

roots

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1 2014



| **CE article**

Mineral trioxide aggregate revisited:
A cement for all seasons

| **special**

“A” sequence of irrigation

| **technique**

Fifth-generation technology in endodontics:
The shaping movement



Where we have been, where we are and where we are going?

Is “Big Brother” watching us?



Dr Gary Glassman

The future of endodontics is bright and holds incredible promise as we continue to develop new techniques and technologies that will allow us to perform endodontic treatment painlessly and predictably. For the past 100 years the objective of dentistry has always been and always should be to maintain the natural dentition wherever possible. And the objective of endodontic treatment has never wavered since root canal treatment was first performed; that being to prevent or treat apical periodontitis such that there is complete healing and an absence of infection, while the overall long-term goal is the placement of a definitive, clinically successful restoration and preservation of the tooth. With the emergence of exciting technologies, clinical endodontics is seeing higher successes never seen before.

The Dental Operating Microscope (DOM), and ultrasonics instruments have allowed us to locate canals with surgical precision while allowing maximum conservation of tooth structure. The design and metallurgy of nickel titanium files (NiTi files) with its super elastic characteristics allow better maintenance of the original canal anatomy, while the motion, rotary, reciprocation, or a combination of both produce less extrusion of debris, increased resistance to cyclic fatigue, allow greater cutting efficiency and reduced time for canal shaping compared to stainless steel files.

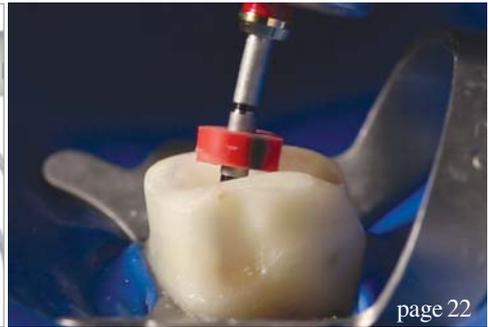
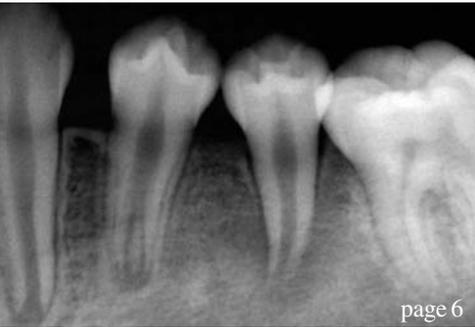
Mineral trioxide aggregate (MTA) has been and continues to be a remarkable and biocompatible restorative material that has become the standard for pulp capping and root perforation, and has salvaged countless teeth that previously had been considered hopeless.

Methods to improve disinfection in the root canal system has been the focus of perhaps the greatest international attention in endodontics. Better root canal disinfection may lead to even greater endodontic successes!

But perhaps the greatest boon to our profession and a pivotal tool in the practice of endodontics is the use of cone beam computed tomography (CBCT). Interpretation of a two-dimensional image of a three-dimensional object can make the interpretation of radiolucencies, complex dental anatomy and surrounding anatomic structures very difficult. CBCT technology, with its three dimensional rendering ability has allowed detection rates of root canal anatomy and detection of periradicular pathology to be dramatically increased. Although the detection of vertical root fractures is difficult at best with both conventional radiology and CBCT, CBCT has been shown to be an excellent supplement to conventional radiography in the diagnosis of root fractures. The differentiation between internal and external resorption; location and size, has allowed diagnosis and subsequent treatment to be more decisive and predictable. Unnecessary investigative treatment may be avoided now that three dimensional evaluation of these 'lesions' can be achieved. The same pertains to the precise nature of a perforation and the role that CBCT plays on its subsequent treatment. Post operative healing can be monitored more accurately with CBCT due to its superior resolution compared to conventional radiology and more 'informed' decisions can be made with respect to treatment planning.

Will the information that the CBCT provides force the clinician to exhaust all efforts to find all the canals and subsequently address the anatomy? Will it force the clinician to elevate their efforts to provide a better debrided canal and a more thorough obturation? Is “Big Brother” watching? I believe the answer to all of the above is YES!!

