection), and cases with persistent disease (after previous endodontic treatment) generally have a lower prognosis in the range of 74-85%.^{1,2} These studies documented the long-term complete radiographic healing related to endodontically-treated teeth, in addition to absence of clinical signs and symptoms. In these and several other longitudinal studies examining the biological healing of periapical tissues, the treatment was done under controlled conditions, with meticulous attention devoted to technique, asepsis and follow-up of patients.

Other studies have examined the survival of endodontically-treated teeth in the mouth for periods of 4-8 years, regardless of radiographic findings. These studies found that the survival of endodontically-treated teeth is 94-97%.^{3,4} These are two distinctly different measures of endodontic outcomes: complete radiographic and clinical resolution of disease vs. survival of teeth that may be functional but not completely healed.

When discussing the merits of endodontic treatment with the patient, the question of the prognosis of endodontic treatment versus implant therapy frequently arises. Recent systematic reviews have shown that there are no differences in outcomes between the restored endodontically-treated tooth and a dental implant.^{5,6} Moreover, several studies in which the outcomes of both procedures were studied showed that implants have on average a higher level of maintenance than endodontically-treated teeth.⁷⁻⁹ Finally, despite the publication of some case reports to the contrary, recent cohort studies have not documented a negative effect

of endodontic pathosis on neighboring implants. It is important to keep these facts in mind when presenting both treatment modalities to the patient.

As is noted before, pulpal diagnosis is very important as it provides an important consideration in discussing the prognosis with the patients, and in the degree to which the root canal system needs to be disinfected prior to filling (see root canal disinfection below). Sensibility tests such as thermal and electrical tests are still the standard of care in determining pulp vitality. In particular, the use of a cold test, like Endo Ice or carbon dioxide snow, together with an electric pulp tester in difficult cases should render an accurate assessment. In cases with difficult interpretation of the test results, the aim should be reproducing the patient's symptom. For example, for a hard to localize pain with cold, teeth can be individually isolated with dental dam, and tested with ice-cold water. Heat testing is used in cases that present with sensitivity to heat. Hot gutta percha is commonly used, together with isolation and exposure to hot water. Studies have shown that cold testing (such as CO₂ snow or Endo Ice) is more reliable in most patients, particularly in children, in teeth with crowns, particularly when using a large applicator surface area.¹⁰ However, in patients older than 50, cold testing has a higher degree of false negative responses than EPT, and so the latter is more reliable.¹¹ Recent findings show that combined electric and thermal pulp testing is able to accurately diagnose 97% of vital pulps and 90% of necrotic pulps, as confirmed by a bleeding pulp upon access preparation.¹² Other pulp testing methods that assess vitality rather than sensitivity, such as laser Doppler flowmetry and pulse-oximetry, are still in development phases.

One of the most important outcomes of endodontic treatment is the resolution of symptoms, most notably, pain. Painful endodontic conditions represent the most prevalent conditions that cause orofacial pain¹³ and most common dental emergencies.¹⁴ In the great majority of endodontic cases, the symptoms resolve after elimination of the etiologic factors, if the cause of symptoms was accurately identified. Occasionally, post-operative pain may occur due to unidentified non-endodontic condition, that may cause symptoms that mimic

endodontic pathosis.¹⁵ However, in some cases, post-operative symptoms that are thought to be endodontic in origin persist, despite seemingly adequate diagnosis and treatment.^{16,17} It is estimated that the incidence of this latter condition is about 5%, and may be due to sensitization of pain receptors in the central nervous system. This kind of pain is usually associated with prolonged pre-operative pain and the presence of other chronic pain conditions.

Digital Imaging and Magnification

Over the last decade, a number of digital radiography and photography systems have become available for the dental practitioner. In endodontics, typical intraoral cameras are not usually able to record intracoronary or intracanal detail with sufficient resolution. Therefore, still or video digital cameras are usually attached to operating microscopes using a beam splitter device. These technologies allow effective documentation of unusual presenting conditions or treatment procedures and enhance patient education about the procedures being performed.

Digital Radiography

Two main types of digital sensors exist: solid-state sensors (which may employ either the charged couple device (CCD) or complimentary metal oxide semiconductor (CMOS) technology), and photo-stimulable phosphor (PSP) sensors. These technologies have equivalent accuracy in endodontic usage compared to film. However, dentists generally prefer solid-state sensors because they provide almost instantaneous acquisition of radiograph during endodontic treatment. Other parameters that should be taken into consideration when selecting among the various digital radiography systems. These parameters include the following:

1. Sensor size

Most available sensors conform to an active surface area equivalent to film size 0, 1 or 2. Some sensors, however, have a larger area than the active surface. Clearly, this presents a problem in that the added size is not clinically usable. However, the main problem with CCD/CMOS sensors pertains to

sensor thickness. These sensors are typically 3-5 millimeters thick, which is much thicker than the PSP sensor. In endodontics, this presents a challenge when the dentist uses these sensors for working radiographs, with the dental dam in place. Occasionally, patients cannot tolerate the thick sensors with the dental dam. In these cases, the dentist could resort to using a size 1 sensor, a wireless CMOS sensor, or a PSP sensor.

2. Durability

Wired sensors are subjected to constant manipulation, which adds strain on the connection between the cord and the sensor. Sensors are constantly placed in positioning devices with infection control barriers, which may exert significant stress on the cord attachment. Other thin holders (which may be autoclavable or disposable) are available for the use with a hemostat to position the sensor in the appropriate location for endodontic working radiographs, as holding the sensor directly by a hemostat will damage it.

3. Support and maintenance plans

Because of the constant upgrades in software interface and the durability problems of most sensors, it is essential that dentists have an adequate maintenance and support plan with the vendor. This assures constant, reliable operation, and minimizes down time and long-term cost.

