Quality Resource Guide

A Guide to Contemporary Endodontic Technology

Author Acknowledgements

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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 evidence is currently still evolving.

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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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Introduction

There is a growing population of patients who seek to save their natural teeth from extraction and are requesting endodontic procedures. 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 general dentists and endodontists to accomplish the basic objectives of endodontic therapy in less time and with more precision. This guide will outline several recent procedural and technological advances, explaining the 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), contemporary vital pulp therapy, local anesthesia, rotary instrumentation, root canal disinfection, endodontic obturation and guided endodontic technologies. This guide is not intended to recommend a particular product or technology, rather it describes the rationale for making a change in the dentist's practice, and the parameters 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 paradigm is becoming even more important due to many reasons. There is now an increased interest in, and improved outcomes of, vital pulp therapy using tricalcium silicates and so the definition of reversible versus irreversible pulpitis is being questioned. Many dental patients are older and present in the dental office with significant medical conditions that can influence the presentation of disease, and the choice of the most appropriate treatment for them. Patients 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 can 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 planning, 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 care 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.

Preoperative diagnosis significantly influences the prognosis of treatment. Studies of endodontic treatment outcomes have shown that the prognosis of non-surgical root canal treatment (NS-RCT) for teeth 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] In addition, it has now been established that enhanced aseptic technique during the treatment[4], increased apical size preparation[5], adequate root canal instrumentation and obturation, and the prompt restoration of the tooth[6] are all critical factors that lead to increased success of treatment and healing of apical periodontitis (AP). The survival of endodontically-treated teeth in the mouth for 4-8 years after treatment, regardless of radiographic findings, is very high, measuring about 94-97%.[7,8]

When discussing the merits of endodontic treatment with the patient, the question of the prognosis of endodontic treatment versus implant therapy frequently arises. Systematic reviews have shown that there are no differences in outcomes between the restored endodontically-treated tooth and a dental implant.[9,10] 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.[11-13] One study showed that survival of endodontically treated teeth and dental implants were similar in the first three years, but the implants had higher survival in longer periods.[14] However, another outcomes study showed that when accounting for drop-out cases, implants also have a much lower survival rate in the long-term.[15] In addition, when evaluating patients who had both endodontic treatment and implant treatment, both treatments had a 95% survival rate with a mean 7.5-year follow-up.[16] Finally, despite the publication of some case reports to the contrary, cohort studies have not documented a negative effect of periapical lesions on neighboring implants. It is important to keep these facts in mind when presenting both treatment modalities to the patient.

Endodontic Diagnosis

Pulp and periapical diagnoses are critical prior to endodontic treatment for the following reasons:

- Determining whether the presenting problem (pain or apical radiolucency) is of endodontic or non-endodontic origin.
- Determining which tooth or teeth are involved.
- Determining whether the disease is localized to superficial pulp tissue or is extending to the periapical tissues (which determines the treatment plan).
- Determining whether periapical disease is localized or is associated with spreading infection.
- Determining the prognosis as noted before.

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, 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 symptoms. Heat testing is used in cases that present with sensitivity to heat. Hot gutta percha or isolation and contact with hot water are typically used. Studies have shown that cold testing with Endo Ice is more reliable in most patients, particularly in children, and in teeth with crowns, particularly when using a large applicator surface area.[17] However, in patients older than 50, cold testing has a higher degree of false negative responses than EPT, and so the latter may be more reliable.[18] A recent study showed that testing with Endo Ice had success of 92% and in teeth with crowns, the success was 87%.[19]