Dr Gary Glassman
 Doctor of Dental Surgery
 Fellow of Royal College of Dentists of Canada



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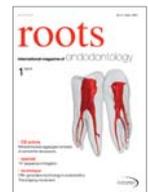
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Cover image: frontal and lateral views of a 3-D reconstruction of a maxillary first premolar showing a three-rooted canal system. This micro-CT image was developed as part of the Root Canal Anatomy Project <http://rootcanalanatomy.blogspot.com> in the Laboratory of Endodontics of the University of São Paulo in Ribeirao Preto, Brazil by Prof. Marco Versiani, Prof. Jesus Pécora & Prof. Manoel Sousa-Neto



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Mineral trioxide aggregate revisited: A cement for all seasons

Author_ Dr Gary Glassman, Canada

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_Pulpal and periradicular pathology develop when the dental pulp and periradicular tissues become exposed to microorganisms. In experimental, germ-free conditions, pulpal and periradicular tissues fail to show the development of pathosis and associated lesions when exposed to bacteria.^{1,2} The conclusion: microorganisms are the main irritants of the dental pulp and periodontium, and sealing the pathways of communication between the root canal system and the periradicular tissues is imperative if bacterial leakage is to be prevented.

An ideal orthograde or retrograde filling material that seals the pathways of communication between the root canal system and its surrounding tissues should be non-toxic, non-carcinogenic, biocompatible, insoluble in tissue fluids and dimensionally stable.^{3,4} Furthermore, the presence of moisture should not affect its sealing ability; it should be easy to use and be radiopaque for recognition on radiographs.⁴

Because existing restorative materials used in endodontics did not possess these "ideal" characteristics,⁴ mineral trioxide aggregate (MTA) was developed and recommended initially as a root-end filling material and subsequently has been used for pulp capping, pulpotomy, apexogenesis, apical barrier formation in teeth with open apices, repair of root perforations and, most recently, in revascularization cases. MTA has been recognized as a bioactive material.^{5,6}

MTA has been shown to seal off the pathways of communication between the root canal system and surrounding tissues, significantly reducing bacterial migration.⁷ It is made up of fine hydrophilic particles that set in the presence of water, and it is composed of tricalcium silicate, dicalcium silicate, tricalcium aluminate, tetracalcium aluminoferrite, calcium sulfate dihydrate (gypsum) and bismuth oxide, which provides it with radiopacity.⁸

Portland cement is the most common type of cement in general use around the world, used as a basic ingredient of concrete, mortar, stucco and most non-specialty grout. It usually originates from limestone. MTA is available as Gray MTA and White MTA. The crystalline structure and chemical composition of Gray and White MTA are similar, except for the presence of iron in Gray MTA. Both contain bismuth

Fig. 1_MTA Angelus (Angelus, Londrina, Brazil) available in resealable vials.

Fig. 1



oxide and calcium silicate oxide. Portland cement is composed mainly of calcium silicate oxide and does not contain bismuth oxide but does contain potassium. Calcium oxide is added in both Angelus White and Gray MTA (Angelus, Londrina, Brazil) to reduce the setting time, which is too long in MTA cements of other brands (Fig. 1).

MTA has a similar mechanism of action to calcium hydroxide⁹ in that the main component of the material, calcium oxide, when in contact with a humid environment, is converted into calcium hydroxide.¹⁰ This results in a high pH of 12.5, making its surroundings inhospitable for bacterial growth and producing an antibacterial effect for a long period of time. But unlike calcium hydroxide products, such as Dycal (DENTSPLY, USA) and MTA Angelus (Angelus, Brazil), it has very low solubility, so it maintains a hard, excellent marginal seal.