Cone Beam Computed Tomography (CBCT)

There has been a growing interest in the incorporation of CBCT in Endodontics. This imaging modality is particularly useful for cases that have complex root or root canal anatomy, suspected perforations or vertical root fractures, or to plan root end surgery in cases where the surgery may affect important neighboring structures. However, an earlier claim that CBCT could differentiate between periapical granulomas and cysts could not be substantiated in more recent findings.¹⁸

Studies have shown that CBCT has a higher accuracy than periapical radiographs in detecting periapical lesions.¹⁹ Therefore, they are especially useful in cases where the outcome of initial treatment is assessed, and to aid in the determination of whether retreatment or root end

surgery is the preferred treatment plan. In this regard, it was recently shown that specialists are more likely to change their endodontic treatment plan, when they review a CBCT volume of a previously treated tooth that may need additional care.²⁰ In addition to identifying missed canals, untreated anatomical space, procedural mishaps, CBCT imaging is also useful in diagnosing root resorptions, some root fractures and the possible source of pain or residual disease, when all other measures have failed to produce a conclusive etiology.

CBCT imaging should still be used only when other diagnostic methods and traditional radiography are not sufficient in providing the required information, and not as a routine method for all cases.²¹

Selecting the right digital imaging system is a decision that should be made after adequate examination of the available products, exploring the interface with office practice management software, and understanding of the support and maintenance options provided. The incorporation of digital imaging into the dental office and within endodontic operations is advantageous to the dentist. However, it is essential to recognize that it involves being constantly aware of changes in the technology, plan for anticipated upgrades and becoming knowledgeable in the best mechanisms of troubleshooting problems that may arise.

Efforts are currently underway to develop imaging modalities that do not utilize ionizing radiation to identify periapical lesions, or tooth abnormalities. Methodologies that involve magnetic resonance imaging, ultrasonography, and optical coherence tomography are among the leading technologies being researched for this purpose. For example, a recent animal study showed that MRI could be used to evaluate the progress of pulp regeneration.²²

Microscopes and Endoscopes in Endodontic Treatment

In the last two decades, the use of microscopes has become very popular among endodontists, and is becoming common among general dentists, periodontists and prosthodontists as well. Surgical microscopes commonly used in endodontic

practices generally offer magnification of about 7-20 fold or even higher. The use of microscopes has allowed a more detailed analysis of endodontic access preparations, identification of calcified canals, view of gross contents of root canals, have aided in the detection of cracks and fractures, and have facilitated surgical endodontics. For example, it is now common following access preparations to use an ultrasonic tip under the microscope to create a trough lingual to the mesiobuccal canals of maxillary molars to search for the MB2 canals, or to create a similar trough between the two mesial canals of mandibular molars to search for a third (middle) mesial canal. The microscope provides sufficient illumination and magnification, and has been shown to assist in detecting additional canals.²³

Some of the higher end microscopes offer unique technological advances. A beam splitter on the microscope connects to a still or video camera for documentation of procedures, and for patient education. Most generic brands of cameras have adapters to fit on microscopes. Attachments are also available that fix the eyepiece position, while allowing the objective lenses to be tilted depending on the patient's position and the site in the mouth. This ensures that the dentist does not change his/her position or posture but is able to adjust the field of view as needed. Dual eyepiece attachments are also available to allow the assistant to have a view of the operative field. A video camera may be connected to an LCD monitor to offer live demonstrations of procedures, or for the staff to follow the progress of a procedure (**Figure 2**)

Research data indicates that there is a measurable difference in performance, at least among novice practitioners, when microscopes are used for specific tasks. For example, a group of predoctoral students were trained and asked to perform endodontic access preparations on extracted maxillary molars, with or without a surgical microscope. The group which used the microscope performed significantly better on this exercise, using a predetermined scale of measurement.²⁴ Therefore, the use of microscopes does facilitate and enhance performance in endodontic practice, at least among students.

Electronic Apex Locators

In the 1990s, the apex locator circuitry was perfected by producing units that emitted dual or multiple currents that had different electrical frequencies. The impedance of currents with different frequencies is different, and this difference increases when the canal becomes narrower, such as at the apical constriction. Therefore, these newer generation instruments allow the measurement of the maximum constriction in the root canal, even if the canal contains an electrolyte, such as blood or sodium hypochlorite.

Recent evidence suggests that contemporary EALs are relatively accurate in determining the working length, compared to radiographs. Both EALs and radiographs, however, have their limitations in being able to determine an accurate working length. Periapical radiographs lack the necessary resolution, and information in the third dimension, that is essential if the canal terminus happens to be on the buccal or lingual surfaces of the root. When using radiographs alone, the length estimate is frequently inaccurate, leading to multiple exposures of the patient, multiple adjustments of the length, and delays in the procedure. One study²⁵ has shown that the use of apex locators (EALs) to determine the estimate of the working length (WL) results in reduced number of radiographic exposures and an increased probability that the estimate is similar to the final WL. More importantly, there was an increased probability that the final root filling level is 0-2 mm short of the radiographic apex, which is an acceptable clinical goal.

With all these advantages of EALs, the practitioner frequently wonders why radiographs are necessary for WL determination, *i.e.*, why can we not advocate the use of EALs exclusively for this purpose. The following are some of the limitations of the use of EALs:

- They do not produce accurate measurement if the canal does not have an apical constriction. This is frequently the case in retreatments, canals with immature apex, or teeth with apical root resorption associated with the presence of a periapical lesion.

- They do not provide any measurement in cases with apical blockage due to calcification, a sharp apical bend or by previous root canal filling materials.
- They do not provide information on canal anatomy, curvature, internal or external resorption, or the possibility of additional canals within the same root.
- They do not provide a permanent record for the WL determination, that can be used if problems arise after instrumentation or filling
- They are difficult or impossible to use in cases where the access is through a metallic restoration.
- They require a period of familiarity, and are sensitive to issues of battery power, and intactness of leads, that frequently compromise their usefulness.