Vital Pulp Therapy

In the last decade or so, there has been a resurgence of interest among general dentists and endodontists in vital pulp therapy (VPT). This was precipitated by the success of direct pulp capping and pulpotomy procedures with tricalcium silicates (TCSs).[26-28] The American Association of Endodontists (AAE) released a position statement in 2021 that addressed the management of cases with very deep caries, typically referred to endodontists for RCT.[29] The AAE acknowledged the success of VPT using TCSs in these cases. However, the recommendation for dentists was to make sure that patients are offered all options for treatment. The AAE stressed that when performing VPT, dentists must ensure adequate preoperative pulpal and apical diagnosis since these procedures are indicated for cases with pulpitis, but not for any tooth with apical periodontitis, symptomatic or asymptomatic. Dentists must remove caries completely, inspect the vital pulp, and observe bleeding that can be stopped by a cotton pellet soaked in 2-4% sodium hypochlorite, before the application of TCS (*e.g.*, ProRoot MTA (Dentsply-Sirona), Biodentine (Septodont, inc.), Endosequence root repair material (Bioceramic putty) (Brasseler), NeoMTA 2 (Avalon Biomed) etc.). The original ProRoot MTA does stain teeth in the long-term, and so the other options listed are more appropriate, especially in anterior teeth. The data shows that VPT, especially pulpotomy with TCSs can effectively control postoperative pain, and lead to equivalent outcomes to the RCT.[28,30]

Digital Imaging & Magnification

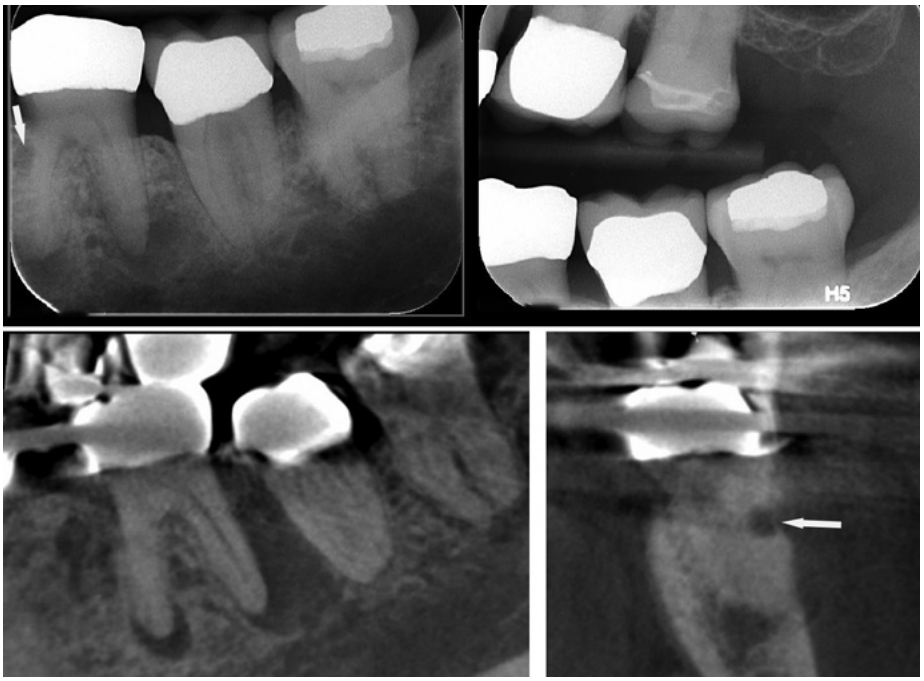
Over the last decade, several digital radiography and photography systems have become available for the dental practitioner. In endodontics, typical intraoral cameras are not usually able to record intracoronal or intracanal detail with sufficient resolution. Therefore, still or video digital cameras 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.

Cone Beam Computed Tomography (CBCT)

CBCT has become an important adjunctive imaging modality in endodontic diagnosis, treatment planning and treatment (**Figure 1**). It is especially useful for cases that have complex root or root canal anatomy, suspected root resorption, traumatic root fractures or lateral luxations, perforations or calcified canals that cannot be located. CBCTs are becoming essential in cases with persistent disease following RCT in order to determine if vertical root fractures are a high possibility, to decide on retreatment versus root end surgery and to plan root end surgery.