Finally, unlike most dental materials, MTA actually needs moisture to set, so it thrives in a moist environment. Of the commercially available MTA products, MTA Angelus is well suited for most of the indicated endodontic procedures due to its setting time of 10 minutes, compared with the four-hour setting time of the other commercially available MTA. It is also packaged in air-tight bottles, allowing the practitioner to use only what is exactly needed, without introducing undue moisture into the remainder and without waste.¹¹

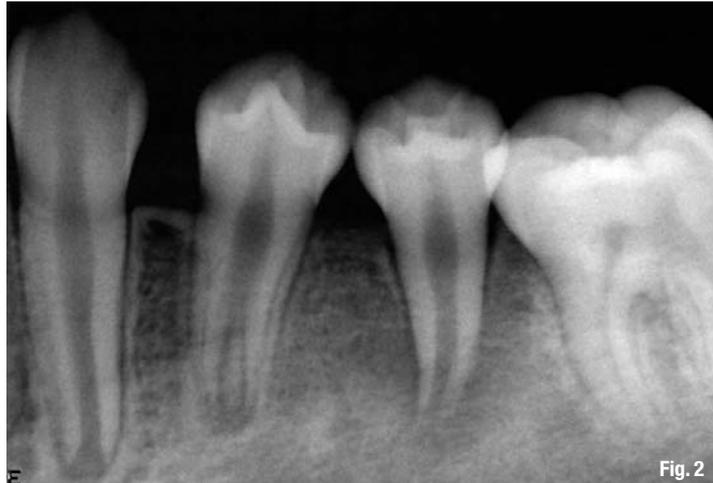


Fig. 2

Endodontic revascularization

Treatment of the immature, non-vital tooth with apical pathology presents several challenges. The mechanical cleaning and shaping of such a tooth with a blunderbuss canal is difficult, if not impossible, to achieve predictably. The thin, fragile lateral dentinal walls can fracture during mechanical filing, and the large volume of necrotic debris contained in a wide root canal is difficult to completely disinfect.¹²

A new technique is presented to revascularize immature permanent teeth with apical periodontitis. The canal is disinfected with copious irrigation and a

Fig. 2 Radiograph of a necrotic lower left second premolar with large periradicular radiolucency with an incompletely formed root, both longitudinally and laterally.



Fig. 3a

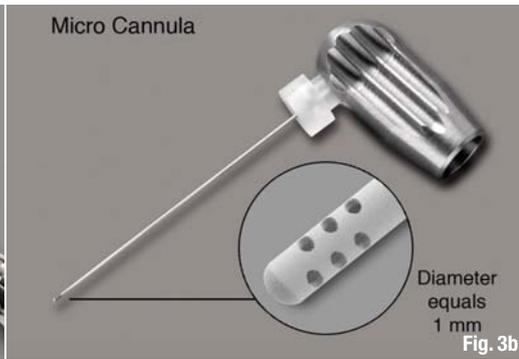


Fig. 3b



Fig. 3c

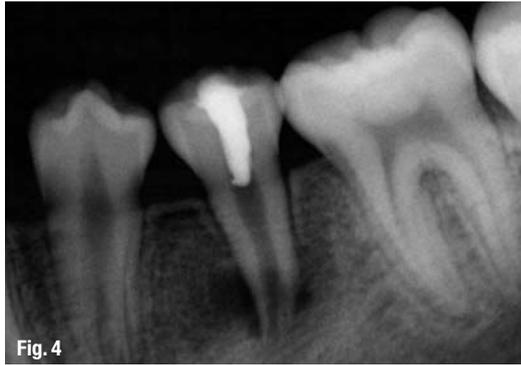


Fig. 3d

Fig. 3a-d EndoVac apical negative pressure delivery system (Axis/SybronEndo, USA).

Fig. 4 After the triple antibiotic paste was inserted into the canal, a temporary restoration was placed.

Fig. 5 Blood clot was induced and MTA Angelus (Angelus, Brazil) was placed over top and then the tooth was restored with bonded composite.



combination of three antibiotics. After the disinfection protocol is complete, the apex is mechanically irritated to initiate bleeding into the canal to produce a blood clot to the level of the cemento-enamel junction.

A double seal of the coronal access is then made, first with MTA over the blood clot and then a bonded composite. The combination of a disinfected canal, a matrix into which new tissue could grow, and an effective coronal seal appears to have the ability to produce an environment necessary for successful revascularization.¹³ The development of normal, sterile granulation tissue within the root canal is thought to aid in revascularization and stimulation of cementoblasts or the undifferentiated mesenchymal cells at the peri-apex, leading to the deposition of a calcific material at the apex as well as on the lateral dentinal walls.¹²

A case of mistaken identity

A 15-year-old girl of Asian descent was referred to the author's private endodontic clinic for evaluation on the lower left second premolar. The healthy young patient with an unremarkable medical history presented with a history of buccal swelling of the left mandibular area and discomfort to direct pressure on the tooth.