Therefore, the optimal use of EALs is in obtaining an accurate estimate of the WL that is followed by radiographic verification and analysis. Frequently, the apex locator indicates a WL that appears to be short of the radiographic apex. In these cases, radiographic analysis usually shows that the endodontic instrument ends at an eccentric point of the root apex, indicating that the apical foramen is not at the radiographic apex.

There are some EAL models on the market in which an electric motor for rotary instruments is incorporated with an EAL. In addition to the traditional apex locator function on the rotary instrument, these EALs provide auto reverse and auto forward functions when the tip of the instrument reaches the apical terminus. Earlier versions of these units incorporated the EAL with the handpiece (such as the Tri Auto ZX by J. Morita Corp), but these handpieces were very heavy. With the advances in electronic circuitry, smaller attachments to the table top units or to the handpiece are made. Contemporary units include the Dentaport ZX (J. Morita Corp., Tokyo, Japan), Endomaster (EMS, Nyon, Switzerland) and the X-Smart dual device (Dentsply-Maillefer). One study comparing the accuracy of these units while in manual or operational modes concluded that there are variations in the measurements made by the units that warrant adherence to a manual preoperative measurement.²⁶

Root Canal Instrumentation

Hand Instrumentation

Modern root canal instrumentation mostly involves mechanized flexible instruments that can efficiently debride the root canal space. However, there is still a very distinct and important role for hand instruments. K-files, H-files, Flexofiles or hand nickel titanium (NiTi) files are useful in exploring the root canal system, obtaining working length, spreading medicament or sealer, or removing previous filling material. There are three areas where hand filing is still the standard of care in practice. These are:

- 1) Initial exploration and enlargement of all narrow curved canals up to size 10 – 20, to provide a glide path for rotary instrumentation. This involves the use of instruments sized 06-10 to negotiate calcified canals. C-file, C+ and C++ files at these small sizes are made of hardened stainless steel and are particularly useful in negotiating these calcified canals (to be discussed later).
- 2) Instrumentation of oval, kidney-shaped, flat canals or canals connected by patent isthmuses. This includes cases with unusual internal anatomical configuration like C-shaped canals.
- 3) Instrumentation of very large canals such as those of adolescents and young immature teeth.

In all these cases circumferential filing with hand stainless steel or NiTi instruments assures adequate debridement in preparation for further rotary instrumentation and/or obturation.

Rotary Instrumentation

The advent of rotary instrumentation in endodontics began in 1988 when it was shown that the bending and torsional properties of files made of NiTi alloy are superior to those made of stainless steel.²⁷ Several years passed before the technology to fabricate endodontic instruments from NiTi was mastered. In the past two decades, a number of different instrumentation systems were introduced on the market. Before discussing these systems, it is essential to outline a few general principles for the selection and use of NiTi instrumentation.

1) Assessment of case difficulty

Following diagnosis, the dentist must always assess the difficulty of the case to be treated. It is essential to have an understanding of which cases lend themselves to the use of a particular technique while minimizing the risk of procedural errors. There are two particular aspects of root canal radiographic morphology that are critical with respect to the use of rotary instrumentation. These are the degree of canal calcification, and the degree and location of canal curvature. Canal calcification is determined subjectively by the degree to which the root canal system is discernible within the image of the tooth. Canal curvature is described by its angle (radius of curvature) as well as its cervico-apical location within the root. Canal curvatures of more than 25-30 degrees are considered to be severe (**Figures 1A and 1B**). Canal curvatures that are confined to the apical third of the root are considered to be more difficult to manage than those that span the entire length of the root, because instrumenting them results in increased stresses on rotary instruments.²⁸

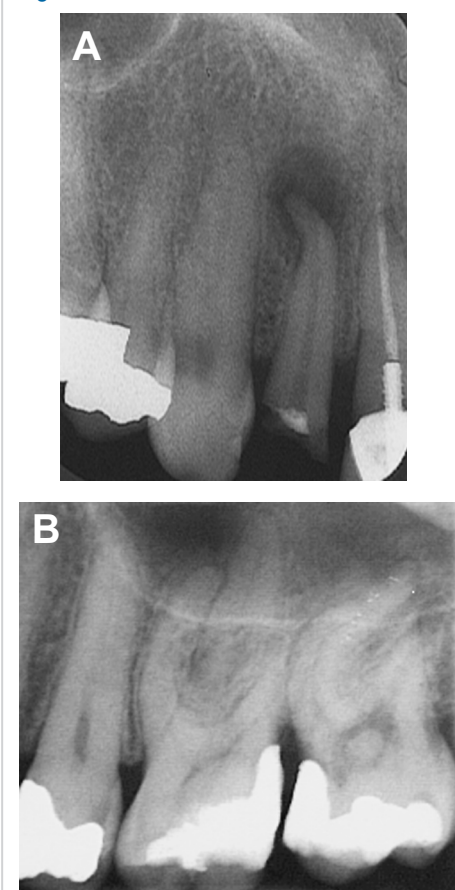
2) Straight-line access

In order to improve access to the coronal third of the root canal and reduce the overall curvature of the canal in a predictable, biological manner, straight-line access is the first step in canal instrumentation regardless of the system used. This is usually accomplished using high taper instruments such as one with a 06 taper. Lack of straight-line access also subjects the instrument to high stresses (**Figures 2a and 2b**).

