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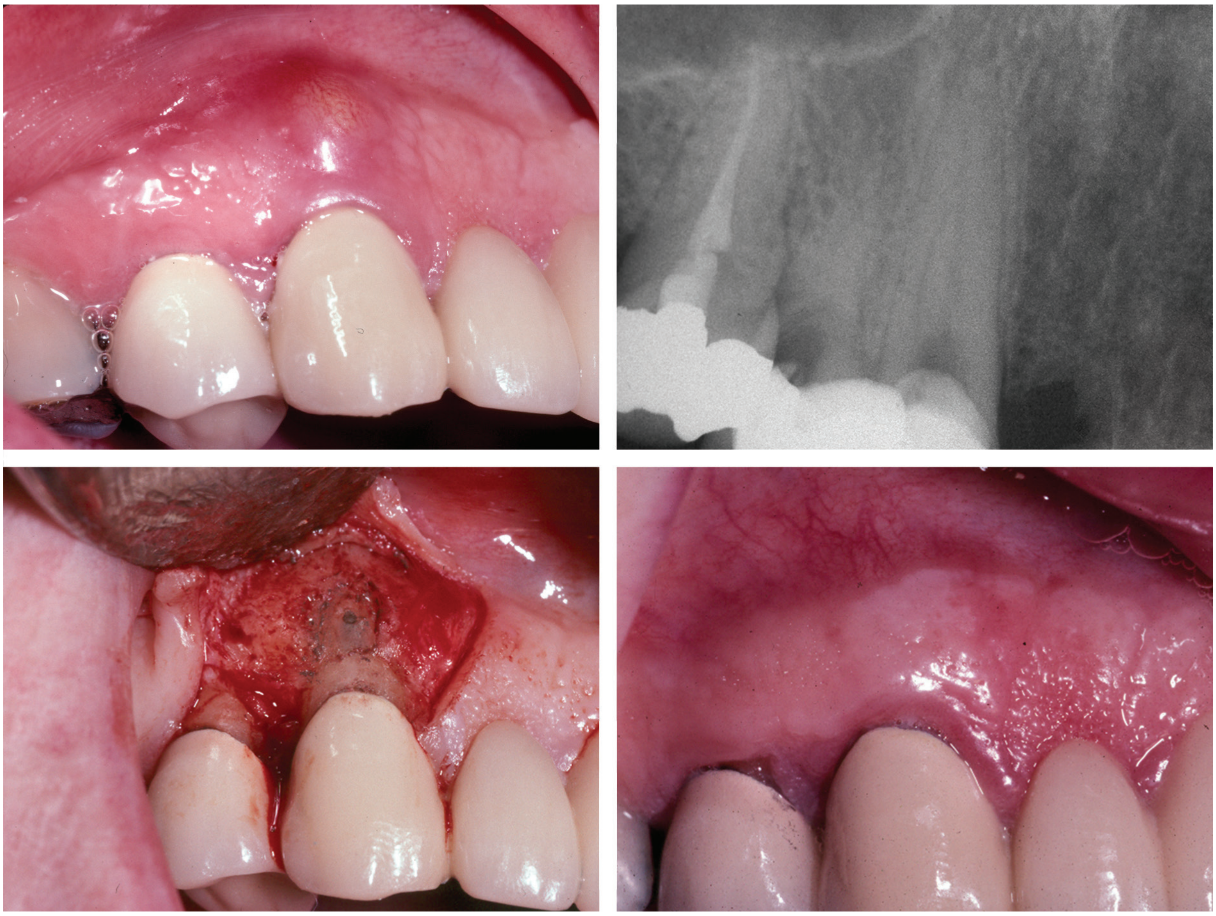

Official Journal of the Endodontic Society of the Philippines

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ABOUT THE ENDODONTIC SOCIETY OF THE PHILIPPINES (ESP) JOURNAL:

THE ESP JOURNAL GUIDELINES FOR AUTHORS:

The ESP Journal calls for interested Endodontic specialists or specialists from other branches of dentistry, general dentists, academicians, researchers, and dental students, who would like to submit papers that would be relevant in the practice, research, and development of Endodontics in the global setting.

The ESP Journal is a refereed journal. All submissions undergo initial review by one member of the editorial board and if approved, will be advanced to the rest of the editorial board for further peer-review.

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- Text should be one font, font size, and font color.
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The title should have no abbreviations. It is important that the title is attention-catching and is reflective of the content and topic.

II. Authors Information:

The entry for author information should be: full name, title, and institutional affiliations (Position, Name of Institution, Department/College, City, Country).

III. Abstract:

The abstract is a concise description of the problem, hypothesis, methods, results, and conclusion. It should be no more than 250 words and is in bold format. 23 keywords may follow the abstract.

IV. Introduction:

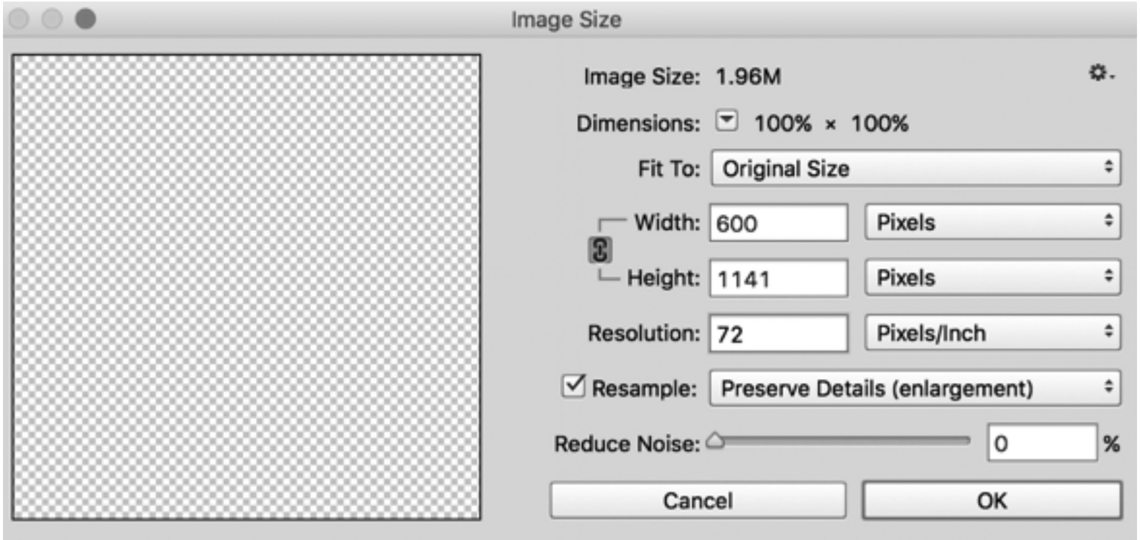
This section should entice readers by describing the need for bridging the gap of a particular knowledge. A few relevant review of literature and historical background of the problem covers this section.

V. Materials and Methods:

Materials and methods should all be described in paragraph form. No bullets are accepted.

VI. Results:

Relevant Figures and Tables that would clearly reflect on possible conclusions are in this section. Each figures and table should have brief descriptions. Figure/Image formats if using Photoshop should be:



VII. Discussion:

This section discusses the current study's result with previous studies and how it can affect the purpose of the study. More importantly, conclusions are drawn in this section.

VIII. Acknowledgments

IX. References:

Reference style follows the following format:

- For published journal articles:
  Author/s (Surname, First and middle Initials). Title. Journal/Publication Year; Volume No: page/s.
  Example: Gutmann JL, Primus CM, Regan JD, Hill G, Woodmansey KF, Tay FR. Biocompatibility of a mineral trioxide aggregate-based root canal sealer - ProRoot® ES (Endo Sealer). Int J Endod Rehabil 2015;1:3-11.
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B. Original Case Reports:

I. Title (same as in Section A)
II. Introduction
III. Case history
IV. Materials and Methods
V. Discussion
VI. Conclusion
VII. Acknowledgments
VIII. References

IV. Submission Procedure

Submissions are to be emailed to espjournal@yahoo.com. Acceptance of article will be notified to the main author through email. Unless the author has complied and has satisfied all members of *The ESP Journal* editorial board before the cut-off date for the upcoming issue, the article will be considered "pending" and will not be published on the said upcoming issue.

ENDODONTICS
Colleagues for Excellence

Endodontic Diagnosis

Dr. Gerald N. Glickman
Dr. Jordan L. Schweitzer

Historically, there have been a variety of diagnostic classification systems advocated for determining endodontic disease (1). Unfortunately, the majority of them have been based upon histopathological findings rather than clinical findings, often leading to confusion, misleading terminology, and incorrect diagnoses (2). A key purpose of establishing a proper pulpal and periapical diagnosis is to determine what clinical treatment is needed (3, 4). For example, if an incorrect assessment is made, then improper management may result. This could include performing endodontic treatment when it is not needed or providing no treatment or some other therapy when root canal treatment is truly indicated. Another important purpose of establishing a universal classification system is to allow for communication between educators, clinicians, students and researchers. A simple and practical system which uses terms related to clinical findings is essential and will help clinicians understand the progressive nature of pulpal and periapical disease, directing them to the most appropriate treatment approach for each condition.

In 2008, the American Association of Endodontists held a consensus conference to standardize diagnostic terms used in endodontics (1). The goals were to propose universal recommendations regarding endodontic diagnoses; develop a standardized definition of key diagnostic terms that will be generally accepted by endodontists, educators, test construction experts, third parties, generalists and other specialists, and students; resolve concerns about testing and interpretation of results; and determine the radiographic criteria, objective test results, and clinical criteria needed to validate the diagnostic terms established at the conference. Both the AAE and the American Board of Endodontics have accepted these terms and recommend their usage across all dental disciplines and health care professions (5, 6, 7). Each of the following diagnostic terms will be defined with typical respective clinical and radiographic characteristics along with representative case examples when appropriate. However, clinicians must recognize that diseases of the pulp and periapical tissues are dynamic and progressive and as such, signs and symptoms will vary depending on the stage of the disease and the patient status. Coupled with this are the limitations associated with current pulp testing modalities as well as clinical and radiographic examination techniques. In order to render proper treatment, a complete endodontic diagnosis must include both a pulpal and a periapical diagnosis for each tooth evaluated.

Examination and Diagnostic Procedures

Endodontic diagnosis is similar to a jigsaw puzzle—diagnosis cannot be made from a single isolated piece of information (4). The clinician must systematically gather all of the necessary information to make a “probable” diagnosis. When taking the medical and dental history, the clinician should already be formulating in his or her mind a preliminary but logical diagnosis, especially if there is a chief complaint. The clinical and radiographic examinations in combination with a thorough periodontal evaluation and clinical testing (pulp and periapical tests) are then used to confirm the preliminary diagnosis (4). In some cases, the clinical and radiographic examinations are inconclusive or give conflicting results and as a result, definitive pulp and periapical diagnoses cannot be made. It is also important to recognize that treatment should not be rendered without a diagnosis and in these situations, the patient may have to wait and be reassessed at a later date or be referred to an endodontist.

Diagnostic Terminology Approved by the American Association of Endodontists and the American Board of Endodontics (5-7)

Pulpal Diagnoses (9-14)

Normal Pulp is a clinical diagnostic category in which the pulp is symptom-free and normally responsive to pulp testing. Although the pulp may not be histologically normal, a “clinically” normal pulp results in a mild or transient response to thermal cold testing, lasting no more than one to two seconds after the stimulus is removed. One cannot arrive at a probable diagnosis without comparing the tooth in question with adjacent and contralateral teeth. It is best to test the adjacent teeth and contralateral teeth

Examination procedures required to make an endodontic diagnosis (8)	
Medical/dental history	Past/recent treatment, drugs
Chief complaint (if any)	How long, symptoms, duration of pain, location, onset, stimuli, relief, referred, medications
Clinical exam	Facial symmetry, sinus tract, soft tissue, periodontal status (probing, mobility), caries, restorations (defective, newly placed?)
Clinical testing: pulp tests	Cold, electric pulp test, heat
periapical tests	Percussion, palpation, Tooth Slooth (biting)
Radiographic analysis	New periapicals (at least 2), bitewing, cone beam-computed tomography
Additional tests	Transillumination, selective anesthesia, test cavity

first so that the patient is familiar with the experience of a normal response to cold.