On clinical examination, the patient was asymptomatic, and the tooth appeared intact, without caries. The presence of an enamel pearl on tooth #45 suggested that one may have been present on this tooth, which was fractured during function, resulting in a microexposure and necrosis of the pulp. The tooth had an open apex associated with a large radiolucency (Fig. 2). Periodontal probings were within normal limits for all teeth in the lower left region. Diagnostic testing was negative to cold and electric pulp testing, with mild sensitivity on percussion and palpation. Because of the presence of a wider than 4 mm open apex and thin dentinal walls prone to possible future fracture,¹⁴ it was felt that an attempt to achieve regeneration of the pulp should be made by a technique similar to that described by Rule and Winter¹⁵ and Iwaya et al.¹⁶

An access cavity was made, purulent hemorrhagic drainage obtained, and the necrotic nature of the pulp confirmed. The root canal was slowly flushed with 20 ml of 5.25 per cent NaOCl for 15 minutes. It was delivered with the master delivery tip and the macro canulae of the EndoVac apical negative pressure delivery system (Axis/SybronEndo, USA) (Fig. 3). The canal was dried with paper points, and a mixture of ciprofloxacin, metronidazole and minocycline paste as described by Hoshino et al.¹⁷ was prepared into a creamy consistency and spun down the canal with a lentulo spiral instrument to a depth of 8 mm into the canal. The access cavity was closed with a sterile cotton pellet placed in the chamber and blue Cosmescore (Cosmedent, USA) (Fig. 4).

The patient returned three weeks later and was asymptomatic. The access was opened and the canal again flushed with 20 ml of 5.25 per cent NaOCl for 15 minutes. It was delivered in the same manner as in the first visit with the master delivery tip and the macro canulae of the EndoVac apical negative pressure delivery system. The canal appeared clean and dry, with no signs of inflammatory exudate. A #30 K-file was introduced into the canal until vital tissue was felt at a depth of 10 mm into the canal space. It was used to irritate the tissue gently to create some bleeding into the canal. The bleeding was stopped at a level of 5 mm below the level of the CEJ and left for 30 minutes, so that the blood would clot at that level.

After 30 minutes, the presence of the blood clot to approximately 5 mm apical of the CEJ was confirmed. White mineral trioxide aggregate, MTA Angelus was carefully placed over the blood clot and allowed to set for 20 minutes. After confirmation was achieved of its set, a bonded composite was placed and the patient was scheduled for follow-up in three months. Unfortunately, the MTA was placed further apically then would have been preferred (Fig. 5).

At the three-month follow-up appointment, the patient was totally asymptomatic, and the radiograph showed complete resolution of the radiolucency, with closure of the apex and thickening of the dentinal walls. Pulp testing was inconclusive (Fig. 6).



Fig. 6 Three-month recall reveals excellent longitudinal apical and lateral dentin development.

Fig. 7 One-year recall radiograph reveals that definitive endodontics had been completed by the patient's new dentist.

At the one-year follow-up appointment, the radiograph revealed that treatment had been performed on this tooth by another dentist, different from her original dentist who made the initial referral. The new dentist, not familiar with revascularization treatment performed, had entered the root canal space, cleaned it out and obturated it with gutta-percha and sealer. Fortunately, the treatment was successful (Fig. 7).

Conclusion

The future of endodontics is bright as we continue to develop new techniques and technologies that will allow us to perform treatment painlessly and predictably and continue to satisfy one of the main objectives in dentistry, that being to retain the natural dentition wherever possible and wherever practical.