3) Negotiating narrow curved canals

As noted before, the use of traditional NiTi rotary instruments must be performed only in canals that are negotiable to the working length. Narrow curved canals should be instrumented first with a hand file of at least size 6, 8 or 10 to establish a glide path, and assure minimal resistance of the canal to rotary instruments. Special hand files, such as C files, C+ or C++ files, are work-hardened K-files, and the small sizes of these are very useful in negotiating calcified canals. This minimizes the risk of separation of small rotary instruments. Special low taper (0.02 mm/mm) NiTi rotary files are currently available to negotiate narrow curved

Figure 1



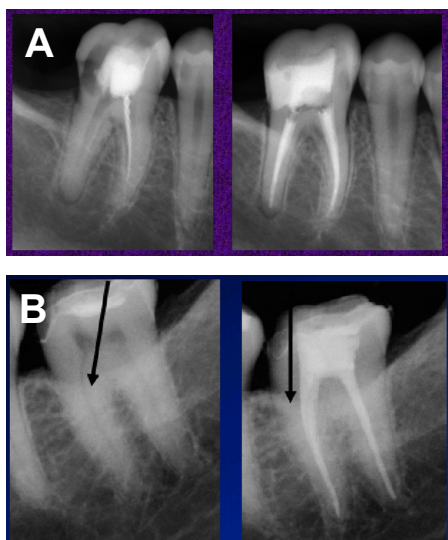
A: Tooth #7 shows severe apical curvature.
B: Tooth #15 shows a large pulp stone as well as a dilacerated curve on the mesial buccal root.

canals after a small size 10 hand file is able to reach the apical terminus. Examples of these are the PathFiles™ (Dentsply) which include three sizes: 13, 16 and 19 or ProGlider files (Dentsply). Preclinical evaluation of these instruments showed mixed results compared with manual filing^{29,30} however, anecdotally, they appear to yield the preflaring of calcified canals more efficiently.

4) Crown down preparation

In most hand instrumentation techniques, the step-back preparation sequence is utilized. The rationale for this is that stainless steel instruments are very rigid and thus the larger sizes tend to straighten root canals or ledge short of the apex. The optimal preparation of canals with rotary instruments involves incremental preparation, starting from the coronal third, and extending apically. This

Figure 2



A: Inadequate straight-line access resulted in instrument separation. Instrument was removed and case was completed with adequate straight-line access.

B: Another case with adequate removal of dentin encroaching on mesial canals to create straight-line access.

is best achieved by starting with a 35/06 or 40/06 instruments and extending the preparation more apically with smaller size/06 instruments until an instrument (perhaps 25/06 or 20/06) reaches the working length. Following this “crown down” incremental approach apical preparation is started. The crown down method assures efficiency in using the instruments, minimizes the chance for binding and separation, and allows debridement of most of the canal before the apical portion is reached. This latter portion may reduce the chance of extrusion of infected debris into the periapical tissues, although this has not yet been demonstrated.

5) Apical preparation

This is an area that receives little attention from manufacturers of most NiTi rotary systems. Most manufacturers focus on the shaping of the root canals only, and advocate the high taper with less emphasis on apical preparation sizes. However, biological cleaning of the root canals, particularly in necrotic cases that have bacterial infection, require some degree of apical preparation of the root canals. A classic series of studies have shown

that the mean apical diameter of root canals one millimeter from the apex corresponds to sizes 30 – 40 endodontic instruments.³¹⁻³³ Therefore, adequate apical preparation to these instrument sizes is necessary to make sure that the canal is adequately engaged and cleaned in an area that is critical because it interfaces with the periapical region. This is typically achieved after the crown down sequence described before by using 04 taper instruments to enlarge the apical portion of the canal until a size 35/04 or 40/04 instrument (in most cases) is easily advanced to the full working length. A study evaluating the healing of periapical lesions one year after treatment showed that increasing the apical size at least three sizes larger than the initial size resulted in significant improvement in healing of the lesions.³⁴

6) Use of lubricating agents

Throughout the use of rotary instrumentation, the canal must be lubricated by sodium hypochlorite and EDTA-based lubricating agents. These agents reduce torque and enhance the gliding of the instruments to debride canal walls. One preclinical study showed that liquid EDTA solution was significantly better than paste lubricant in reducing torque with ProFile and ProTaper instrumentation.³⁵

7) Use minimal force

The effectiveness of rotary or reciprocating instruments is determined by the ability of these instruments to be activated in the canal with relatively low resistance. If the dentist applies too much force on the instrument, the instrument is likely to encounter too high torsional forces, which lead to instrument separation. In order to balance the need for effective canal preparation with the risk of instrument binding and separation, most contemporary electric motors employ a torque control mechanism that allows the instrument to stop, and provide a warning signal if the torque encountered exceed a preset level. A good rule of thumb is for the dentist to apply sufficient force on the instrument as is necessary to write with a sharp pencil without breaking the tip of the pencil. Finally, the dentist should remember that the small size instruments fracture at much lower torque than larger instruments for a given taper.

As noted before, one of the main purposes of the crown-down instrumentation technique is to allow the preparation of the canal incrementally in order to reduce the surface area in contact with the instrument at any one time. Instruments with larger taper are advanced for shorter distance within the canal. They are followed by instruments with successively less taper, which penetrate deeper but again engage a small surface area of the canal, until the entire length of the canal is prepared. If an instrument is introduced into the canal that fits the canal size, it is more likely to bind and separate. The exception to this may be reciprocating instruments, which are high taper instruments that are activated in the canal until they reach the working length.

8) Rotary instruments are disposable instruments

Studies have shown that root canal instruments lose their effectiveness after multiple uses. Furthermore, after initial crack formation within the instrument, successive use would cause crack propagation and instrument failure. Therefore, every effort should be exercised to discard the instrument after a single use, particularly if it has been stressed in a narrow canal. Exceptions to this general rule are where the instrument is used with minimal resistance. In these cases the use of the instruments from 3-5 times would be appropriate. If instruments are to be re-used, they should be inspected under magnification to assure that they have not been deformed, and a method should be established for keeping track of how many times an instrument is used.

9) Use with torque control motors

These motors allow the operator to set the maximum torque that would stop the instrument automatically. The motor may also have auto reverse and auto forward features, which aim to disengage an instrument that binds in the canal if the torque reaches a certain level. Motors usually have automatic torque settings of different types of instruments depending on their taper, the speed and the reciprocation. These are safety features that enhance the ability of the operator to recognize instances when the instrument is binding in the canal, and when further activation may cause fracture.