Reversible Pulpitis is based upon subjective and objective findings indicating that the inflammation should resolve and the pulp return to normal following appropriate management of the etiology. Discomfort is experienced when a stimulus such as cold or sweet is applied and goes away within a couple of seconds following the removal of the stimulus. Typical etiologies may include exposed dentin (dentinal sensitivity), caries or deep restorations. There are no significant radiographic changes in the periapical region of the suspect tooth and the pain experienced is not spontaneous. Following the management of the etiology (e.g. caries removal plus restoration; covering the exposed dentin), the tooth requires further evaluation to determine whether the "reversible pulpitis" has returned to a normal status. Although dentinal sensitivity per se is not an inflammatory process, all of the symptoms of this entity mimic those of a reversible pulpitis.

Symptomatic Irreversible Pulpitis is based on subjective and objective findings that the vital inflamed pulp is incapable of healing and that root canal treatment is indicated. Characteristics may include sharp pain upon thermal stimulus, lingering pain (often 30 seconds or longer after stimulus removal), spontaneity (unprovoked pain) and referred pain. Sometimes the pain may be accentuated by postural changes such as lying down or bending over and over-the-counter analgesics are typically ineffective. Common etiologies may include deep caries, extensive restorations, or fractures exposing the pulpal tissues. Teeth with symptomatic irreversible pulpitis may be difficult to diagnose because the inflammation has not yet reached the periapical tissues, thus resulting in no pain or discomfort to percussion. In such cases, dental history and thermal testing are the primary tools for assessing pulpal status.

Asymptomatic Irreversible Pulpitis is a clinical diagnosis based on subjective and objective findings indicating that the vital inflamed pulp is incapable of healing and that root canal treatment is indicated. These cases have no clinical symptoms and usually respond normally to thermal testing but may have had trauma or deep caries that would likely result in exposure following removal.

Pulp Necrosis is a clinical diagnostic category indicating death of the dental pulp, necessitating root canal treatment. The pulp is non-responsive to pulp testing and is asymptomatic. Pulp necrosis by itself does not cause apical periodontitis (pain to percussion or radiographic evidence of osseous breakdown) unless the canal is infected. Some teeth may be non-responsive to pulp testing because of calcification, recent history of trauma, or simply the tooth is just not responding. As stated previously, this is why all testing must be of a comparative nature (e.g. patient may not respond to thermal testing on any teeth).

Previously Treated is a clinical diagnostic category indicating that the tooth has been endodontically treated and the canals are obturated with various filling materials other than intracanal medicaments. The tooth typically does not respond to thermal or electric pulp testing.

Previously Initiated Therapy is a clinical diagnostic category indicating that the tooth has been previously treated by partial endodontic therapy such as pulpotomy or pulpectomy. Depending on the level of therapy, the tooth may or may not respond to pulp testing modalities.

Apical Diagnoses (9-14)

Normal Apical Tissues are not sensitive to percussion or palpation testing and radiographically, the lamina dura surrounding the root is intact and the periodontal ligament space is uniform. As with pulp testing, comparative testing for percussion and palpation should always begin with normal teeth as a baseline for the patient.

Symptomatic Apical Periodontitis represents inflammation, usually of the apical periodontium, producing clinical symptoms involving a painful response to biting and/or percussion or palpation. This may or may not be accompanied by radiographic changes (i.e. depending upon the stage of the disease, there may be normal width of the periodontal ligament or there may be a periapical radiolucency). Severe pain to percussion and/or palpation is highly indicative of a degenerating pulp and root canal treatment is needed.

Asymptomatic Apical Periodontitis is inflammation and destruction of the apical periodontium that is of pulpal origin. It appears as an apical radiolucency and does not present clinical symptoms (no pain on percussion or palpation).

Chronic Apical Abscess is an inflammatory reaction to pulpal infection and necrosis characterized by gradual onset, little or no discomfort and an intermittent discharge of pus through an associated sinus tract. Radiographically, there are typically signs of osseous destruction such as a radiolucency. To identify the source of a draining sinus tract when present, a gutta-percha cone is carefully placed through the stoma or opening until it stops and a radiograph is taken.

Acute Apical Abscess is an inflammatory reaction to pulpal infection and necrosis characterized by rapid onset, spontaneous pain, extreme tenderness of the tooth to pressure, pus formation and swelling of associated tissues. There may be no radiographic signs of destruction and the patient often experiences malaise, fever and lymphadenopathy.

Condensing Osteitis is a diffuse radiopaque lesion representing a localized bony reaction to a low-grade inflammatory stimulus usually seen at the apex of the tooth.

Diagnostic Case Examples

Fig. 1. Mandibular right first molar had been hypersensitive to cold and sweets over the past few months but the symptoms have subsided. Now there is no response to thermal testing and there is tenderness to biting and pain to percussion. Radiographically, there are diffuse radiopacities around the root apices. ***Diagnosis: Pulp necrosis; symptomatic apical periodontitis with condensing osteitis.*** Non-surgical endodontic treatment is indicated followed by a build-up and crown. Over time the condensing osteitis should regress partially or totally (15).

Fig. 2. Following the placement of a full gold crown on the maxillary right second molar, the patient complained of sensitivity to both hot and cold liquids; now the discomfort is spontaneous. Upon application of Endo-Ice® on this tooth, the patient experienced pain and upon removal of the stimulus, the discomfort lingered for 12 seconds. Responses to both percussion and palpation were normal; radiographically, there was no evidence of osseous changes. ***Diagnosis: Symptomatic irreversible pulpitis; normal apical tissues***. Non-surgical endodontic treatment is indicated; access is to be repaired with a permanent restoration. Note that the maxillary second premolar has severe distal caries; following evaluation, the tooth was diagnosed with ***symptomatic***

irreversible pulpitis (hypersensitive to cold, lingering eight seconds); symptomatic apical periodontitis (pain to percussion).

Fig. 3. Maxillary left first molar has occlusal-mesial caries and the patient has been complaining of sensitivity to sweets and to cold liquids. There is no discomfort to biting or percussion. The tooth is hyper-responsive to Endo-Ice® with no lingering pain. Diagnosis: reversible pulpitis; normal apical tissues. Treatment would be excavation of the caries followed by placement of a permanent restoration. If the pulp is exposed, treatment would be non-surgical endodontic treatment followed by a permanent restoration such as a crown.

Fig. 4. Mandibular right lateral incisor has an apical radiolucency that was discovered during a routine examination. There was a history of trauma more than 10 years ago and the tooth was slightly discolored. The tooth did not respond to Endo-Ice® or to the EPT; the adjacent teeth responded normally to pulp testing. There was no tenderness to percussion or palpation in the region. ***Diagnosis: pulp necrosis; asymptomatic apical periodontitis.*** Treatment is non-surgical endodontic treatment followed by bleaching and permanent restoration.

Fig. 5. Mandibular left first molar demonstrates a relatively large apical radiolucency encompassing both the mesial and distal roots along with furcation involvement. Periodontal probing depths were all within normal limits. The tooth did not respond to thermal (cold) testing and both percussion and palpation elicited normal responses. There was a draining sinus tract on the mid-facial of the attached gingiva which was traced with a gutta-percha cone. There was recurrent caries around the distal margin of the crown. ***Diagnosis: pulp necrosis; chronic apical abscess.*** Treatment is crown removal, non-surgical endodontic treatment and placement of a new crown.

Fig. 6. Maxillary left first molar was endodontically treated more than 10 years ago. The patient is complaining of pain to biting over the past three months. There appear to be apical radiolucencies around all three roots. The tooth was tender to both percussion and to the Tooth Slooth®. ***Diagnosis: previously treated; symptomatic apical periodontitis.*** Treatment is nonsurgical endodontic retreatment followed by permanent restoration of the access cavity.

Fig. 7. Maxillary left lateral incisor exhibits an apical radiolucency. There is no history of pain and the tooth is asymptomatic. There is no response to Endo-Ice® or to the EPT, whereas the adjacent teeth respond normally to both tests. There is no tenderness to percussion or palpation. Diagnosis: pulp necrosis; asymptomatic apical periodontitis. Treatment is nonsurgical endodontic treatment and placement of a permanent restoration.

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AAE Communique Newsletter

Successful Local Anesthesia: What Endodontists Need to Know

Al W. Reader, D.D.S., M.S.

Patients in pain will be hard to anesthetize for a number of reasons (for example, TTX receptors, decreased excitability thresholds, altered resting potentials, excitability of nociceptors isoforms, and patient apprehension) (1). Currently, there is no simple solution to anesthetizing mandibular molars in patients presenting with symptomatic irreversible pulpitis. That is, there is no magic solution or technique for nerve block that will provide predictable pulpal anesthesia (1). In the majority of patients, only supplemental techniques will be effective (1).

Symptomatic Irreversible Pulpitis

Mandibular Success (no or mild pain upon endodontic access or instrumentation) of the inferior alveolar nerve block (IANB)(2) in these patients will be around 28% for the first molars, 25% for the second molars, and 39% for the premolars – which will not be high enough to ensure profound pulpal anesthesia. Additionally, articaine is not better than lidocaine for IANBs (1). Mepivacaine plain (3% Carbocaine, 3% Polocaine) is the same as 2% lidocaine with 1:100,000 epinephrine for IANBs (1). This is very important clinically because the plain 3% mepivacaine could be used in patients when epinephrine is contraindicated or medical conditions dictate caution.

One important fact to remember: Patients do not always achieve pulpal anesthesia with the IANB in endodontics (1), but this is NOT your fault.

What Methods may Increase Success in Patients?

Oral Conscious Sedation

Triazolam (Halcion)(1) and alprazolam (Xanax)(3) should not be used as a way to reduce pain during endodontic treatment because consciously-sedated patients will be able to detect and experience pain unless measures are used to provide profound local anesthesia; they can be used for anxiety reduction.

Gow-Gates Technique

Using a two-cartridge volume of 2% lidocaine with 1:100,000 epinephrine, the success rate with the Gow-Gates technique of 35% (4) was similar to the 24% to 35% success rates of the IANB in previous studies in patients presenting with symptomatic irreversible pulpitis (1).

Buffered Anesthetic Solutions

A 2% or 4% buffered lidocaine formulation (with epinephrine) did not result in an increase in the success rate, or a decrease in injection pain, over non-buffered lidocaine formulations with epinephrine in patients presenting with symptomatic irreversible pulpitis (5,6). Theoretically, the higher pH should have resulted in a higher success rate. However, the body intrinsically has an efficient buffering system that maintains tissues at physiologic pH. The pH conversion buffering process could occur within several minutes. One study reported a freshly prepared 2% lignocaine with epinephrine formulation (pH 5.25) being converted to a pH of 7.17 within three minutes following an intradermal injection (7). This physiologic conversion may help explain why buffering an anesthetic did not demonstrate any benefit in increasing anesthetic success.

Supplemental Buccal Infiltration of Articaine

In patients with symptomatic irreversible pulpitis, a supplemental buccal infiltration of articaine is not reliable for pulpal anesthesia. Success rates (ability to access and instrument the tooth without pain or mild pain) were only 42% for the first molars, 48% for the second molars, and 73% for the premolars (2).

Effect of Preemptive Medications on Success

Ibuprofen, a combination of ibuprofen/acetaminophen, and a combination of acetaminophen/hydrocodone (1,8) have been given preemptively before the IANB. No significant effect was shown on the success of the IANB. Other preemptive medications (ketorolac, indomethacin, diclofenac, and others) have shown mixed results (9-11). Further analysis on the use of these other preemptive medications should be performed in patients presenting with symptomatic irreversible pulpitis.

Proven Supplemental Methods to Help with Pulpal Anesthesia in Symptomatic Irreversible Pulpitis

Intraosseous Anesthesia
The supplemental intraosseous injection, using the Stabident or X-tip system, of a cartridge of 2% lidocaine with 1:100,000 epinephrine will be successful approximately 90% of the time in mandibular posterior teeth (1,12-14). Onset is immediate and duration is very good for the endodontic appointment. The supplemental intraosseous injection of a cartridge of mepivacaine plain (3% Carbocaine, 3% Polocaine) will be successful 80% of the time (1). Repeating the intraosseous injection using another cartridge of 3% mepivacaine will increase success to 98% (1). This plain solution could be used in patients when epinephrine is contraindicated or when medical conditions dictate caution.

Intraligamentary (PDL) Injection
A supplemental intraligamentary injection is successful from 48% to 74% of the time (1,12,15). Re-injection will increase success to over 90%. However, duration of pulpal anesthesia is fairly short.