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about the author

roots



Gary D. Glassman, DDS, FRCD(C), graduated from the University of Toronto, Faculty of Dentistry in 1984; and graduated from the Endodontology Program at Temple University in 1987, where he received the Louis I. Grossman Study Club Award for academic and clinical proficiency in endodontics. The author of numerous publications, Glassman lectures globally on endodontics, is on staff at the University of Toronto, Faculty of Dentistry, in the graduate department of endodontics, and is adjunct professor of dentistry and director of endodontic programming for the University of Technology, Jamaica. He is a fellow of the Royal College of Dentists of Canada and the endodontic editor for *Oral Health dental journal*. He maintains a private practice, Endodontic Specialists, in Toronto, Ontario, Canada. He can be reached through his website, www.rootcanals.ca

Apexification with mineral trioxide aggregate (MTA): A case report

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_Abstract

Mineral trioxide aggregate (MTA) was introduced as an alternative to traditional materials for the repair of root perforations and pulp capping and as a retrograde root filling owing to its superior biocompatibility and ability to seal the root canal system. Traditionally, calcium hydroxide ($\text{Ca}(\text{OH})_2$) has been the material of choice for the apexification of immature permanent teeth but MTA holds significant promise as an alternative to multiple treatments with $\text{Ca}(\text{OH})_2$. This paper discusses the use of $\text{Ca}(\text{OH})_2$ as a traditional apexification material and provides an overview of the composition, properties and applications of MTA with emphasis on its use in the apexification of immature permanent teeth. A case report is presented to demonstrate its use.

_Introduction

Trauma causes cessation of root development and fragile root canals become weak, making it difficult to create an artificial barrier or induce closure of apical foramina with calcified tissue.¹ MTA was first described in dental scientific literature in 1993,² and was given approval for endodontic use by the US Food and Drug Administration in 1998. Up to 2002, only one MTA material, consisting of grey-coloured powder, was available and then white MTA was introduced. Both formulae contain 75% Portland cement, 20% bismuth oxide and 5% gypsum by weight.

The aim of apexification is the production of mineralised apical tissue and to limit bacterial infection in immature anterior tooth. The inadequacy of $\text{Ca}(\text{OH})_2$

Fig. 1_ Radiographic examination found involvement of the pulpal tissue and the presence of periapical lesions due to dental trauma.

Fig. 2_ The first attempt to place MTA in the right maxillary central incisor (tooth 11).



Fig. 1



Fig. 2



Fig. 3



Fig. 4

Fig. 3 The apical plug of MTA in the apical third of the canal.

Fig. 4 Conventional obturation with gutta-percha.

apexification owing to the need for multiple visits for refreshment and reinfection because of its temporary seal^{3,4} led to the use of MTA, which forms a barrier and prevents microleakage. It is biocompatible and facilitates the formation of dentinal bridges and cementum, and regeneration of the periodontal ligament.⁵ It has the ability to stimulate cytokine release from the bone cells, indicating that it actively promotes hard-tissue formation.⁶

Case report

A 14-year-old female patient suffering from painful symptoms caused by her maxillary central incisors was examined in the Department of Pediatric Dentistry and Orthodontics of Al-Quds University in Jerusalem for evaluation and treatment.

Investigation revealed a trauma four years before associated with an enamel–dentine fracture. No treatment had been performed at that time. Approximately two years later, a fluctuant swelling developed in the apical area of the teeth. Symptoms also included tenderness to percussion. Drainage was established by lingual access in the pulp chamber. Treatment was interrupted by the patient for no reason and, four years later, an attempt at apexification using $\text{Ca}(\text{OH})_2$ paste was carried out for six months by another dentist, but no apexification was observed for either tooth.

When the patient was referred to our department, extra- and intra-oral examinations (including