Advantages of Root Canal Preparation with NiTi Instruments

- **Maintain canal shape:** Studies have shown that NiTi hand and rotary instrumentation is capable of enlarging root canals while maintaining the original curvature, *i.e.*, there is reduced chance of ledging, or apical transportation compared to stainless steel instrumentation.
- **Reduce the extrusion of debris apically:** While rotating in the root canal, the instruments are designed to bring debris coronally. With hand instrumentation there is apical extrusion of debris, presumably due the pumping action during filing.
- **Reduce dentist fatigue:** There reduced stress on the operator with rotary instrumentation, particularly in small canals. In general the dentist becomes more efficient when using rotary instrumentation.
- **May improve long-term outcomes:** There have been some reports comparing endodontic treatment outcomes in cases treated with NiTi and stainless steel instrumentations. Studies that compared hand NiTi, and stainless steel instruments showed that NiTi instruments produced more favorable canal shaping,³⁶ and radiographic healing outcomes.³⁷ A more recent outcome study has shown that cases treated with NiTi rotary instrumentation have less procedural errors and a better long-term outcome compared with cases treated by hand instrumentation.³⁸

Disadvantages and Relative Contraindications

- **File separation:** This is perhaps the most serious drawback for the use of rotary instrumentation. Studies have shown that this occurs in about 1.6-3.3% of cases treated.^{39,40}
- **Double curves (dilaceration of the root - Figure 1b):** Double curves subject the instrument to excessive stresses. The plane of one of the curves may be in the third dimension, not visible on a radiograph. These require angled radiographs in order to appreciate their presence and magnitude.

- **Very small calcified canals:** Generally, these cases should be referred to an endodontic specialist, because they are more difficult to negotiate and treat.
- **Canals that join apically or have a sharp apical bend (Figure 1a):** As stated previously, the instrument in these cases is subjected to sudden increases in stresses and can easily fracture.

How to Reduce the Risk of Instrument Separation with Rotary Instruments

- **Instrument all canals** to a size 20 hand instrument or with PathFiles before using traditional rotary instrumentation
- **Use the light pressure on the instrument,** and a torque control motor
- When the dentist starts to use this technology, he/she should **lower the rpm gauge** by 50-100 units below the recommended level for the system being used until familiarity and expertise with the system is gained. The exception to this are sharp “non-landed” instruments such as the ProTaper and EndoSequence, which need to be used at the recommended speed to avoid binding.

Common Newer Rotary Instrument Systems

ProTaper Universal, ProTaper Gold, ProTaper Next and ProTaper Retreatment (Dentsply-Sirona)

The ProTaper Universal instruments have been a popular system for about a decade. They involve 6-8 instruments that have variable taper and are used in succession to treat most canals. ProTaper files are non-landed. The Universal and Retreatment have a triangular cross-section, whereas the Next has a rectangular cross section to add strength to the instrument. The retreatment instruments have three instruments with modified tips to help removing gutta percha. ProTaper Gold is the same design as ProTaper Universal, except with a change in the metallurgy of the instrument that allows it to be more flexible. All these Instruments are generally operated at 250-300 rpm.

Endo Sequence and BioRace (Brasseler)

These instruments do not have radial lands. To prevent instrument binding, they have an alternating contact design that minimizes the surface area of the instrument in contact with the canal wall at any time. The instruments have a triangular cross section and are electrochemically polished to prevent surface irregularities. These surface irregularities may initiate instrument fracture. These instruments require operation at a higher rpm (typically about 500-600) in order to glide smoothly and prevent binding. Because they have less surface area in touch with the dentin they are considered low torque instruments. In vitro testing showed that these instruments may have a higher propensity for fracture,⁴¹ although the cleaning ability in root canals is not different from Profile or Protaper instruments.⁴²

ProFile Vortex and Vortex Blue (Dentsply-Sirona)

These instruments are available in ISO sizes 15-50, and in .04 and .06 tapers. They are made of a new NiTi alloy configuration called the M-Wire. This allows the instrument to have a higher torsional strength, fatigue resistance and increased flexibility.

Twisted Files (Sybron Endo)

These instruments are manufactured by twisting rather than grinding the nickel titanium wire, and are then subjected to a proprietary heat treatment to increase their flexibility and resistance to torsional fatigue. This is known as R-phase heat treatment. These instruments are available in taper .04 (sizes 25, 40 and 50), .06 (sizes 25, 30 and 35) and size 25 at tapers .08, .10 and .12.

TRUShape 3D (Dentsply-Sirona) and XP-endo Shaper and XP-endo-Finisher (Brasseler) files

These newer files are characterized by having an unusually curve in the shape (Figure 3). There are designed so that when they rotate in a canal that has an oval or non-geometric shape they provide maximal contact with the canal wall. In theory this should enhance disruption of microbial biofilms, debridement of vital tissues, retreatment and removal of medicaments from the root canal. Preclinical studies have shown some value in this regard, although one recent study showed that when hypochlorite was used, there was no difference compared with traditional files.⁴³

EdgeFile, EdgeTaper, EdgeEvolve and EdgeSequel (EdgeEndo)

These files are designed to simulate the design and efficacy of other file systems, but are offered at lower cost. Little objective research is available to evaluate the efficacy of these instruments.

Because of the variety of systems available, the dentist is frequently uncertain as to which system he/she should use. Generally speaking, dentists should consider the volume of endodontic therapy in their practice, and whether they are treating moderately difficult cases, such as molars, or only simple cases. For dentists who treat only simple cases with straight large canals, rotary instrumentation will probably not offer them significant advantages. For dentists who perform more demanding cases, they should use systems which have been evaluated objectively and found to yield reliable results, and not just rely on manufacturers' claims. The dentist should request from manufacturers literature on objective data, which have been published in referred journals. Specifically, data on the incidence of instrument separation, maintenance of canal shape following instrumentation and effectiveness of apical preparation should be sought. Manufacturers usually emphasize the speed of preparation, and the number of instruments needed for completed preparation; however, from a clinical effectiveness perspective this data is usually not useful. Cost is another important factor. The reduced number of repeated use for these instruments should be factored into the cost calculation. Studies have shown that the Twisted File (SybronEndo) and ProFile Vortex or Vortex Blue (Dentsply-Sirona) have superior cyclic fatigue (delayed failure with continuous rotation) and flexibility when compared with similar sizes of older systems such as ProFiles and Endo Sequence.⁴⁴⁻⁴⁸ However, one paper showed that Twisted Files have reduced torsional stress resistance (less absolute strength in rotation) compared to other systems.⁴⁹ It is important to note that these in vitro studies are preclinical in nature, and the true performance of most of these systems clinically is currently unknown.