Nitrous Oxide
Nitrous oxide has a potential benefit because of its sedation and analgesic effects. Administration of 30%50% nitrous oxide will increase the success of the IANB in patients with irreversible pulpitis (16). When supplemental intraosseous or intraligamentary injections fail and the pulp is not exposed, administering nitrous oxide is very helpful in achieving anesthesia.

Intrapulpal Anesthesia
In approximately 5-10% of patients with irreversible pulpitis, supplemental injections do not produce pulpal anesthesia. Therefore, intrapulpal anesthesia is indicated and will be successful if given under backpressure. The disadvantage is that the injection is painful and should only be used after all other supplemental techniques have been given.

Maxillary Molar Anesthesia in Patients with Symptomatic Irreversible Pulpitis
The success (no or mild pain upon endodontic access or instrumentation) ranged from 54% to 88% (1,17) using a one or two-cartridge volume of 2% lidocaine with 1:100,000 epinephrine. Therefore, not all patients achieve pulpal anesthesia. There doesn't appear to be a difference between articaine and lidocaine for maxillary buccal infiltrations (18-20). It has also been found that longer roots may be associated with more failures (21).

Incision and Drainage Procedure
Buffering lidocaine did not significantly decrease the pain of infiltrations before I & D or significantly decrease the pain of the I & D procedure, when compared to a non-buffered 2% or 4% lidocaine (with epinephrine) formulation, in symptomatic patients presenting with moderate-to-severe pain, a diagnosis of pulpal necrosis and an associated acute swelling (22,23). Additionally, moderate-to-severe pain was experienced in a large number of patients with the I & D procedure. While the theory of buffering local anesthetics is logical, in reality the presence of a buffer in the local anesthetic may not be enough to overcome the lowered excitability thresholds and peripheral sensitization associated with such significant inflammatory and infectious conditions in a patient with pulpal necrosis and associated acute swelling.

New Formulations for Anesthesia

Kovanaze Nasal Spray
The combination of tetracaine topical anesthetic and oxymetazoline (a vasoconstrictor) has recently been approved by the FDA for dental use. It could be used in patients who are needle phobic and has been recommended for restorative procedures on teeth numbers 4 to 13 and A to J (in children who weigh 88 pounds or more). Further research is needed to confirm the efficacy of the Kovanase nasal spray for anesthesia of maxillary teeth and for endodontic patients.

Exparel (Liposomal Bupivacaine)
Administration of Exparel (theoretically providing local anesthesia for up to 72 hours because of the slow release of bupivacaine) as an infiltration (it is not approved for nerve blocks) did not reduce pain to manageable clinical levels in patients with untreated, symptomatic irreversible pulpitis (24) or postoperatively following debridement in symptomatic patients, diagnosed with pulpal necrosis, and experiencing moderate to severe preoperative pain (25). Perhaps, in the future, Exparel could be studied for nerve blocks following FDA approval.

We have made significant advances in pain management for our endodontic patients. The future may hold even more exciting developments.

Dr. Reader currently serves as professor emeritus and program director of advanced endodontics at Ohio State University in Columbus, Ohio. He was also a director of the American Board of Endodontics. He has authored over 100 papers and abstracts, and presented over 80 lectures to societies and professional organizations. His research includes local anesthesia and endodontics. He received his D.D.S. and M.S. degrees and endodontic training from OSU.

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Biography

Dr. Reader currently serves as professor emeritus and program director of advanced endodontics at Ohio State University in Columbus, Ohio. He was also a director of the American Board of Endodontics. He has authored over 100 papers and abstracts, and presented over 80 lectures to societies and professional organizations. His research includes local anesthesia and endodontics. He received his D.D.S. and M.S. degrees and endodontic training from OSU.

ENDODONTICS
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Canal Preparation and Obturation: An Updated View of the Two Pillars of Nonsurgical Endodontics

Ove A. Peters, DMD, MS, PhD

The ultimate goal of endodontic treatment is the long-term retention in function of teeth with pulpal or periapical pathosis. Depending on the diagnosis, this therapy typically involves the preparation and obturation of all root canals. Both steps are critical to an optimal long-term outcome. This publication is intended to update clinicians on the current understanding of best practices in the two pillars of nonsurgical endodontics, canal preparation and obturation, and to highlight strategies for decision making in both uncomplicated and more difficult endodontic cases.

Prior to initiating therapy, a clinician must establish a diagnosis, take a thorough patient history and conduct clinical tests. Recently, judicious use of cone beam computed tomography (CBCT) has augmented the clinically available imaging modalities. Verifying the mental image of canal anatomy goes a long way to promote success in canal preparation. For example, a missed canal frequently is associated with endodontic failures (1). As most maxillary molars have two canals in the mesiobuccal root, case referral to an endodontist for microscope-supported treatment should be considered. Endodontists are increasingly using CBCT and the operating microscope to diagnose and treat anatomically challenging teeth, such as those with unusual root anatomies, congenital variants or iatrogenic alteration. The endodontic specialist, using appropriate strategies, can achieve good outcomes even in cases with significant challenges (Figure 1).

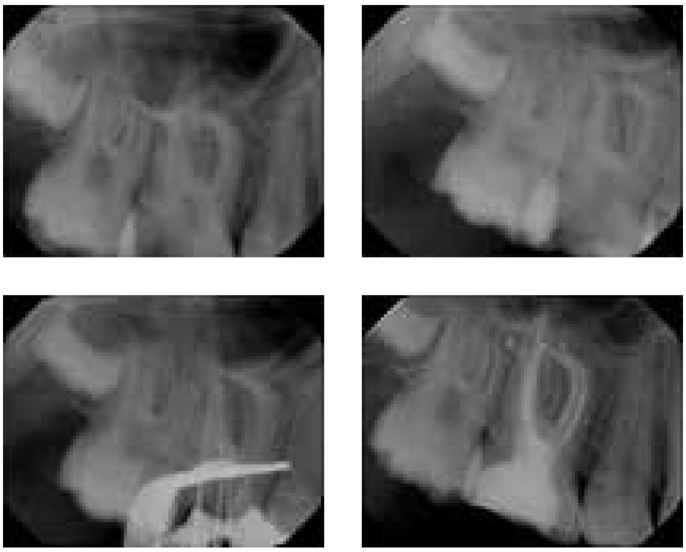

Fig. 1. Root canal treatment of tooth #3 diagnosed with pulp necrosis and acute apical periodontitis. The mesiobuccal root has a significant curve and two canals with separate apical foramina. (Case courtesy of Dr. Jeffrey Kawilarang.)

Preparation of the Endodontic Space

The goal of canal preparation is to provide adequate access for disinfecting solutions without making major preparation errors such as perforations, canal transportations, instrument fractures or unnecessary removal of tooth structure. The introduction of nickel-titanium (NiTi) instruments to endodontics almost two decades ago (2) has resulted in dramatic improvements for successful canal preparation for generalists and specialists. Today there are more than 50 canal preparation systems; however, not every instrument system is suitable for every clinician and not all cases lend themselves to rotary preparation. Several key factors have added versatility in this regard. For example, the emergence of special designs such as orifice shapers and mechanized glide path files. Another recent development is the application of heat treatment to nickel titanium alloy, both before and after the file is manufactured. Deeper knowledge of metallurgical properties is desirable for clinicians who want to capitalize on these new alloys. Finally more recent strategies such as minimally invasive endodontics have emerged (3).

Basic Nickel Titanium Metallurgy

What makes NiTi so special? It is highly resistant to corrosion and, more importantly, it is highly elastic and fracture-resistant. NiTi exists reversibly in two conformations, martensite and austenite, depending on external tension and ambient temperature. While steel allows 3% elastic deformation, NiTi in the austenitic form can withstand deformations of up to 7% without permanent damage or plastic deformation (4). Knowing this is critical for rotary endodontic instruments for two reasons. First, during preparation of curved canals, forces between the canal wall and abrading instruments are smaller with more elastic instruments, hence less preparation errors are likely to occur. Second, rotation in curved canals will bend instruments once per rotation, which ultimately will lead to work hardening and brittle fracture, also known as cyclic fatigue. Steel can withstand up to 20 complete bending cycles while NiTi can endure up to 1,000 cycles (4).

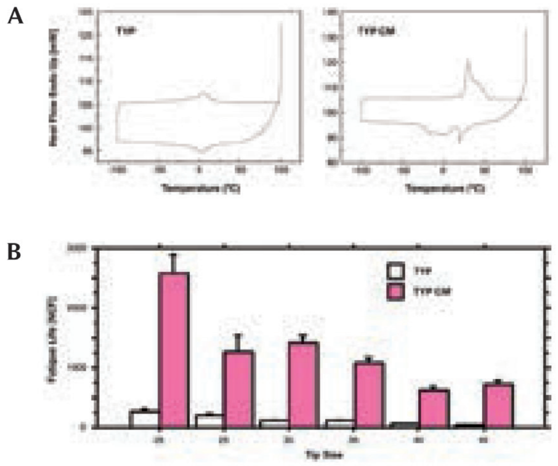

Fig. 2. Behavior of controlled-memory nickel-titanium rotaries compared to standard instruments. Shown is data from Typhoon™. Differential scanning calorimetry shows the transition between austenite and martensite at about 5°C for standard NiTi and at about 25°C for controlled-memory (CM) alloy (A). At room temperature, this results in a drastically increased fatigue lifespan (B). (Image A modified and reprinted with permission from Shen et al. J Endod 2011;37:1566-71.)

Recently manufacturers have learned to produce NiTi instruments that are in the martensitic state and even more flexible than previous files. Figure 2 shows how instrument conditions (austenite vs. martensite) are determined in the testing laboratory, using prescribed heating and cooling cycles (5). Heat-treated files with high martensite content typically do not have a silver metallic shade but are colored due to an oxide layer, such as gold or blue. It is important to note that CM files frequently deform; however, with a delicate touch, cutting is adequate and often even superior to conventional NiTi instruments (6). It is imperative for clinicians to retrain themselves prior to using these new instruments to avoid excessive deformation and subsequent instrument fracture.

Preparation Strategies

Experimental and clinical evidence suggests that the use of NiTi instruments combined with rotary movement results in improved preparation quality. Specifically, the incidence of gross preparation errors is greatly reduced (7). Canals with wide oval or ribbon-shaped cross-sections present difficulties for rotary instruments and strategies such as circumferential filing and ultrasonics should be used in those canals. Studies found that oscillating instruments recommended for these canal types did not perform as well (8), particularly in curved canals. Specific instruments developed to address these challenges include the Self-Adjusting File (SAF) System (ReDentNOVA, Raana, Israel), TRUShape® (Dentsply Sirona, Tulsa, OK) and XP Endo® (Brasseler, Savannah, GA). However, there is no direct clinical evidence that these instruments lead to better outcomes.

Canal transportation with contemporary NiTi rotaries, measured as undesirable changes of the canal center seen in cross-sections of natural teeth, is usually very small. This indicates that canal walls are not excessively thinned and apical canal paths are only minimally straightened (Fig. 1), even when preparing curved root canals. While preparation usually removes dentin somewhat preferentially towards the outside of the curvature (9), current NiTi instruments, including reciprocating files, can enlarge the canal path safely while minimizing procedural errors.

Almost all current rotaries are non-landed, meaning they have sharp cutting edges, and they can be used in lateral action towards a specific point on the perimeter. This “brushing” action allows the clinician to actively change canal paths away from the furcation in the coronal and middle thirds of the root canal (10) but may create apical canal straightening when taken beyond the apical constriction. Circumferential engagement of canal walls by active instruments may lead to a threading-in effect but contemporary rotaries are designed with variable pitch and helical angle to counteract this tendency.

An important design element for all contemporary rotaries is a passive, non-cutting tip that guides the cutting planes to allow for more evenly distributed dentin removal. Rotaries with cutting, active tips such as dedicated retreatment files should be used with caution to avoid preparation errors.

NiTi Instrument Usage

As a general rule, flexible instruments are not very resistant to torsional load but are resistant to cyclic fatigue. Conversely, more rigid files can withstand more torque but are susceptible to fatigue. The greater the amount and the more peripheral the distribution of metal in the cross section, the stiffer the file (11). Therefore, a file with greater taper and larger diameter is more susceptible to fatigue failure; moreover, a canal curvature that is more coronal is more vulnerable to file fracture.