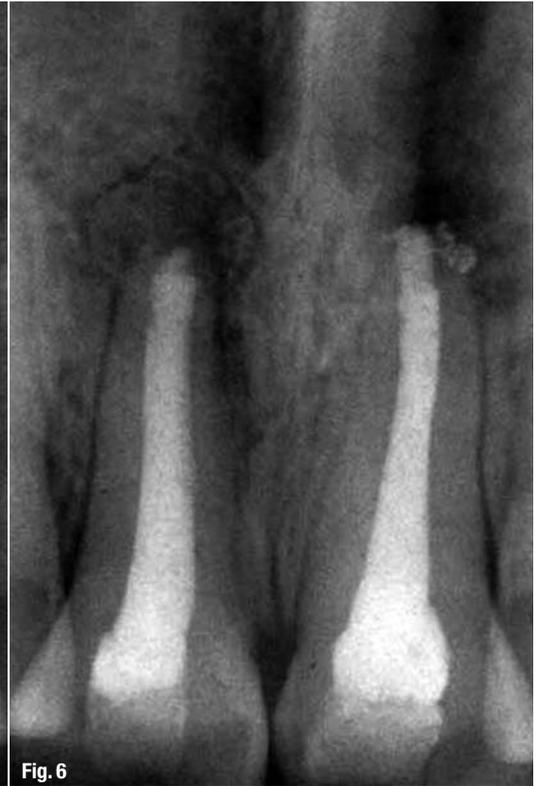
radiology) were performed through which it was established that the left and right maxillary central incisors were in normal position with enamel–dentine fracture. The root canals were wide, the roots incompletely formed with open apices and there were periapical lesions (Fig. 1). Cleaning and shaping of the root canal system was achieved under rubber dam isolation. The solution used for irrigation was 2.5% sodium hypochlorite. Root canal length was determined using an apex locator and confirmed radiographically. $\text{Ca}(\text{OH})_2$ paste was placed in the canals for one week for disinfection. During the second appointment, $\text{Ca}(\text{OH})_2$ was removed by mechanical instrumentation and flushed from the root canals by means of sterile water irrigation. The canals were dried using sterile paper points. MTA was prepared immediately before use, placed into the canals with an MTA carrier and compacted with a hand plugger to create an apical plug of 3 to 4 mm in accordance with the manufacturer's instructions. A radiograph was taken to check whether any apical extrusion had occurred.

The apical plug failed in the first attempt on the right maxillary central incisor (Fig. 2). The MTA was rinsed out with sterile water and the procedure was repeated (Fig. 3). Moist paper points were placed in the canals and the access cavities were closed with a temporary restorative material, IRM (DENTSPLY).

Two days later, the coronal and middle thirds of the canals were filled with gutta-percha by a vertical

Fig. 5 _ Radiographic follow-up at six months.

Fig. 6 _ Radiographic follow-up at 12 months.



warm compaction technique and the access cavities were sealed in conjunction with the final restoration (Fig. 4). Periradicular healing was assessed clinically and radiographically at six, eight and 12 months (Figs. 5 & 6). The use of MTA followed by conventional endodontic treatment resulted in apical formation in the two central incisors (Fig. 6).

Discussion

The traditional use of Ca(OH)_2 apical barriers has been associated with unpredictable apical closure, extended time taken for barrier formation, difficulties in patient compliance, and the risk of reinfection resulting from the difficulty in creating long-term seals with provisional restorations and susceptibility to root fractures arising from the presence of thin roots or prolonged exposure of the root dentine to Ca(OH)_2 .⁷ Thus, the one-visit apexification technique is gaining popularity. One-visit apexification has been defined as the non-surgical condensation of a biocompatible material into the apical end of a root canal. The rationale is to establish an apical stop that would enable the root canal to be filled immediately. Torneck et al.⁸ found that when apical closure takes place clinically with Ca(OH)_2 , there is incomplete bridging of the apex histologically. Periapical inflammation persists around the apices of many teeth because necrotic tissue exists in the corners and crevices of the bridge.

A major target area of biomedical research is the restoration of lost bone. To this end, a resorbable tri-

calcium phosphate ceramic was developed. Koenigs, Brilliant and Driskell⁹ found that use of this material induced apical closure in vital teeth of primates with open apices. Regeneration of the periodontal ligament occurred around the apices of teeth and it was associated with minimal inflammatory response. Herbert documented the long-term success of using a tricalcium phosphate plug as an apical barrier for one-visit apexification. In other studies, teeth with open apices were obturated using an apical barrier with dentine and Ca(OH)_2 plugs or dentine chips and hydroxyapatite.¹⁰