Figure 3

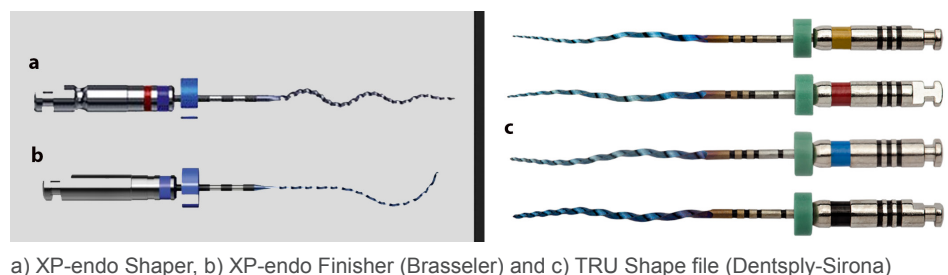


Figure 4



Motor and files for the WaveOne System (Dentsply-Sirona). The instruments are sizes 20/06, 25/08 and 40/08, each intended for use as the single instrument for the tooth/or canal involved.

Reciprocating Files

Reciprocating files follow the principle that the use of watch-winding motion can be extended to allow a motor to engage an instrument with high taper in the canal so that it can incrementally be advanced throughout the entire working length. This concept was introduced in technique paper in 2008.⁵⁰ This concept is very attractive, because it has been known for a long time that reciprocal motion significantly reduces the chance for binding of the instrument, allow efficient negotiation, reduce torsional stresses and instrument failure due to cyclic fatigue. Thus, one instrument can potentially be used to instrument the root canal, with fewer chances for separation and operation that is more efficient. Two main reciprocating systems are available: WaveOne (Dentsply-Sirona, USA) (Figure 4) and Reciproc (VDW, Germany). When the instrument is activated it rotates a fraction of a turn (exact amount differs between instruments) in a clockwise direction and then a smaller fraction of a turn counter clockwise. This results in a net

advancement of the turn in a clockwise direction. However, the counter clockwise component assures that the instrument does not bind, thus reducing torsional forces etc. The TF Adaptive system by Sybron Endo is designed to allow reciprocation if there is resistance in the canal, and rotation if there is no resistance.

Preliminary bench top experiments show these instruments to meet the criteria from a metallurgical and functional perspective. However, treatment outcome studies are not available for them yet. Moreover, a significant limitation of this concept is the lack of apical preparation of the root canal as discussed previously. Thus it is not clear whether the use of one instrument (typically it is a size 25 at the tip) would allow adequate debridement of the apical microbial biofilm.

Root Canal Disinfection

As noted before, there are two distinct diagnostic categories of endodontic pathosis that affect the prognosis: cases with vital (albeit inflamed) pulp,

and cases with pulp necrosis and a periapical infection. Because of the differences in prognosis for both types of cases, it is important to emphasize more specific disinfection protocols in cases with infections because it has been shown in several studies that elimination of cultivable bacteria at the time of root filling results in better treatment outcomes.^{51,52} For these reasons, there has been an increasing interest in recent years in methods of root canal disinfection. Sodium hypochlorite remains the gold standard in root canal irrigation. It is an excellent disinfectant, it dissolves vital and necrotic tissue and it acts as a lubricant during instrumentation. However, in the root canal environment, there are restrictions in the being able to deliver enough hypochlorite to disrupt microbial biofilms in all canal anatomical intricacies. Thus studies have shown that following hypochlorite irrigation, about 40-60% of root canals remain with viable bacteria. Furthermore, the use 17% ethylenediaminetetraacetic acid (EDTA), in alternating irrigations with hypochlorite, is now common to remove the smear layer. The smear layer may harbor bacteria and impede the effects of root canal medicaments on bacteria in dentinal tubules.

Biopure MTAD (Dentsply-Sirona) is a root canal irrigant that contains a mixture of a tetracycline isomer (doxycycline), citric acid and detergent. This solution has been shown to kill root canal bacteria in bench top experiments. However, outcome studies have not shown that this irrigant is beneficial.⁵³ Another recently introduced irrigant is QMix (Dentsply-Sirona), which combines chlorhexidine and EDTA. The concept of this irrigant is to remove the smear layer while disinfecting dentin. However, screening studies show mixed efficacy compared with hypochlorite.^{54,55}

The method of irrigation may make a significant difference in the efficacy of irrigation. Irrigation must be performed with the tip of the needle as deep as possible in the canal without binding with dentin. If the needle binds then the irrigant may be extruded periapically, which can result in a hypochlorite accident. It has been known for a long time that irrigation with a loose needle in the canal is only to the level of the tip of the needle, therefore,

small gauge needles such as Max-i-probe gauge 28 or 30 should be used to irrigate most canals to achieve good needle penetration.