Studies have shown that CBCT has a higher accuracy than periapical radiographs in detecting periapical lesions.[31] 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 has been shown that specialists are about 40-50% more likely

Figure 1



Patient presented with signs and symptoms of symptomatic irreversible pulpitis in the mandibular left quadrant. Clinical examination and periapical, bitewing radiography confirmed the diagnosis to arise from tooth #18, although #19 had pulp necrosis and asymptomatic apical periodontitis. CBCT imaging confirmed the carious lesion on #18 revealing the source of the chief complaint, and an invasive root resorption on #19 (white arrows) that caused pulp necrosis but was asymptomatic.

to change their endodontic treatment plan, when they review a CBCT volume of a previously treated tooth that may need additional care.[32,33] 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.

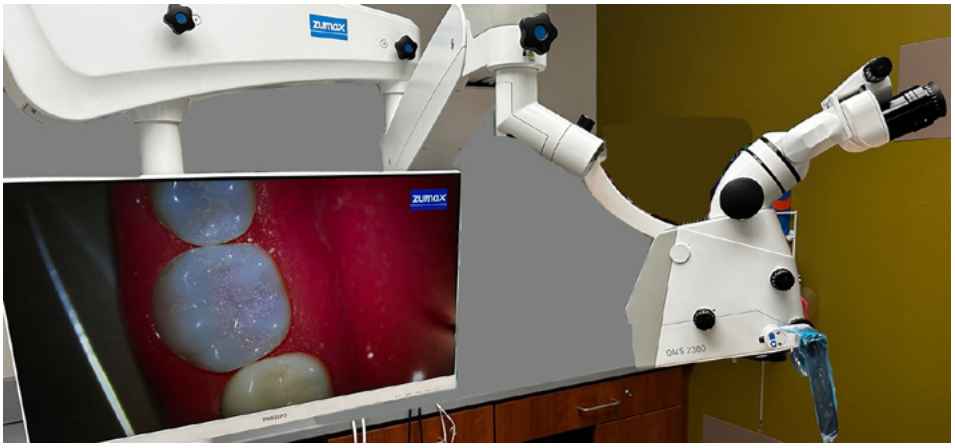
CBCT imaging should still be used only when other diagnostic methods and traditional radiography are not sufficient in providing the required information, and not as a routine method for all cases.[34,35]

Microscopes 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 mesio-buccal 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.[36] A recent paper also suggests that this has resulted in better treatment outcomes.[37]

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**).

Figure 2



Live feed from a microscope with built-in monitor (with ability to record still or video imaging) (Zumax, Medical Co. Ltd.)

In addition to microscopes,, there are also a few high resolution videoscopes like the MoraVision system (moravision.com). These videoscopes use high resolution cameras and monitors to allow the provider and assistant to visualize the area of operation without the need for a microscope. Recent studies suggest that they are comparable to a microscope in utility, but that the microscope is still the preferred magnification tool in endodontics.[38]

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 15 – 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) Minimal 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, and disruption of microbial biofilms on the canal walls, in preparation for further rotary instrumentation and/or obturation.

Rotary Instrumentation:

TIn the past three decades, several 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. Difficult is assessed by the degree of canal calcification, and the degree and location of canal curvature. Canal curvatures of more than 25-30 degrees are considered severe (**Figures 3A and 3B**). 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.[40]

2) Straight-line access

To improve access to the coronal third of the root canal and reduce the overall curvature of the canal in a predictable, 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 40/04 or a 35/04. Lack of straight-line access also subjects the instrument to high stresses (**Figures 4A and 4B**).

3) Negotiating narrow curved canals

As noted, 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 small hand file sizes 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 such as PathFilesTM (Dentsply achieve the pre-flaring of calcified canals more efficiently.

4) Crown down preparation

The optimal preparation of canals with rotary instruments involves incremental preparation starting from the coronal third, and extending apically. This is best achieved by starting with larger 40/04 or 35/04 instruments and extending the preparation more apically with smaller size/04 instruments until an instrument (perhaps 25/04 or 20/04) reaches the working length. Following this "crown down" incremental approach apical preparation is done. 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. The canal must be filled with irrigant the whole time.

5) Apical preparation

Cleaning of the root canals requires some degree of apical preparation to allow the antimicrobial irrigant to reach the apical third. This larger apical size allows an irrigation needle of sufficient gauge (see later) to passively penetrate deep into the canal allowing adequate disinfection. A recent systematic review showed the importance of apical preparation to more than size 30.[5]

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.