Instrument handling has been shown to be associated with file fracture. For example, a lower rotational speed (~250 rpm) results in delayed build-up of fatigue (12) and reduced incidence of taper lock (13). Material imperfections such as microfractures and milling marks are believed to act as fracture initiation sites (14). Such surface imperfections after manufacturing can be removed by electropolishing but it is unclear if this process extends fatigue life (15).

Manufacturers’ recommendations stress that rotaries should be advanced with very light pressure; however, the recommendations differ with regard to the way the instruments are moved. A typical recommendation is to move the instrument into the canal gently in an in-and-out motion for three to four cycles, directed away from the furcation, then withdraw to clean the flutes.

It is difficult to determine exactly the apically exerted force in the clinical setting; experiments have suggested that forces start at about 1 Newton (N) and range up to 5 N (16). Precise torque limits have been discussed as a means to reduce failure. Most clinicians use torque-controlled motors, which are based on presetting a maximum current for a DC electric motor.

In order to reduce friction, manufacturers often recommend the use of gel-based lubricants in dentin; however, such lubricants have not been shown to be beneficial and actually did increase torque for radial-landed ProFile® instruments (17). Therefore, it is recommended to flood the canal system with sodium hypochlorite (NaOCl) during the use of rotaries. The best way to do this is to create an access cavity that can act as a reservoir (Figure 3).

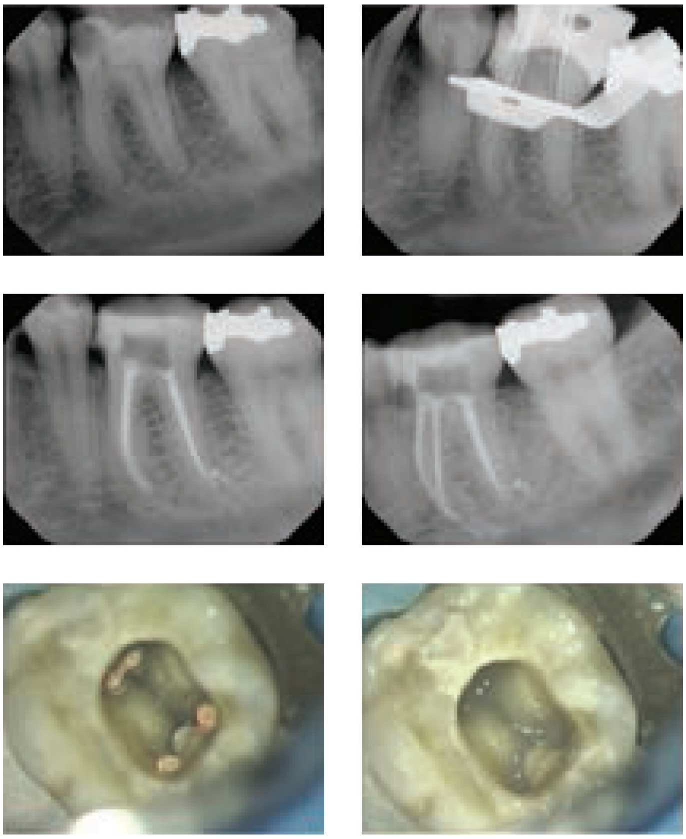

Fig. 3. Root canal treatment of tooth #19 with four canals diagnosed with irreversible pulpitis and acute apical periodontitis. A second canal in the distal root of a mandibular molar is not infrequent. Note multiple apical foramina in both the mesial and the distal apices. Prior to temporization the orifices were protected with a barrier of light-curing glass ionomer. (Case courtesy of Dr. Paymon Bahrami.)

There are several concerns about reusing NiTi instruments. The effectiveness of disinfection procedures is not clear. It has been shown that protein particles cannot completely be removed from machined nickel-titanium surfaces (18). Moreover, it is clear that with additional usage, the chance for instrument fracture increases. Current recommendations advise that clinicians are judicious when reusing rotary instruments as there is no conclusive evidence of disease transmission occurring.

Recently, the term minimally invasive endodontics has been used to describe smaller-than-usual apical sizes and perhaps more importantly, an understanding that the long-term success of root canal-treated teeth will improve by retaining as much dentin structure as feasible (3). The thought process for this was the finding that most root-canal treated teeth survive 10 years and longer (19). In studies, the reasons cited for the extraction vary but in many cases teeth are either fractured or non-restorable for other reasons (20, 21). In consequence, a smaller coronal dimension of rotaries is considered while maintaining apical sizes to support antimicrobial efficacy. There currently is no direct clinical evidence to support this strategy but it is clear that root fractures pose problems in the long-term outcomes of our patients. Another recent development is the emergence of certain specialized rotaries, such as dedicated orifice shapers and so-called glide path files. The orifice shapers have larger tapers, such as .08, which means that they are not flexible and can overprepare at the canal orifice level. Glide path files, for example PathFiles® and ProGlider® (Dentsply Sirona), are delicate instruments and may fracture when used incorrectly. It is recommended to use a small K-file (size #10) before any rotary instrumentation and to use a delicate touch.

Clinical Results

While results from in vitro studies on rotary systems are abundant, clinical studies on these instruments are sparse. Comparing NiTi and stainless steel K-files, Pettiette et al. (7) found less canal transportation and fewer gross preparation errors such as strip perforations. Subsequently, using radiographic evaluation of the same patient group, they demonstrated better healing in the NiTi group (22). An earlier outcome study with three rotary preparation paradigms did not show any difference between the three systems with an overall favorable outcome rate of about 87% (23).

The most consistent clinical results are obtained when the manufacturer's directions are followed. While these vary by instrument, a set of common rules apply to root canal preparation. Root canal systems are best prepared in the following sequence:

- Analysis of the specific anatomy of the case
- Canal scouting
- Coronal modifications
- Negotiation to patency
- Determination of working length
- Glide path preparation
- Root canal shaping to desired size
- Gauging the foramen, apical adjustment

Obturation of the Endodontic Space

A well-shaped and cleaned canal system should create the conditions for intact periapical tissues. On the other hand, this root canal system is inaccessible to the body's immune system and therefore it cannot combat coronal leakage. Accordingly, best practices dictate that root canals should be filled as completely as possible in order to prevent ingress of nutrients or oral microorganism. None of the established techniques for root canal filling provides a definitive coronal, lateral and apical seal (24).

Basic Strategies in Root Canal Obturation

Ideally, root canal fillings should seal all foramina leading to the periodontium, be without voids, adapt to the instrumented canal walls, and end at working length. There are various acceptable materials and techniques to obturate root canal systems including:

- sealer (cement/paste/resin) only
- sealer and a single cone of a stiff or flexible core material
- sealer coating combined with cold compaction of core materials
- sealer coating combined with warm compaction of core materials
- sealer coating combined with carrier-based core materials

Several of these techniques have shown comparable success rates regarding apical bone fill or healing of periradicular lesions, so a clinician may choose from a variety of techniques and approaches that works best for him or her. Existing research directs clinicians towards preparation and disinfection of the root canal as the single most important factor in the treatment of endodontic pathosis, and no particular sealing technique can claim superior healing success (25).

Current Developments in Root Canal Obturation Materials

After the introduction of MTA (mineral trioxide aggregate) as a material for perforation repair and apical surgery more than two decades ago, materials with similar bioactive properties now are available as root canal sealers. Bioceramic root canal cement (BC Sealer™, Brasseler) has clinically acceptable radiopacity and flow (26). Moreover, it is welltolerated in cell culture experiments (27). However, there is no clinical evidence that using this cement leads to better outcomes. In fact, most research has indicated the type of cement used has comparatively little impact (28).

In contemporary practice, heat generators are used to plasticize gutta-percha. Additionally, cordless heating devices are available. Another recent addition is a carrier-based material, Guttacore® (Dentsply Sirona), which uses modified gutta-percha materials instead of plastic as its base. Early data indicate that obturation with this new material is similar to warm vertical compaction or lateral compaction (29).

Practical Aspects of Obturation

The main steps in the sequence of root canal obturation are:

- choosing a technique and timing the obturation
- selecting master cones
- canal drying, sealer application
- filling the apical portion (lateral and vertical compaction)
- completing the fill
- assessing the quality of the fill

The root canal system should be assessed before choosing an obturation technique. In the presence of open apices or procedural errors such as apical zipping and also for teeth with apices in close proximity to the mandibular canal, there is significant potential for overfills. In order to avoid such mishaps, these cases may be better obturated with cold lateral condensation to avoid overfilling, or in some cases, MTA may be placed as a barrier.

In general, canals should only be filled when there are no symptoms of acute apical periodontitis or an apical abscess, such as significant pain on percussion or not dryable due to secretion into the canal. Gutta-percha cones first should be disinfected by submerging them in an NaOCl solution for about 60 seconds.

In addition to a solid filler such as gutta-percha, a sealer or cement should be used. Most sealers are toxic in the freshly mixed state, but this toxicity is reduced after setting. When in contact with tissues and tissue fluids, zinc oxide eugenol-based sealers are absorbable while resin-based materials typically are not absorbed (30). Some by-products of sealers may adversely affect and delay healing. Therefore, sealers should not be routinely extruded into the periradicular tissues.

The appropriate amount of sealer is then deposited into the canal system. This may be done using a lentulo spiral, a K-file or the master cones themselves; each method is acceptable, provided that an appropriate amount of sealer is deposited. If the master cones are the carrier for the sealer, they should be removed and inspected for a complete coating with sealer and then replaced in the canal.

The master cones are placed close to working length using a slight pumping motion to allow trapped air and the excess sealer to flow in a coronal direction. The marking on the cone should be close to the coronal reference point for working length determination. For lateral compaction, a preselected finger spreader is then slowly inserted alongside the master cone to the marked length and held with measured apical pressure for about 10 seconds. During this procedure, the master cone is pushed laterally and vertically as the clinician feels the compression of the gutta-percha. Rotation of the spreader around its axis will disengage it from the gutta-percha mass and facilitate removal from the canal.

The space created by the spreader is filled by inserting a small, lightly sealer-coated accessory gutta-percha cone. Using auxiliary cones larger than the taper of the spreader will produce voids or sealer pools in the filling and should be avoided. The procedure is repeated by inserting several gutta-percha cones until the entire canal is filled.

For vertical compaction, electrically heated pluggers are used to melt a master cone fitted to length. Tapered guttapercha cones optimize the hydraulic forces that arise during compaction of softened gutta-percha with pluggers of a similar taper. After fitting the master cone as before, different hand pluggers and heated pluggers are placed into the root canal to verify a fit to within 5 to 7 mm of the apical constriction.

For both lateral and vertical compaction the gutta-percha mass in each canal should end about 1 mm below the pulpal floor, leaving a small dimple. In cases where placement of a post is planned, gutta-percha is confined to the apical 5 mm (31). All root canals that do not receive a post may be protected with an orifice barrier (Figure 3) to protect from leakage prior to placement of a definitive restoration (32). This has been shown to promote healing of apical periodontitis (33). Materials that are suitable for such a barrier include light-curing glass ionomers, flowable composites or fissure sealants. In order to facilitate retreatment if necessary, such a barrier should be thin so that the gutta-percha fill is just visible.

Radiographic Appearance of Filled Root Canal Systems

Prepared and filled canals should demonstrate a homogenous radiopaque appearance, free of voids and filled to working length. The fill should approximate canal walls and extend as much as possible into canal irregularities such as an isthmus or a c-shaped canal system. This is difficult to achieve clinically and frequently requires the clinician to use a thermoplastic obturation technique. This complicated procedure may benefit from the use of the dental operating microscope.

Other anatomical spaces that may be filled include accessory canals that are most common in the apical root third (Fig. 3, mesial and distal root) but may be found in other locations such as the furcation. It has been well established that accessory anatomy may contribute to periapical periodontitis (34) but clinical experience suggests the role of accessory anatomy in causing bone resorption is comparatively small. Indeed it appears that filling accessory canals is not predictable and not per se a prerequisite for success (35).

In order to avoid overextension of root filling material into the periapical tissue, specifically in the mandibular canal, it is recommended to accurately determine working length to prevent destruction of the apical constriction. For infected root canal systems, it seems that the best healing results are achieved when the working length is slightly short of the tip of the root, as visible on a radiograph (25, 36).