Technologies that may enhance irrigation may involve sonic or ultrasonic activation. This may be applied to a file loosely fitting in a canal filled with the irrigant (passive ultrasonic/sonic irrigation) or directly to the irrigation needle. There is some clinical evidence that ultrasonic irrigation enhances bacterial elimination in teeth with complex anatomy,⁵⁶ however, randomized controlled trials failed to show a significant improvement with sonic or ultrasonic irrigation in teeth with single canals.^{57, 58}

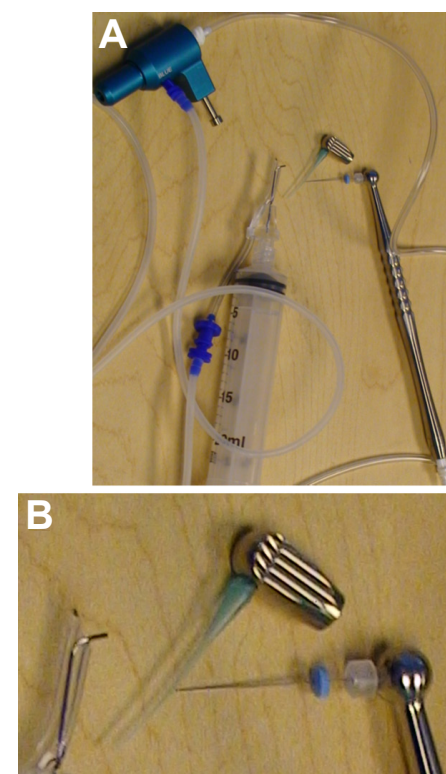
Another technology that has been popular among many clinicians is the use of negative apical pressure (EndoVac, Kerr-SybronEndo). This device involves delivering the irrigant into the pulp chamber that is then aspirated by a needle deep into the canal. Two sizes of aspirating needles are used: a plastic macro aspirator and a 32 gauge needle with apical perforations that can penetrate close to the working length in most teeth (**Figure 5**). Clinical trials have shown that this approach significantly reduces postoperative pain within 24 hours of the procedure.⁵⁹ However, the antibacterial efficacy does not appear to be enhanced, at least in one trial in which teeth with large single canals were included.⁶⁰ More research is needed in cases where traditional irrigation cannot be applied to the full length of the canal. Also, a newer model of the device will be available soon, that will enhance the usability of the device in a busy practice.

A novel technology for cleaning root canals has recently been introduced called GentleWave (Sonendo, Laguna Hills, CA). This technology is primarily intended for posterior teeth, in which a tight seal is applied on the occlusal surface of the teeth, and a mist of sodium hypochlorite is activated by ultrasonic energy into the root canal system that had received minimal instrumentation. The objective is to allow the hypochlorite to permeate the complex root canal anatomy to debride and disinfect the root canal system, prior to obturation. Preliminary bench top experiments shows improved

debridement of this system compared to traditional methods.⁶¹ Case series of clinical cases in which this system was used were reported to have good outcomes.⁶² However, clinical outcomes compared to controls have not been reported, and the system is very expensive to acquire.

The use of lasers to disinfect root canals has been researched for decades. Studies have shown that for lasers to kill root canal bacteria, lengthy application would be required, which would raise the temperature to hazardous levels. A recent randomized clinical trial was reported in which the use of Nd:YAG laser to disinfect root canal was compared to 1% sodium hypochlorite. The results showed no difference between the two protocols. Therefore, the use of lasers for this purpose is currently not supported.

Figure 5



EndoVac set up: **A:** Blue device connects to the vacuum hook up for the dental chair. Shown are the irrigation syringe with the short delivery needle, the plastic macro aspiration needle and the micro aspiration needle that can be set to the working length using the marker. **B:** Larger view of the needles.

A common method currently used to reduce root canal bacteria is to place calcium hydroxide paste in the root canal between appointments. A systematic review of the clinical use of calcium hydroxide has shown mixed results on its effectiveness in reducing root canal infection. Calcium hydroxide is slow in its action, and requires 1-3 weeks to be effective. This means that cases with infections should be treated in more than one appointment if the reduction of canal bacteria is the objective. Finally, only 2-3 outcome studies to support the specific use of calcium hydroxide are available, and they are equivocal.⁶³ However, as noted before, several outcome studies do agree that elimination of bacteria results in better treatment outcomes. Thus many practitioners today advocate multiple strategies for the elimination of root canal bacteria, in cases of infections, including the use of calcium hydroxide. If the canal is not to be filled at the same appointment, a medicament such as calcium hydroxide is generally recommended, to prevent bacterial growth between appointments in the empty canal.

Root Canal Filling

There have been a growing number of technologies used for in root canal filling in recent years. The newer technologies involve thermoplasticized gutta percha. In the following section a brief description of the available systems will be provided.

Traditionally, lateral condensation of gutta percha has been the technique taught in most dental schools. However, filling of root canals with vertical compaction of heat plasticized gutta percha was also popular, in a few dental schools, but required a more laborious instrumentation of root canals to ensure a highly tapered preparation. With the advent of rotary instrumentation and the use of instruments with high taper in a crown-down manner, the difficulties of preparing a highly tapered canal while maintaining the original canal shape were reduced. Thus the vertical compaction method became more popular, because it assured good seal when tested with microleakage studies. The use of the System B (Kerr-Sybron Endo), which allows an endodontic plugger to be electrically heated to preset values (usually 200 degrees C), further popularized this

technique particularly among endodontists. The System B provides a more controlled heat source that can easily be used to both plasticize the gutta percha when warm, and compact the gutta percha mass when cold. The method involves selecting a plugger that fits within 4-5 mm of the empty canal, then placing a master cone point to the working length. The System B plugger is driven through the cone to reach its pre-determined position, then maintained cold under pressure to condense the gutta percha in the apical third of the canal. The plugger is then heated again briefly to disengage it from the mass and withdrawn promptly.

Another heat source device that could provide the same functionality is the Touch 'n Heat (SybronEndo). This device comes with pluggers, as well as spreaders that can be used for warm lateral condensation. When using the System B or the Touch 'n Heat, the dentist can continue to back fill the canal with a device that injects plasticized gutta percha such as the Obtura III system (Kerr-SybronEndo) or the Calamus unit (Dentsply-Sirona). The Obtura System involves a high temperature (again about 200 degree C) thermoplasticized gutta percha (GP) that is injected from a gun into the root canal. All systems require sealer to be used; however, thermoplasticized GP may fit better into the canals space irregularities.