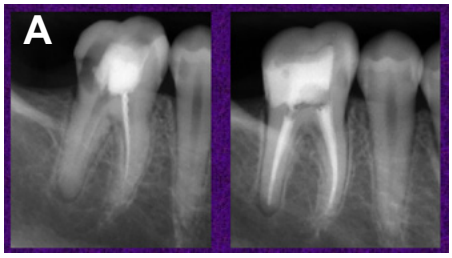
7) Use minimal force

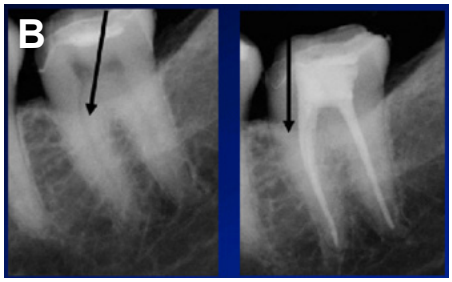
The effectiveness of rotary or reciprocating instruments is determined by the ability of these instruments to be activated in the canal with relatively low resistance. If the dentist applies too much force on the instrument, the instrument is likely to encounter too high torsional forces, which lead 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 enough 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, one of the main purposes of the crown-down instrumentation technique is to allow the preparation of the canal incrementally to reduce the canal

Figure 3

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.

Figure 4





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.

surface area in contact with the instrument at any one time. Instruments with larger sizes are initially advanced for shorter distances within the canal. They are followed by instruments with successively less sizes, which penetrate deeper but again engage a small surface area of the canal, until the entire length of the canal is prepared.

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 calcified canal. Exceptions to this general rule are where the instrument is used with minimal resistance. In these cases, the use of the instruments up to 3 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 re-cycled.

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. Many contemporary motors are hand-held and may incorporate an apex locator for ease of use. The torque parameters in some newer motors correlate with the degree of resistance encountered such as in the EndoPilot (Komet, Germany).

Advantages of root canal preparation with NiTi instruments

- Maintain canal shape: Studies have shown that NiTi rotary instrumentation can enlarge root canals while maintaining the original curvature.
- Reduce the extrusion of debris apically.
- Reduce dentist fatigue with rotary instrumentation, particularly in small canals.
- May improve long-term outcomes.

Disadvantages & 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.[48,49]
- Double curves (dilaceration of the root - **Figure 3B**): 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 periapical radiograph.
- 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 3A**): As stated previously, the instrument in these cases is subjected to sharp 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.
- Keep the instrument in constant motion, with adequate lubrication in the canal. If the instrument is not advancing to a pre-set depth, larger and/or smaller instruments can be used to reduce coronal or apical resistance, respectively, before re-introducing the instrument.
- 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.

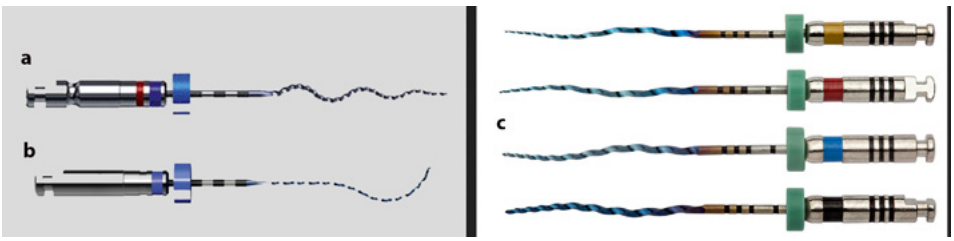
Common Newer Rotary Instrument Systems

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

  The ProTaper Universal instruments have been a popular system for many years. They involve 6-8 instruments that have variable tapers 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.
- 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.

Figure 5



a) XP-endo Shaper, b) XP-endo Finisher (Brasseler) and c) TRU Shape file (Dentsply-Sirona)

- TRUShape 3D (Dentsply-Sirona) and XP-Endo Shaper and XP-Endo-Finisher (Brasseler) files
  These newer files are characterized by having an unusual curve in the design (**Figure 5**). There are designed so that when they rotate in a canal that has an oval or irregular 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 several recent studies showed that when hypochlorite was used, there was no difference in disinfection compared with traditional files.