Determination of apical canal anatomy is often difficult. It may be appropriate for second mandibular molars that are in close proximity to the mandibular canal to be referred to a specialist. Overfills are not only an impediment to healing but in the worst case can be associated with permanent nerve damage. In general, undesirable and uncorrectable outcomes of root canal treatment, identifiable on the final radiograph, include:

- excessive dentin removal during access and instrumentation
- preparation errors such as perforation, ledge formation and apical zipping
- presence of an instrument fragment in not fully disinfected canals
- obturation material overfill and overextension

Each of these outcomes must be documented and the patient notified as they may reduce the likelihood of a successful outcome. In cases such as par- or dysesthesia after an overfill, immediate referral to a surgeon is indicated.

Summary and Conclusions

Root canal preparation with contemporary instruments is a predictable procedure in most cases for a well-trained clinician following established guidelines. Cases with a recognized high degree of difficulty are best referred to an endodontist. While many cases can be treated successfully in routine practice, the additional training, expertise and technology of endodontists is necessary in cases that are beyond the typical spectrum. The best long-term outcomes are obtained when a correctly planned final restoration is placed as soon as possible after root canal treatment is completed (Figure 4). Root canals may be filled through various methods, typically using a combination of a cement and a solid filling material such as gutta-percha. The specific obturation material used appears to have a smaller role on outcomes. Overfills, particularly into the area of the inferior alveolar nerve, have the potential to permanently harm a patient. The absence of gross errors that are associated with persistent presence of bacterial infection and excessive dentin removal during access and canal preparation have the greatest impact on outcomes.

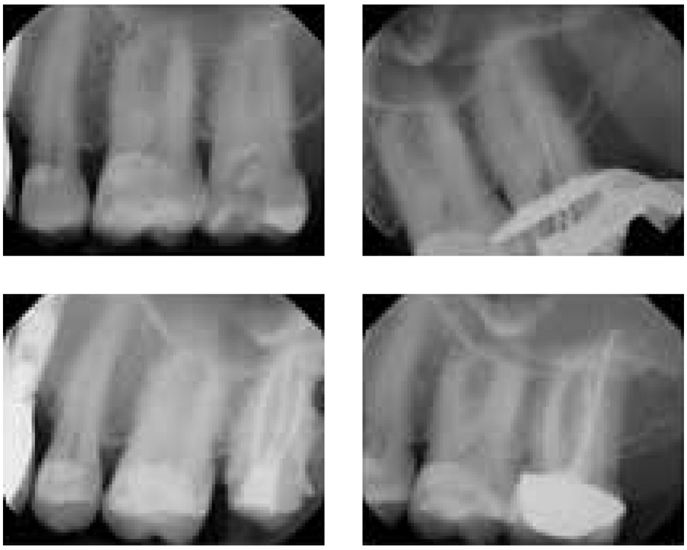

Fig. 4. Root canal treatment of tooth #15 with four canals, diagnosed with irreversible pulpitis and acute apical periodontitis. The tooth was restored with a crown immediately after finalizing the root canal treatment. (Case courtesy of Dr. Reza Hamid)

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Creative Integration of Clinical Techniques for Tooth Retention

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Vivian Manjarres, DDS, Cert Endo

Abstract
Often creative techniques must be used during root canal procedures, especially when the patient has the desire to retain a tooth that could easily be condemned. This case report will detail the management of a maxillary premolar with an open apex and fractured post in an adult patient, in which the tooth was recommended for extraction along with subsequent implant placement. A focus is presented on both the treatment planning and procedural issues.

Introduction
A 57-male patient with a non-contributory medical history presented for a second opinion regarding a tooth that had a fractured post and which his general dentist had recommended for extraction and implant placement. While the extraction and implant seemed reasonable to him, he wished to know if there was a possibility to retain the tooth. He was in no pain at the time, but did a lot of overseas travel and was concerned that he might have problems during his travels regardless of the treatment plan chosen.

Visually, a clinical exam showed that a post in the maxillary premolar was fractured slightly below the remaining tooth structure and flush with the opening of the root canal. The tooth had some type of incomplete root canal procedure previously and the root was short but there was good bone coronally. Radiographically, a large periapical lesion was present that encompassed the root apex and upon closer inspection, the root canal appeared to have a large open apex possible due to root resorption (Fig. 1). Furthermore, the teeth immediately adjacent to the tooth in question had already been crowned, which negated the placement of a fixed bridge. Moreover, the patient's oral hygiene was less than ideal, which he openly admitted. Treatment options were discussed with the patient, with the provision that if the post could not be removed and the root canal could not be properly cleaned, disinfected and obturated, extraction may be the best course of treatment.

Fig. 1.

Issues of concern along with implications for the clinician indicated in italics:

- Ability to remove the post without fracturing the root *(access to the post; avoiding removal of excess tooth structure; having the necessary tools to remove the post, such as an ultrasonic, appropriate tips of a post removal kit; experience removing posts, etc.)*
- Ability to remove and clean the root canal of the previous root filling (oval root canals are more difficult to clean; having the appropriate file systems; ultrasonic or sonic capability; attempting to remove debris coronally, etc.)
- The potential of pushing debris past the end of the root that was open apically *(application of hand and/or rotary instruments in a manner that prevents the pushing of debris; where to terminate the root canal shaping and cleaning procedures, etc.)*
- The ability to properly obturate the canal, which most likely was oval and had a greater buccal-lingual dimension than its mesial-distal dimension *(choice of root canal filling technique and root canal sealer and experience with the technique chosen; amount of sealer and where placed; degree of compaction; filling in all dimensions, etc.)*

- The ability to seal the root canal without expressing a large amount of filling material into the periapical tissues *(viscosity of the sealer, compaction technique; use of an apical plug of collagen for a stop; use of mineral trioxide aggregate, etc.)*
- The ability to restore the tooth if the root canal procedures could be accomplished *(should crown lengthening be done first; is there sufficient coronal tooth structure; occlusal function, etc.)*
- If the post could not be removed, would the tooth be a candidate for periapical surgery *(unlikely in this case due to root length and the tooth must still be restored properly; skill of the dentist to even consider surgery, etc.)*

Treatment procedures

Prior to any active treatment, the periodontal tissues surrounding the tooth and its adjacent counterparts were carefully probed to ensure the presence of a uniform sulcus and to determine whether or not crown lengthening might be necessary. The tissues were reasonably healthy with no abnormal probings and there was sufficient tooth structure for dental dam isolation and tooth restoration with a well-fabricated post-core and crown. No carious tooth structure was detected. Since the fracture of the post and crown had occurred recently, the interdental space between the first molar and first premolar had not collapsed.

Post removal

Post removal was accomplished by first using small stainless steel hand K-files (#10 & 15) on the buccal and lingual surfaces along the post. Often when there is an oval canal, these areas contain only cement and can be easily penetrated if there has been any coronal leakage. In this case a small amount of penetration was achieved approximately 3 mm alongside the post. Then a small ultrasonic tip (ProUltra ENDO #3 - Dentsply Sirona, Tulsa Dental, Tulsa OK, USA) was used to further remove any cement and to begin to break up the cement layer in other areas around the post (Satelec P5, Dentsply Sirona, Tulsa Dental Specialities, Tulsa,OK, USA) . Ultimately during this process, movement of the post was noted and a larger ultrasonic tip (ProUltra ENDO #2 - Dentsply Sirona, Tulsa Dental, Tulsa OK, USA) was placed on the side of the post itself using greater amounts of energy with application in a circular fashion around the post to enhance its movement. During this process the post could be seen vibrating and moving in a circular pattern, which allowed it to be removed from the canal with a hemostat.

Canal shaping and cleaning

With the post removed the canal length was estimated and a small K-file (#20) was advanced to 1.0 mm short of the observable end of the root, as the filling material present was loose and fluid. The size of the file chosen was based on the size of the canal visible on the radiograph. The working length was determined and removal of the debris in the canal was achieved with both hand K-files and H-files (Hedström files) (Dentsply Sirona, Tulsa Dental, Tulsa OK, USA) along with larger rotary instruments (ProFileTM Dentsply Sirona, Tulsa Dental, Tulsa OK, USA). Irrigation was done with full-strength sodium hypochlorite (NaOCl - 6%) during the cleaning process. Upon completion the irrigant was activated with an ultrasonic file (#25) in a passive manner for 60s, with additional irrigant being place in the canal during activation and aspiration. The smear layer was removed with 17% EDTA (Inter-Med/Vista Dental Products, Racine, WI, USA) in conjunction with ultrasonic activation. Finally the canal was rinsed with sterile water and dried; this was then followed by placement of 2% chlorhexidine (Patterson Dental, St. Paul, MN, USA) for 60s, followed by drying the canal with paper points.

Crucial in this shaping and cleaning process was the attempt to bring all foreign debris coronally, in addition to allowing for any apical drainage that may occur. During these procedures the patient was informed that success had been achieved in post removal and root canal debridement. Additionally, because the patient traveled extensively, he was offered the opportunity to complete the entire procedure at this visit, for which he agreed.

Root canal obturation

The challenge of root canal obturation was met using a creative approach based on technical procedures and the potential for a biological response.

1. A custom gutta-percha cone was fabricated using a large cone (#80) that was softened apically in chloroform for 3s, then seated into the canal carefully to a point 1.0 mm from the root apex. At first it went in easily and was held there for 5s before removal.
2. Upon removal, there were portions of the cone that had not become adapted to the canal wall therefore 1.5 mm of the cone was cut off with a scalpel on a glass slab. This was then softened again apically in chloroform for 23s and then placed again to the desired canal length. This had to be repeated once more before examination of the cone showed that it had adapted in all dimensions to the root canal walls apically and that upon placement it demonstrated a good snugness at the desire position. A radiographic was taken ensure the apical position of the master gutta-percha cone.
3. The adapted cone was placed in 70% alcohol for 30s to remove residual chloroform, then air dried.
4. At this point the focus was on what root canal sealer to use. Most sealers placed apically in this situation would do nothing more than assist in sealing the canal but may also impact biologically upon the tissues, delaying any possible healing.
5. Roths 801 sealer was chosen as the main sealer. The custom-fit cone was lightly coated apically with sealer and placed slowly in the canal. The cone was removed after 3s and examined to see if contact had been made on all of the walls, as evidenced by the wiping of the sealer off the majority of the cone's surface.
6. Once the cone was examined and sufficient contact had been satisfied, an even lighter coating of sealer was again placed on the cone, which was then rolled into white MTA powder, with the powder adhering to the surface of the sealer-coated master cone. Subsequently the master cone was placed to length and held with gentle pressure for 5s.
7. The coronal aspect of the cone was seared off with heat and the cone was gently compacted vertically to finish the obturation.

Fig. 2.

A final radiograph was taken the patient was returned to his general dentist for restoration of the tooth (Fig. 2). Note the root filling is retained with the confines of the canal at a point where the root walls diverge apically. This is one of the benefits of creating a custom-fit cone. Furthermore, note the lack of extrusion of filling material apically, even with the second application of sealer and added MTA powder. The patient returned for a recall evaluation approximately 9 months later (Fig. 3). He was symptom-free and there is some evidence that there is healing apically and possible hard tissue formation into the aperture of the open apex. A post-core has been placed, and while the radiograph would suggest that the crown was tied together with a new crown on the molar that was not the case. Possible decay is present below the crown margin on the first premolar.

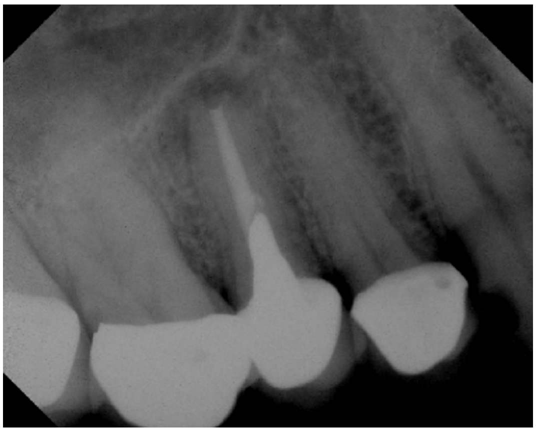

Fig. 3.