Other systems are available in which there is a core material with coating of gutta percha. An example of this is GuttaCore (Dentsply-Sirona). This system consists of GP on a harder core of cross-linked gutta percha, which is fabricated in different sizes. The instrumented canal is first measured using a metal sizing instruments to assess the size of the carrier to use. Next, the suitable carrier is placed in a small oven that is provided with the system, which warms the outer GP to a temperature that can be molded into the canal space. While these systems offer efficiency and ease of use, they do not provide adequate length control. Furthermore, retreatment of cases with the older plastic carriers present particular challenges, as the core material is frequently difficult to remove. GuttaCore was introduced to facilitate the retreatment process.

It is important to emphasize that the seal in any gutta percha filling is dependent on the adequate application of sealer. Many different types of sealers are available. They vary according to the material and the setting time. While the seal of most available sealers are comparable, it is recommended that the dentist not use sealers that contain paraformaldehyde as they have been shown to be quite irritating to periapical tissues. Eugenol-based materials also produce some inflammation on the cellular level; however, they are used by many dentists, as it is believed that without microbial irritants, the inflammation is subclinical in its magnitude. Calcium hydroxide-based sealers are very well tolerated. However, there is no value for calcium hydroxide within a sealer, since after setting the material cannot ionize and raise the pH, which is how calcium hydroxide is effective against microbial irritants. More recently, a number of tricalcium silicate-based sealers have been introduced. These sealer, like MTA, are very biocompatible, and can be used in a single cone technique with gutta percha. However, outcome studies on this approach have not been reported.

Regenerative Endodontics

Over the past decade, there has been a growing interest in the preservation of the vital pulp through pulp capping procedures, or regeneration of pulp following necrosis in teeth with immature apex. The reason for this interest is a combined interest in promoting the continued development of the root in immature teeth, as well as the surge of information on stem cell research that offer the possibility of regeneration of the pulp dentin complex.

The advent of tricalcium silicate based materials such as ProRoot MTA (Dentsply-Sirona), MTA Plus (Avalon Biomed), Bioaggregate (Verio Dental Co) and Biodentine (Septodont), provides a wealth of biocompatible, and antimicrobial materials that have good sealing abilities. Outcome studies have shown reasonable success of pulp capping of carious exposures, in asymptomatic teeth with vital pulp, with MTA.^{64,65}

Immature teeth with pulp necrosis and apical lesions present a special problem because of the inability to perform traditional endodontic treatment, the weak structure of the tooth and the lack of alternative treatments for the young child. Seminal case reports have introduced the technique of pulp revascularization, following

disinfection with antibiotic mixtures and induction of a blood clot that is covered with MTA.^{66,67} Numerous case reports, case series or cohort studies have shown that in these cases control of infection, and increase in root length and dentin thickness are possible. Animal studies have revealed that most of the mineralized tissue

following revascularization is cementum or bone, and that the single most important factor in revitalization is bacterial control.⁶⁸ Moreover, MTA placed in the chamber and some antibiotics, such as minocycline, can cause significant discoloration. Therefore, continued refinement of the protocol and treatment outcome studies are currently underway.

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POST-TEST

Internet Users: This page is intended to assist you in fast and accurate testing when completing the “Online Exam.” We suggest reviewing the questions and then circling your answers on this page prior to completing the online exam.

(2.0 CE Credit Contact Hour) Please circle the correct answer. 70% equals passing grade.

1. The survival of endodontically-treated teeth in the mouth, 4-8 years after treatment is:

- a. 94-97%
- b. 84-87%
- c. 75-85%
- d. 65-75%

2. The use of the following approach has been shown to improve long-term healing in endodontics:

- a. Using NiTi compared to stainless steel instruments for complete canal preparation.
- b. Using reciprocating compared to rotary NiTi instruments.
- c. Using 02 taper versus 04 taper NiTi instruments in apical preparation.
- d. Using precurving instruments of any type, compared to straight instruments.

3. GentleWave by Sonendo is:

- a. Psychological management of endodontic patients.
- b. The use of potent analgesics for endodontic treatment.
- c. An ultrasonic activation of hypochlorite to disinfect the lightly instrumented canal.
- d. An effective management protocol for children.

4. The following statement is true about the use of Electronic Apex Locators:

- a. They complement radiographs as means of determining the working length and identifying the root canal anatomy.
- b. They are inaccurate and of little use in modern endodontics.
- c. They provide accurate data to the extent that working radiographs are no longer necessary.
- d. Either radiographs or apex locators should be used, the use of both is redundant.

5. Electronic apex locators are inaccurate in the following situation:

- a. endodontic retreatment
- b. when apex is immature or highly resorbed
- c. there is purulence in the canal
- d. dilacerated canals

6. Reciprocating filing systems:

- a. provide effective cleaning of the root canal system.
- b. provide more efficient shaping of the canal with a single instrument.
- c. are the preferred instruments for retreatment.
- d. are associated with improved clinical outcomes.

7. The following is the most important limitation of NiTi rotary instrumentation:

- a. file separation
- b. ledging
- c. apical transportation
- d. perforation

8. Recently, a number of rotary instrumentation systems have been introduced that involve the use of twisted wire. The advantage of these systems compared with traditional systems is:

- a. improved cutting of dentin.
- b. reduced cyclic fatigues (in bench studies).
- c. reduced fracture in patient studies.
- d. reduced extrusion of debris into the periapical region.

9. The best available evidence today has shown that:

- a. the use of calcium hydroxide results in better long-term outcomes.
- b. single visit cases have better long-term outcomes compared to multi-visit cases.
- c. elimination of cultivable bacteria at the time of obturation results in better outcomes.
- d. persistence of bacteria at the time of obturation has no effect on the long-term outcomes.

10. Endodontic regenerative procedures:

- a. Have been proven to be effective in randomized trials.
- b. Aim to achieve better disinfection of infected canals with antibiotics.
- c. Are preferred in teeth with mature apex.
- d. Are indicated in cases with internal resorption.

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Evaluation - A Guide to Contemporary Endodontic Technology 4th Edition

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