- 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. They are generally comparable in utility and properties to other file systems.

Because of the variety of systems available, the dentist is frequently uncertain as to which system he/she should use. 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 anterior cases with straight large canals, rotary instrumentation will probably not offer them significant advantages. For dentists who perform more challenging 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 refereed journals.

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. Whether the instrument is designed to be used only once should be factored into the cost calculation. It is important to note that most studies on files are preclinical in nature, and the true performance of most of these systems clinically is currently unknown.

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. 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 in the US: WaveOne (Dentsply-Sirona, USA) (**Figure 5**) and EndoSequence (Brasseler) (**Figure 6**). 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 counterclockwise. This results in a net advancement of the turn in a clockwise direction. However, the counterclockwise component assures that the instrument does not bind, thus reducing torsional forces etc.

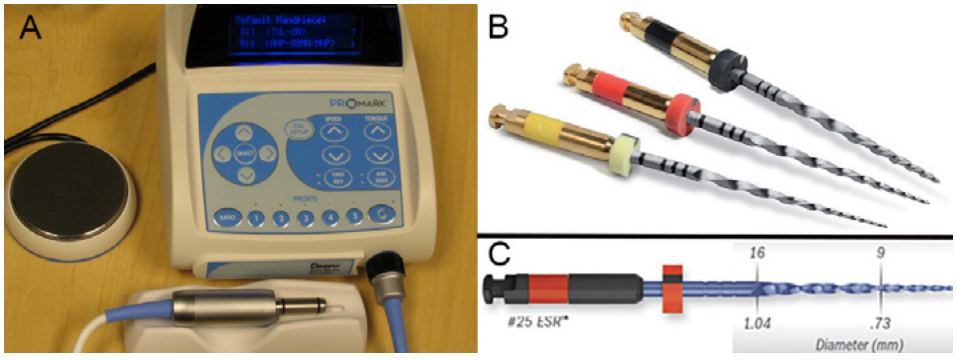
Preliminary bench top experiments show these instruments to meet the criteria from a metallurgical and functional perspective. However, treatment outcome studies are not available for them yet. Moreover, a significant limitation of this concept is the lack of apical preparation of the root canal, as discussed previously, and the significant coronal flaring due to the high taper. Therefore, their use is generally decreasing currently.

Root Canal Disinfection

As noted, there are two distinct diagnostic categories of endodontic pathosis that affect the prognosis: cases with vital (albeit irreversibly 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 better disinfection at the time of root filling results in better treatment outcomes.[4,52,53] 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 the entirety of root canal intricacies. Thus, studies have shown that following hypochlorite needle irrigation, about 40-60% of root canals remain with viable bacteria. The use of 17% ethylenediamenetetracetic 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.

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

Figure 6



A) ProMark Motor (Dentsply-Sirona). B) 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. C) ESR Endosequence Reciprocating (Brasseler).

possible in the canal without binding in the canal. 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, or the NaviTip 31 (**Figures 7A and B**) should be used to irrigate most canals to achieve good needle penetration in most canals following the apical preparation regimen recommended before.

Several technologies are currently available to enhance irrigation, by allowing the irrigant to permeate the complex root canal anatomy (**Figure 7**). These may involve applying sonic or ultrasonic activation to a file loosely fitting in a canal filled with the irrigant (passive ultrasonic/sonic irrigation) or directly to the irrigation needle as it is delivering the irrigant. There is some clinical evidence that ultrasonic irrigation enhances bacterial elimination in teeth with complex anatomy,[57] however, randomized controlled trials failed to show a significant improvement with sonic or ultrasonic irrigation in teeth with single canals.[58,59]