At 30 mos (Fig. 4), the patient presented with what appears to be almost complete healing apically, however some important observations should be noted. First, his oral hygiene had deteriorated, which he claimed was due to his negligence because of his busy travel schedule. Second, there definitely appeared to be caries around the margins on both premolars and on the distal of the molar, beneath the crown. Third, he had had an implant placed in the position of his second maxillary molar that had not been restored as yet. However, what was really interesting was there was very little tooth structure left in his mandibular arch for the “to-be-restored-implant” to be in occlusion. Unfortunately,

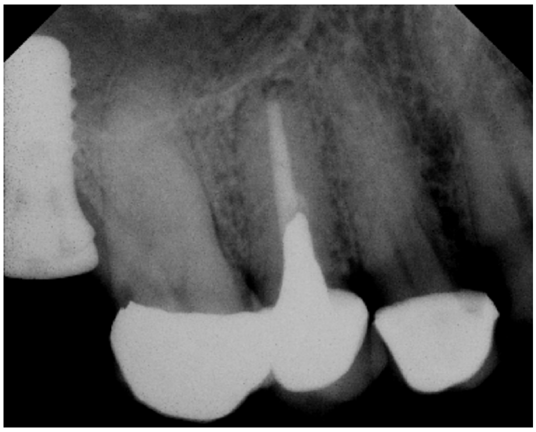

Fig. 4.

further recall evaluations could not be made as the patient’s contact information was unavailable.

Discussion of Importance Concepts in This Case

Often in the contemporary practice of dentistry when patients presents with a fractured crown, or in this case both the crown and post fracture, the first inclination is to extract the tooth and place an implant. However, each case deserves a complete assessment and the patient’s desires must be recognized. The latter can only occur if the dental professional is knowledgeable of all the options, takes the time to educate the patient thoroughly and objectively and provide the patient with guidance, along with a reasonable prognosis for each potential treatment choice. If this cannot be done, then the patient should be referred to a specialist who can address the issues posed by the clinical findings and facts.

Post removal can be accomplished in many ways, but from a contemporary viewpoint the careful application of ultrasonic energy has proven to be highly successful.[1,3] However, there is always the risk of creating root fractures with this method, albeit the incidence is small[4] and when posts are easily accessible coronally, sometimes the use of a post puller is less invasive.[5,6]

The development of a custom master cone is a technique that has long history of usage[7] especially before the advent of the core-carrier technique in which softened gutta-percha is introduced on a carrier into the canal. Using a custom cone helps to prevent the movement of filling material beyond the desired length and is especially effective when the apical foramen is large or has been altered by apical resorption. Furthermore, by adapting the cone apically, there is increased likelihood of establishing a thorough apical seal[7]

The use of MTA was designed to enhance a hard tissue response apically. This technique was used prior the advent of MTA or bioceramic-based root canal sealers (ProRoot® ES, DentsplySirona, Tulsa Dental Specialties, Tulsa, OK, USA; EndoSequence® BC Sealer, Brasseler, Savannah, GA, USA). While these sealers have become popular in the last few years,[8] there is a paucity of information on outcomes with regards to the enhanced healing of periapical lesions in humans, although animal studies have generally been positive.9 While some clinicians may have chosen to place an apical plug of MTA, it is more difficult to place without extrusion and a full adaptation to the apical anatomy may have been more difficult. Subsequently the canal would still have to be obturated with presumably gutta-percha and sealer.

The reporting of this case in this manner is designed to give the clinician ideas and options on how to retain teeth that have been compromised. It was also designed to provide an "introspective approach" for each step in the case management. This is just one of many creative approaches that can be used when similar circumstances are present.

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Biography

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Exploring the Scope of Endodontics: A focused case report that highlights pulp preservation in a permanent tooth

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Abstract
The scope of Endodontics reaches far beyond just root canal procedures. Coupled with the concept of minimally invasive dentistry, the prevention and management of pulpal disease can often result in pulp preservation and significant economic benefits to the patient. This paper will address one area in which pulp and tooth preservation can be achieved effectively for the patient.

Introduction
The contemporary scope of Endodontics reaches far beyond the mere provision of root canal procedures for tooth retention.[1] In fact, there are a many as 15 distinct clinical procedures that fall within that scope. Coupled with a focus on minimally invasive dentistry,[2] the prevention and management of pulpal disease to the point of engaging the healing processes within the pulp is receiving greater attention for the clinician.[3-9] These procedures will include indirect and direct pulp capping and partial pulpotomy or complete pulpotomy in permanent teeth with both incomplete and complete root development as depicted on a two-dimensional radiograph. This case report will focus on the use of a partial pulptomy procedure in a symptomless permanent molar with no periapical pathosis and completed root formation as a definitive procedure with a focus on pulpal healing and preservation.

Case Report
A ten-year old female patient presented with a chief complaint of having a hole in her lower tooth - #46. She was referred for a root canal procedure on this tooth based on the radiographic appearance only; no pulp testing or clinical exam had been done. She presented with no history of symptoms, including no spontaneous pain, no pain to thermal changes and chewing.

Clinical Exam
The gingival tissues were normal, there was no discomfort to lateral or vertical percussion and not abnormal responses to thermal testing. Radiograph findings were within normal limits with maybe a slight change in the periodontal ligament width apically. There was no evidence of mineralization in the pulp chamber space. There was however, evidence of extensive carious coronally (Fig. 1a - yellow arrow). Also noted was the band of dentin that appeared to separate the advancing caries from the pulp itself (Fig. 1a - white arrows). The diagnosis at that time was a normal pulp that may be compromised by carious invasion.

Treatment Plan
- Caries removal in a stepwise fashion from the borders inward
- If the pulp is exposed a clinical assessment will determine the course of management, such as pulp cap or partial/full pulpotomy at which time the actual diagnosis may change.
- Potential for a pulp cap, partial pulpotomy/pulpotomy or complete root canal procedures

Treatment Procedures
The patient was anesthetized and the tooth was isolated with a dental dam. Gross caries excavation was performed initially with a sharp spoon excavator from the borders inward and apically until removal of the carious lesion in the depth of the excavation resulted in an area of minimal bleeding. A round diamond bur was used to remove the remaining dentin overlying the pulp subjacent to the mesial pulp horn. Subsequently the cavity was rinsed lightly with sodium hypochlorite (5.25%) using a sterile cotton pellet to wipe the cavity clean using minimal to no pressure. Minimal to no hemorrhage was noted at that time and a fresh pulp wound was evident. Mineral Trioxide Aggregrate (White ProRoot MTA - Dentsply Sirona, Ballaigues, Switerland) was placed, followed by a glass ionomer (ChemFlex – Dentsply, Konstanz, Germany) and bonded composite (Composite Híbrido AP.H – Dentsply, Petrópolis RJ, Brasil) (Fig. 1b - blue arrow). Note that the MTA was placed without compressing in into the dental pulp.

Patient Re-evaluation
The patient was re-examined at 30 days, 60 days, 12, 18, 27, 36 and 48 months. No symptoms or signs were present at any re-evaluation interval. However, a thick band of hard tissue was seen at 12 mos (Fig. 1c - red arrow), with a more dense and extensive

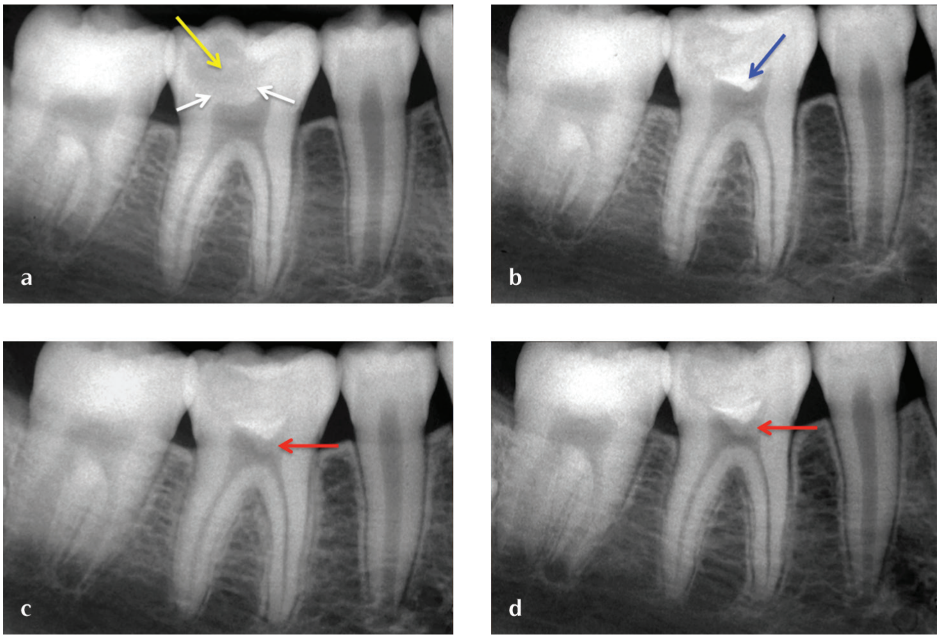

Fig. 1a. Radiograph prior to treatment showing deep caries (yellow arrow) and a white band of apparently hard tissue separating the carious lesion from the coronal pulp (white arrows); there may be some subtle changes in the periodontal ligament space around the mesial root;

Fig. 1b. Following careful excavation and pulp exposure and a partial pulpotomy, MTA was placed (blue arrow);

Fig. 1c. The red arrow indicates at 12 months that a hard tissue barrier was forming (red arrow);

Fig. 1d. The hard tissue barrier (red arrow) appears to be increasing in mineralization. The periodontal ligament space appears stable at 24 months.

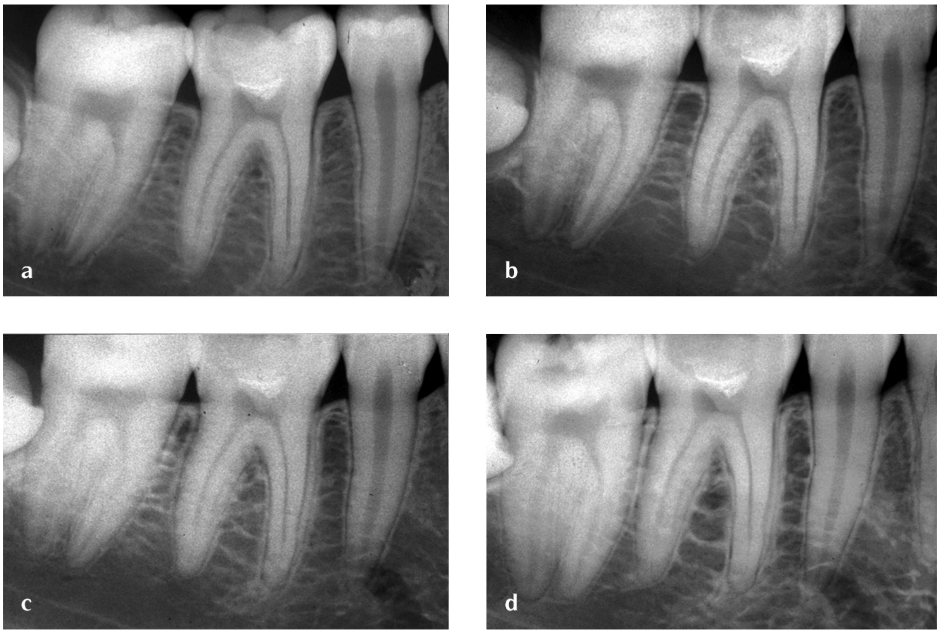

Fig. 2a. 27-month radiograph; both the mineralization in the pulp chamber and the status of the periodontal ligament space appear stable.

Fig. 2b. 36-month radiograph shows enhanced mineralization in the chamber, but with out complete closure of the chamber; the canals appear patient and the periodontal ligament space appears to be normal.

Fig. 2c. 48-month radiograph; no significant changes from the 36-month recall evaluation.

Fig. 2d. 72-month radiograph; increased mineralization in the pulp chamber, but the chamber is still patent as are the root canal; the periodontium appears normal.

band of mineralized tissue at 24 mos (Fig. 1d - red arrow). The amount of hard tissue within the chamber increased at each time interval however, at no time did the pulp chamber undergo complete mineralization (Figs. 2 a-d, 27, 36, 48 and 72 mos, respectively). Likewise, the status of the periapical bone appeared satisfactory, the canals appeared patent and the tooth responded normally to thermal testing at all time intervals.