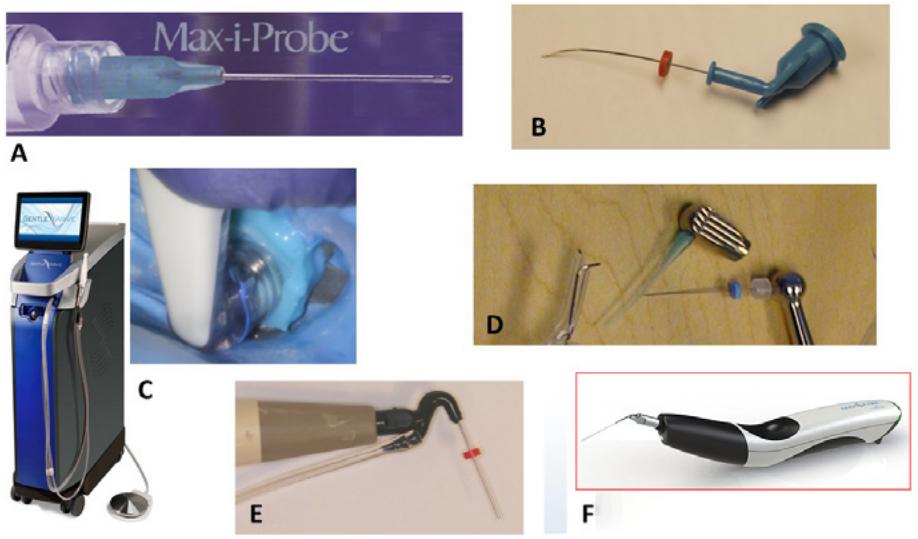
Another technology that has been popular among many clinicians is the use of negative apical pressure (EndoVac, Kerr Endodontics). This device involves delivering the irrigant into the pulp chamber that is then aspirated by a needle deep into the canal. Two sizes of aspirating (evacuating) needles are 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 7**). Clinical trials have shown that this approach significantly reduces postoperative pain within 24 hours of the procedure.[60]

A newer technology for cleaning root canals has been introduced called GentleWave (Sonendo, Laguna Hills, CA) (**Figure 7C**). For this technology a tight seal is created using a light-cured resin material and a sealing cap on the occlusal surface of the teeth. 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, and then be suctioned using negative pressure through the applicator. Preliminary studies show improved debridement of this system compared to traditional methods.[62] Case series of clinical cases, in which this system was used, reported good outcomes[63,64] and comparable post-operative pain to ultrasonic irrigation.[65] Users of the GentleWave system advocate minimal canal instrumentation, as the system does not require large preparations to be used. Nevertheless, clinical outcomes compared to controls have not been reported.

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 excessive levels that may cause charring, ledging or irritation of the periodontal ligament. Antimicrobial efficacy of lasers in eliminating clinical root canal infection has shown mixed findings.[66,67]

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. Randomized trials do not show that the use of calcium hydroxide medication in multiple appointment enhances treatment outcomes one year post-operatively.[68] However, as noted previously, several 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.

Figure 7



Commonly used and newer root canal irrigation or disinfection technologies: Irrigation needles (A) Max-i-probe (Dentsply-Sirona) and (B) NaviTip 31-gauge (Ultradent), (C) GentleWave (Sonendo) device and handpiece applied on platform, (D) EndoVac (Kerr Endodontics) delivery tip, macro and micro evacuation cannulas; (E) ProUltra Piezo Flow ultrasonic irrigation needle (Dentsply-Sirona) and (F) EndoUltra (Passive ultrasonic instrumentation) (Vista Dental Products).

Root Canal Filling

There have been a growing number of technologies used 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 has also been popular, in a few dental schools, but required a more extensive 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 in microleakage studies. The use of the System B (Kerr Endodontics), which allows an endodontic plugger to be electrically heated to preset values (usually 200 degrees C), further popularized this technique particularly among endodontists. 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 (Kerr Endodontics). This device comes with pluggers, as well as spreaders that can be used for warm lateral condensation. When using System B or Touch 'n Heat, the dentist can continue to back fill the canal with a device that injects plasticized gutta percha such as the Elements or Obtura III systems (Kerr-Endodontics) 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, even the thermoplasticized gutta percha. 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 or metallic carriers has been particularly challenging, 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 is 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 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. Resin sealers such as AH-Plus remain the most popular root canal sealer currently, and the one to which newer sealers is frequently compared in studies. More recently, several tricalcium silicate-based sealers have been introduced. These sealers, like MTA, are very biocompatible, and can be used in a single cone technique with gutta percha. In addition, they expand slightly upon setting, presumably enhancing the seal. One clinical observational outcome study showed reasonable success in cases that had minimal canal preparation and were obturated with a single cone and Bioceramic (BC) Sealer (Brasseler).[69]