Discussion

The use of a pulp capping or a partial pulpotomy has been an acceptable procedural choice in teeth with minimal to no symptoms, for which the diagnosis may be considered as a minimally reversible pulpitis. In contemporary endodontic applications, this approach does not have to be limited to teeth with lack of complete root formation, as permanent teeth with complete root formation in both the young and older patient may benefit from this procedure;[8] although with a cariously exposed pulp, a partial pulpotomy has yielded a markedly high success rate in young teeth.[9] However, an overall consensus in the use of a partial pulpotomy or pulpotomy may be lacking as standardized outcome criteria may be lacking based on extensive reviews of the literature.[9,10]

From a biological and technical standpoint, it is possible in the present case that the dentin at the base of the carious lesion was infiltrated with bacterial byproducts, with minimal to no bacteria actually in the pulp. Likewise minimal to no bacterial penetration may have been aided by the formation of reactionary dentin that formed below a calciotraumatic line (Fig. 3) in the pulp,[11] thereby minimizing inflammation and accounting for the lack of symptomology. However, clinically it may be difficult to differentiate between affected and infected dentin, and the lack of signs and symptoms and the appearance of minimal bleeding at the site of initial exposure and the ability to control any hemorrhage with minimal effort will often guide the clinician in treatment choices.

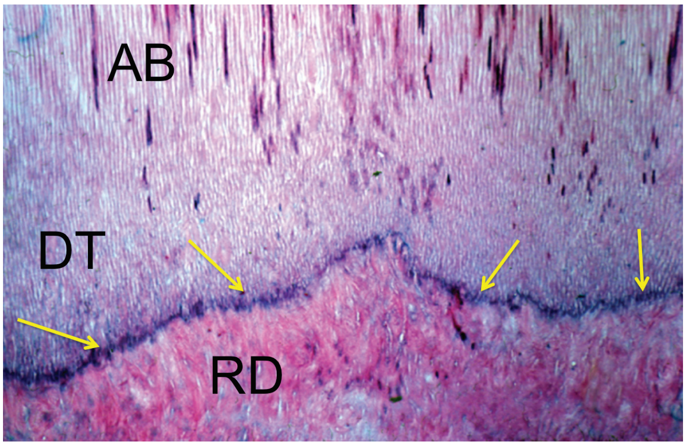

Fig. 3. Section of dentin that shows the dentinal tubules (DT); the advancing bacteria (AB); the reactionary dentin (RD); and the calciotraumatic line (yellow arrows). Note lack of tubule organization in the reactionary dentin.

Currently, the best method of managing teeth as was found in this case report appears to be based heavily on the ability to control pulpal hemorrhage by using sodium hypochlorite with minimal to no applied pressure.[12-14] This is followed by placing MTA, which currently is the optimum material for use in vital pulp therapy.[12-15] Compared with the use of a traditional material, such as calcium hydroxide, MTA has superior long-term sealing ability and stimulates a higher quality and greater amount of reparative dentin. In medium-term clinical assessment, it has demonstrated a high success rate. Thus, MTA should be considered as a good substitute for calcium hydroxide in vital pulp procedures.

A controversial aspect of this treatment approach may lie in the issue of calcific metamorphosis with obliteration of the chamber and access to the root canals. This has been identified as a potential contraindication should root canal procedures be indicated for a tooth in the future following any type of vital pulp therapy.[16] As noted in the recall evaluations in this case, even though there was hard tissue formation within the chamber, even on two-dimensional radiographs up to 72 months, both the chamber and root canals appears accessible. By necessity then routine radiographic assessment may be indicated along with pulp testing to monitor the progress of the treatment rendered.[16]

A key point to focus on in these types of cases is that the pulp has amazing reparative processes and a balance between infection, inflammation and tissue healing must be considered for ultimate treatment decisions. While this is a singular case report, and the approach to management may not be applicable to all cases, a careful diagnostic assessment and well-thought out treatment plan, especially when economics is of major consideration will enable the clinician to provide the best treatment possible for positive patient outcomes. It is these types of outcomes that have the hallmark of the dental profession for over 100 years.

*“**Tooth Saving Should be the Dentist’s Aim.** — It is not the greatest achievement of science or the highest development of art to produce things available to only favored individuals, but rather those things which lie within the reach of the majority, and which produce the greatest good for the greatest number. In the practice of dentistry every encouragement should be given to those who are striving for better methods of combating disease, or the production of better materials with which to replace lost tissue, but enthusiasm in our work and admiration for unusual attainment should not lead us to lose sight of the fact that a service which will save the most teeth for the greatest number of people is, after all, the true standard by which the attainments of our profession should be measured. — **Editorial, The Pacific Dental Gazette, October, 1910**.”*[17]

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Biography

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Managing an Inadvertent Access Opening Perforation

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While a properly prepared and shaped access opening is essential to have unimpeded entry into the root canal orifices, problems may occur during the cutting of this opening. The deviations usually result in excessive removal of significant tooth structure or perforation of the tooth in the cervical region above, at or below the crest of the bone. The error lies with failure to recognize the angle of the root once it leaves the coronal structure or failure to angle the bur in the handpiece in the long axis of the root. This case report will address this latter issue, with the management of a coronal root perforation due to an improperly angled bur during access opening preparation.

Keywords: access preparation, mineral trioxide aggregate, root perforation, surgical repair

Introduction

Inadvertent coronal root perforations can occur during endodontic access opening preparation in anterior teeth, thereby creating a defect in the tooth, soft tissue and in many cases the bone (13). These deviations are usually due primarily to one or more of the following factors; 1) irregular angulation of the root to the crown of the tooth; 2) use of a bur that may be too big or too long for the size of the coronal-root complex; 3) erroneous angulation of the bur when entering the crown of the tooth; or 4) failure to reorient the bur down the long axis of the root once the pulp chamber has been penetrated. Once a perforation occurs the consequences of this deviation and its management are based completely on the location of the perforation and whether or not it impacts on the supporting periodontium. Likewise, it may also impact on the planned restorative procedure.

Case Report

A 43-year old woman presented with the chief complaint of acute gingival swelling over the maxillary right canine (tooth 13) (Fig. 1). The patient related a history of an acute toothache in this same area while on vacation some 3 weeks earlier. There had been no swelling at the time. Emergency dental treatment was sought and was received in that location. As related by the patient, the treatment consisted of some procedure performed on the tooth together with a postoperative course of antibiotics. The symptoms had resolved completely. Upon returning from the vacation one week prior to the current examination, the area began to feel sore to the touch and became increasingly swollen.

Fig. 1. Patient presents with a buccal/vestibular swelling in the attached gingiva

Fig. 2. Radiograph of the maxillary canine with a large radiolucency in the coronal-third of the canal

The clinical examination identified an existing fixed prosthesis extending from tooth 11 to tooth 15. There was an obvious acute swelling in the labial marginal periodontium over tooth 13 the maxillary right canine abutment, but there was no evidence of swelling or tenderness over the apex. A routine endodontic access preparation had been made on the palatal aspect of the crown that was well sealed with a temporary filling material. Periodontal probings were completely within normal limits circumferentially. The radiograph indicated a generous access preparation to the level of crestal bone in the coronal tooth structure, visible apical to the crown margin (Fig. 2). The location of the swelling, the normal periodontal probings and the recent access procedure led to the tentative diagnosis of a labial access perforation. Surgical exploration was recommended to both confirm the diagnosis and repair the defect.

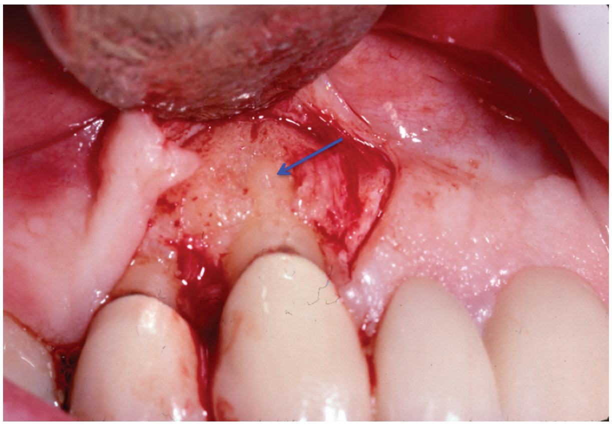

Fig. 3. Tissue reflected showing radicular dehiscence and buccal root defect (blue arrow)

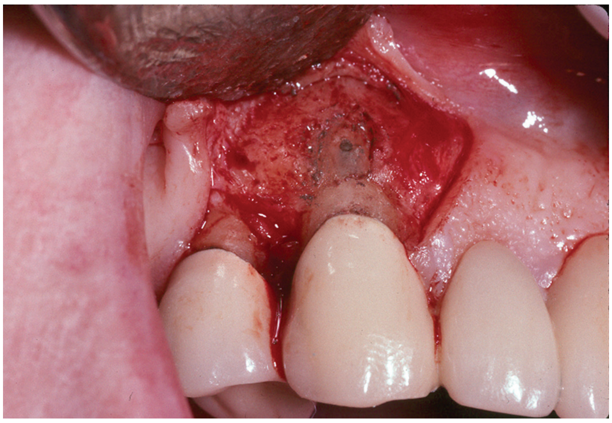

Fig. 4. Repair of defect with MTA

Under routine local anesthesia, a mucoperiosteal tissue flap with one vertical releasing incision was elevated over tooth 13 exposing a mid-labial perforation approximately 2 mm apical to crestal bone level (Fig. 3) There was no material in the defect itself. Without further preparation or enlargement, the perforation was repaired with mineral trioxide aggregate (MTA - ProRoot MTA, Dentsply SironaTulsa Dental Specialities, Tulsa, OK, USA) (Fig. 4) and the tissue was repositioned and sutured (Fig. 5). On a second appointment, two weeks later, the root canal procedure was completed (Fig. 6).

Fig. 5. Tissue repositioned and sutured

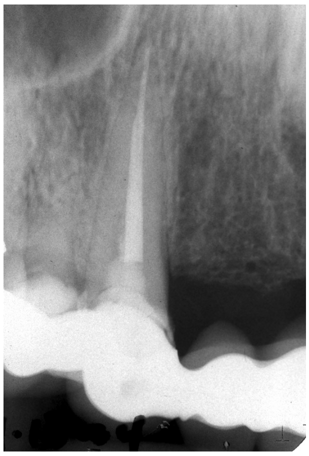

Fig. 6. Completed root canal procedures

Ten months later, the patient was seen on referral for another unrelated endodontic problem. At this time, tooth 13 was also reevaluated. The periodontium was well healed, periodontal probings were again within normal limits and the patient was free from any symptoms (Fig. 7).

Fig. 7. Recall evaluation showing absence of swelling and normal tissue contours

Discussion

Treatment planning the management of perforations that occur during access opening preparation depends on many factors that may include: 1) location of the perforation - above, at or below the crestal bone; 2) size of the perforation; 3) potential contamination of the perforated area; 4) presence or absence of periodontal inflammation and/or pathologic probings; 5) radiographic parameters using periapical films or CBCT assessment; 6) anticipated material to be used for the sealing of the perforation; 7) access to the perforation; 8) time elapsed from time of perforation to repair; 9) choice of non-surgical vs. surgical repair; and 10) skill and experience of the clinician.

When considering the repair of a labial perforation, the tissue flap design is somewhat limited to a full mucoperiosteal elevation over the tooth in question. However, creative approaches may include a combination of incision designs based on thorough probing and palation, taking into account 1) the potential for dehiscences or fenestrations; 2) the bony architecture; and 3) the quality and width of the attached gingiva. A submarginal incision over the potential defect in these cases would be contraindicated, as ultimate healing may be compromised regardless of the nature of the defect repair. Second, all efforts must be made to protect attached fibers crestal to the actual perforation to ensure proper tissue repositioning and stabilization during healing. This would also imply that great attention to tissue health and wound closure is essential to prevent the development of inflammation and a periodontal defect due to a migrating marginal periodontitis (4, 5).

Ideally any material used for a perforation repair should provide an adequate seal, be biocompatible, and have the capacity of inducing osteogenesis and cementogenesis. Over the years, many materials have been used to seal root perforations including amalgam (2, 6, 7), calcium hydroxide (8, 9), resin-reinforced glass ionomer cements (10-12), and calcium hydroxide-based root canal sealers (13). Currently, mineral trioxide aggregate (MTA) appears to be the material of choice to seal root perforations (3, 14, 15).

MTA has the property of forming hydroxyapatite crystals by crystallization at the material-dentin interface and in the interior of the dentinal tubules (16). Studies have also shown that MTA is favorable for encouraging cementoblast (17) and periodontal ligament fibroblast (18) attachment and growth. Furthermore, MTA stimulates osteoblast differentiation (19) and inhibits bone resorption by regulating osteoclast activity (20).

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Biography
Dr. Paul Lovdahl is a specialist with his practice limited to Endodontics in Bellingham, WA.