Regenerative Endodontic Therapy

There has also been a growing interest in the 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 offers the possibility of regeneration of the pulp dentin complex.

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.[73, 74] Numerous case reports, case series, cohort studies, randomized trials and systematic reviews 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.[75] As noted, MTA placed in the chamber and some antibiotics, such as minocycline, can cause significant discoloration. Therefore, newer tricalcium silicates, non-minocycline antibiotics (such as metronidazole and ciprofloxacin together with clindamycin, doxycycline or a cephalosporin) or regular calcium hydroxide medicament can be used to control the infection. Observational studies have shown that antibiotic formulations are better than calcium hydroxide.[76,77]

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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 accuracy of cold testing in teeth without and with crowns was:**
   a. 92 – 87%
   b. 87 – 84%
   c. 77 – 74%
   d. 62 – 60%

2. **PathFiles are:**
   a. Stainless steel hand instruments used to negotiate calcified canals to the working length.
   b. NiTi hand instruments used to negotiate calcified canals to the working length.
   c. NiTi rotary instruments with 0.02 taper, used to negotiate calcified canals to the working length.
   d. NiTi reciprocating instruments used to negotiate calcified canals to the working length.

3. **GentleWave by Sonendo is:**
   a. Psychological management of endodontic patients.
   b. The use of potent analgesics for endodontic treatment
   c. A device to multisonically activate a mist of hypochlorite to disinfect the lightly instrumented canal
   d. An effective management protocol for children

4. **The following is an appropriate material for pulp capping or partial pulpotomy in an anterior tooth:**
   a. Biodentine
   b. MTA
   c. Dycal
   d. Theracal

5. **Which of the following is the most accurate modality in detecting apical periodontitis:**
   a. Periapical radiograph
   b. Panoramic radiograph
   c. CBCT
   d. MRI

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, several rotary instrumentation systems have been introduced that involve the use of heat treatment. The advantage of these systems compared with traditional systems is:**
   a. improved cutting of dentin.
   b. reduced cyclic fatigue.
   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. better root canal disinfection 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 produce dental pulp tissue
    b. Aim to achieve better disinfection of infected canals with topical antibiotics or calcium hydroxide
    c. Are preferred in vital cases to vital pulp therapy
    d. Are indicated in cases with internal resorption.

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2. How would you rate the quality of the content?	☐	☐	☐	☐	☐	
3. Please rate the effectiveness of the author.	☐	☐	☐	☐	☐	
4. Please rate the written materials and visual aids used.	☐	☐	☐	☐	☐	
5. The use of evidence-based dentistry on the topic when applicable.	☐	☐	☐	☐	☐	☐ N/A
6. How relevant was the course material to your practice?	☐	☐	☐	☐	☐	
7. The extent to which the course enhanced your current knowledge or skill?	☐	☐	☐	☐	☐	
8. The level to which your personal objectives were satisfied.	☐	☐	☐	☐	☐	
9. Please rate the administrative arrangements for this course.	☐	☐	☐	☐	☐	

10. How likely are you to recommend MetLife's CE program to a friend or colleague? *(please circle one number below:)*

10 **9** **8** **7** **6** **5** **4** **3** **2** **1** **0**

extremely likely — neutral — not likely at all

What is the primary reason for your 0-10 recommendation rating above?

11. Please identify future topics that you would like to see:

Thank you for your time and feedback.

MetLife

To complete the program traditionally, please mail your post test and registration/evaluation form to:
MetLife Dental Quality Initiatives Program | 501 US Highway 22 | Bridgewater, NJ 08807