Management of an S – Shaped Canal Using Protaper Universal for Hand-Use

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Introduction

In clinical conditions, two curves can be present in the same root canal trajectory. This type of geometry is denoted as the "S" shape, and it is a challenging condition (Machado et al. 2014). Common causes of failures in such cases are primarily related to procedural errors such as ledges, fractured instruments, canal blockages, zip and elbow creations (Sakir et al. 2014). To prevent these errors, it is important to visualize and to have knowledge of the internal anatomy relationships before undertaking endodontic therapy (F. J. Vertucci 2005). Understanding these unusual root canal morphologies will help in proper debridement and cleaning and shaping of the root canal systems and thus contribute to success in endodontics (Khandelwal V 2012).

Case Report

This is a case of a 23 year old female UP dental student referred from the UP – PGH Dental Infirmary to the UE Graduate School Endo-Perio Clinic for consultation of her tooth 37 due to pain upon mastication. Upon clinical examination a fistula (Fig. 1) was observed on the buccal area of tooth 37 and gutta percha tracing (Fig. 2) was done confirming that tooth 37 was the origin of the fistula and was recommended for RCT (Fig. 3).

Fig. 1. Pre-operative photograph of tooth 37

Fig. 2. Clinical photograph of gutta percha tracing of tooth 37

HPI: Four years PTC, the patient noticed a cavity on tooth 37 and went to the dentist. The dentist restored it with composite filling. A week after, the patient felt a sharp and continuous pain but no oral medication was taken. Two weeks passed, the patient still experienced sharp pain, but it transitioned into spontaneous pain. Three weeks after, the pain subsided. Three years PTC, the patient felt dull pain upon biting. Two weeks after, the pain subsided. Two years PTC, the patient had her radiograph taken of tooth 37 as part of her Roentgenology class, and her professor noticed an apical radiolucency on the said tooth and recommended the patient to undergo RCT. The patient did not proceed with the treatment due to lack of time. A few months after, another radiograph was taken and the patient underwent diagnostic procedures on tooth 37 during her laboratory class in the Endodontic subject. Tooth 37 did not respond to thermal tests, but tested positive with percussion. A year PTC, the discomfort on tooth 37 subsided. A month PTC, the patient felt severe pain on the tooth 37 and drank pain relievers. The patient visited the UP – PGH Dental Infirmary and was referred to the UE Graduate School Endo-Perio Clinic. A few days after, the patient noticed a fistula on the buccal side of tooth 37. During consultation the patient only experienced slight pain upon mastication. The medical history is non-contributory.

Diagnostic Tests: Clinical evaluation revealed large composite restoration with a presence of a fistula on buccal area. Gutta percha tracing was done and pointed at the furcation of tooth 37. Percussion and palpation tests were positive with a 1st degree mobility on tooth 37, while the adjacent (tooth 36) and contralateral (tooth 47) were negative with palpation and percussion with the absence of mobility. Radiographic evaluation revealed recurrent caries resulting to pulpal exposure. Apical radiolucencies were observed at the mesial and distal roots. An S-shaped mesial canal was also present, and the apical foramen of the distal canal can be seen exiting approximately 2mm before the radiographic apex.

Fig. 3. Radiograph of gutta percha tracing of tooth 37

Diagnosis: Necrotic Pulp with Chronic Apical Abscess (AAE 2013 classification)

Treatment Proper: Restoration and recurrent caries were removed and access preparation was done. MB, ML and D canals were located. Patency of the canals was done using a pre-curved 6, 8, 10 files (M-Access™ Dentsply Sirona, Tulsa Dental, Tulsa OK, USA) files. ProGlider™ 21mm was used to create a smooth enlarged pathway of the canal. WL was then established using Tri-Auto ZX (J. Morita Corporation, Kyoto, Japan). Biomechanical preparation of the 3 canals was done using ProTaper Universal FHU following the manufacturer's instruction. The tooth was irrigated with 0.5% NaOCl and 17% EDTA was used. After the completion of the biomechanical preparation, the apical constriction was gauged with a .02 taper NiTi file for the selection of the master cone. The tooth was obturated with .02 taper gutta percha and slow-setting

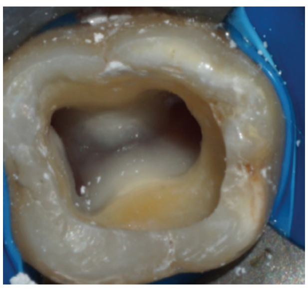

Fig. 4. Clinical photograph of complete caries removal and access preparation of Tooth 37

ZOE (ZOB-Seal™, Meta Biomed Co., Cheongju City, Korea) using lateral condensation technique. The gutta percha was cut at the orifice and GC Fuji VII™ (GC Corporation Tokyo, Japan) was used for the coronal seal. Direct occlusal onlay was done using SDR™ (Dentsply Sirona, Tulsa Dental, Tulsa OK, USA) and 3M Filtek™ (3M ESPE St. Paul, MN USA) composite resins. Radiographs were taken from preoperative, IAF, MAF, MAC, obturation and postoperative procedures showing the final restoration.

Fig. 5. Clinical radiograph showing apical foramen exiting not at the radiographic apical tip of tooth 37

Fig. 6. Master Apical File radiograph showing the curvature of the three canals

Fig. 7. Master Apical Cone radiograph

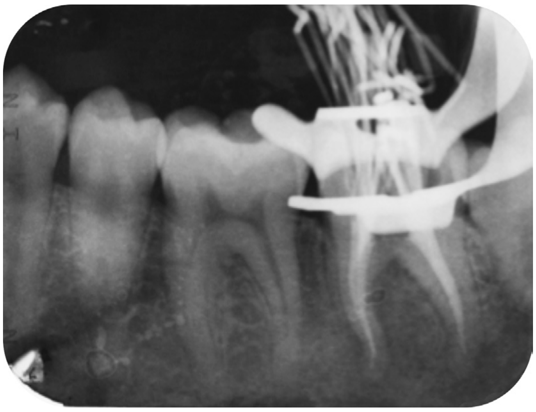

Fig. 8. Radiograph of obturation before cutting of gutta percha cones

Fig. 9. Clinical photograph of obturation after cutting of gutta percha cones

Fig. 10. Clinical photograph of tooth 37 after treatment

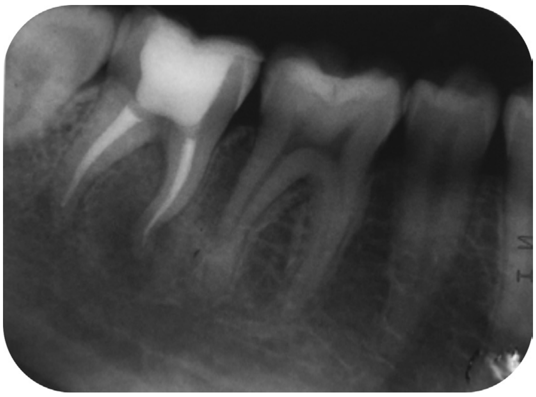

Fig. 11. Radiograph of tooth 37 after treatment

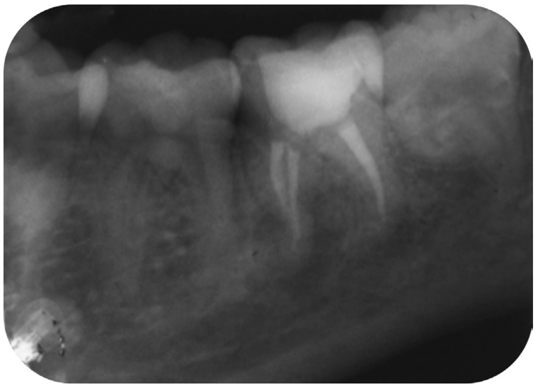

Fig. 12. Radiograph of tooth 37 after treatment using SLOB technique

Case Discussion

The diagnosis of the patient's tooth 37 was Necrotic Pulp with Chronic Apical Abscess based on the Diagnostic Terminology Approved by the AAE and ABE of 2013. A fistula was observed on the buccal surface of the said tooth. Gutta percha tracing was done and confirmed that the fistula originated from tooth 37. Percussion and palpation on the tooth both tested positive, accompanied by a 1st degree mobility.

Canal patency was confirmed using size 6, 8 and 10 files. Working length of the 3 canals was established using Tri-Auto ZX™ (J. Morita Corporation, Japan) and verified by radiograph. Canals were enlarged until size 10 file and ProGlider™ (Dentsply Sirona, Tulsa Dental, Tulsa OK, USA) 21mm was used in each canal (X Smart™ Dentsply Sirona, Tulsa Dental, Tulsa OK, USA). Pre-flaring is the pre-enlargement of canals needed to decrease the fracture risk of NiTi instruments inside the canal. With pre-flaring the taper lock on the instrument tip is decreased and a glide path is created that facilitates the penetration of the subsequent rotary instruments regardless of the technique used. The ProGlider™ starts working in the cervical to coronal region of the canal, facilitating the use of subsequent instruments by removing coronal obstructions. The ProGlider™ has also been shown to be highly effective in preserving canal anatomy and creating no apical abnormalities (D' Agostino et al. 2014).

In this case, two curvatures can be seen at the middle and apical thirds with measurements of 29 and 39 degrees respectively. An angle that is equal or greater than 20 degrees is already considered severe (Schneider SW 1971).

A major advantage of nickel titanium alloy is its ability to retain flexibility with increased taper. This has resulted in the development of groups of instruments that have a two to six times greater taper than the ISO standardized 0.02 file and/or to have a variable taper. Hand NiTi instruments can also be selected instead of rotary instruments in teeth with difficult canal anatomy and/or problematic handpiece access. Hand instrumentation is particularly useful as an adjunct to rotary preparation where the canal system exhibits severe curvature in its apical third (Saunders E 2005).

The irrigant used in this case is 0.5% NaOCl. According to a study, using 0.5% NaOCl for 30 minutes reduced CFU of E.faecalis to zero for both strains tested. This compares with 10 min for 1.0%, 5 min for 2.5% and 2 min for 5.25% *($p< 0.001$)* (Radcliffe et al. 2004). There is no consensus regarding the 'correct' concentration for use in endodontic procedures (Cheung & Stock 1993) because concentrations used have ranged from 0.5 to 10.0% w/v. (Matsumoto et al. 1987). Results of the previous study done by Matsumoto et al. in 1987 over cytotoxicity led Bystrom & Sundqvist (1983) to recommend the use of 0.5% NaOCl in order to minimize cytotoxicity yet retain antimicrobial efficacy.

In this case, the mesial canals were enlarged up to size F1 to avoid canal straightening. Published study demonstrated that varying degrees of canal straightening and transportation towards the outer aspect of the curvature were evident when curved canal enlarged with ProTaper instruments (Yoshimine Y et al. 2005).

In manual ProTaper instrumentation group, F2 file step at apical 1 mm level had significantly large centering ratio and the amount of deviation (Schafer E et al. 2004).

The apical foramen of the distal canal was also observed 2mm before the radiographic apex. The apical foramen is not always located in the center of the root apex. This distance is not always constant and may increase as the tooth ages because of the deposition of secondary cementum. It may exit on the mesial, distal, labial or lingual surface of the root, usually slightly eccentric (Chaudhari et al. 2004).

Cold lateral condensation was used over warm vertical compaction in this case due to the difficulty of obturation due to the canal curvature. Cold lateral condensation (CLC) as an obturation of technique is widely applied by dental practitioners throughout the world because of its advantages of controlled placement of gutta-percha in the root canal (Peng et al. 2007).

Direct Composite onlay restoration was the final restoration of choice. According to a study, endodontically treated teeth were successfully restored with indirect composite inlay and onlay restorations. However, the fractures that accompanied the inlay restorations were more severe and were unable to be restored (Alshiddi et al. 2006).

Although a coronal seal may be produced by a well-filled root filling, a coronal restoration with margins that prevent bacterial penetration, or both, data derived from a retrospective clinical study suggest that a favorable endodontic treatment outcome may be achieved even in poorly filled root canals when the quality of the coronal restoration is adequate (Ray and Trope 1995).

Conclusion

As seen on the radiograph, the S-shaped canal curvature retained its shape, was enlarged adequately and properly obturated up to the length with the absence of voids.

Adequate access cavity preparation, proper selection of files, good instrumentation technique and careful obturation can result to a better treatment.

Periodic recall of the case is as important to monitor the success of the treatment.

Note: This case report won 3rd place at the 2016 Dentsply Asia University Endodontic Case Contest held at Hong Kong University, November 2016.

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