There is increasing popularity of the one-visit apexification technique using MTA as an osteoconductive apical barrier. MTA is relatively non-cytotoxic and stimulates cementogenesis. This material generates a highly alkaline aqueous environment by leaching of calcium and hydroxyl ions, rendering it bioactive by forming hydroxyapatite in the presence of phosphate-containing fluids. Unlike the extended use of Ca(OH)_2 in immature roots, prolonged filling of these roots with MTA did not reduce their fracture resistance.¹¹

Torbinejad¹² reported the ingredients in MTA as tricalcium silicate, tricalcium aluminate, tricalcium oxide and silicate oxide with some other mineral oxides that were responsible for the chemical and physical properties of aggregate. The powder consists of fine hydrophilic particles that set in the presence of moisture. The hydration of the powder results in a colloidal gel with a pH of 12.5 that will set in approxi-

mately 3 hours. MTA has a compressive strength equal to intermediate restorative material and SuperEBA (Bosworth) but less than that of amalgam. It is commercially available as ProRoot MTA (DENTSPLY), and has been advocated for use in the immediate obturation of an open root apex.

MTA has the ability to induce cementum-like hard tissue when used adjacent to the periradicular tissue. MTA is a promising material as a result of its superior sealing property, its ability to set in the presence of blood and its biocompatibility. Moisture contamination at the apex of tooth before barrier formation is often a problem with other materials used in apexification. As a result of its hydrophilic property, the presence of moisture does not affect its sealing ability. Shabahang et al¹³ examined hard-tissue formation and inflammation histomorphologically after treating open apices in canine teeth with osteogenic protein-1, MTA and Ca(OH)₂. MTA induced hard-tissue formation with the most consistency, but the amount of hard-tissue formation and inflammation was not statistically different among the three materials.

MTA has demonstrated the ability to stimulate cells to differentiate into cells that form hard tissue

and to produce a hard-tissue matrix. A number of animal studies have demonstrated a more predictable healing outcome when MTA is used compared with teeth treated with Ca(OH)₂.¹⁴ In a prospective human outcome study, 57 teeth with open apices were obturated with MTA in one appointment. Forty-three of these cases were available for recall at 12 months, of which 81% of cases were classified as healed.¹⁵ Despite its good physical and biological properties, its extended setting time has been a disadvantage. Calcium chloride has been used to stimulate the hardening process of MTA and studies have shown that both its physico-chemical properties and sealing ability were improved by the addition of calcium chloride.

_ Conclusions

Based on this study's results, the following conclusions can be made:

- _ MTA showed clinical and radiographic success as a material used to induce apical closure in necrotic immature permanent teeth.
- _ MTA is a suitable replacement for Ca(OH)₂ for the apexification procedure.

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Biological & Conservative



“A” sequence of irrigation

Author_ Dr Philippe Sleiman, Lebanon

Fig. 1_EndoVac system.



During the last several years, endodontics has progressed to the point where treatment has become less traumatic for the patient and less stressful for the dentist. While the use of nickel-titanium rotary instruments has allowed us to gain time during endodontic treatment, it can tempt us to neglect one of the main objectives of endodontics, that is the cleaning, or the chemical preparation, of the root canal system—we need to be clear on whether we are treating a canal or a root canal system. The main goal of root canal treatment is to completely eliminate the various components of the pulpal tissue, calcification and bacteria; to place a hermetic seal to prevent infection or reinfection; and to promote healing of the surrounding tissues, if needed.

There are many root canal preparation sequences available, such as crown-down, step-back and modified step-back. There are also many techniques for filling the root canal system, such as vertical compaction of warm gutta-percha, System B (SybronEndo) and lateral condensation. But do we have a protocol or a sequence for irrigation? In 2005, my irrigation protocol suggestions were published in an article in the *Oral Health* journal, and what follows here is an update thereof.

We must ask ourselves why we irrigate, and what irrigation protocol will provide the cleanest canal. In this context, let us remember that shaping is the result of endodontic instruments opening the space of lesser resistance, or what it is more commonly referred to as the main canal, while the cleaning results from irrigation. Therefore, there are two types of preparation. The first one is chemical and the sec-

ond one is mechanical. It is the chemical preparation that will be discussed in the scope of this article.

It has been proven that there is a close correlation between these two types of preparation. In fact, apical preparation with a larger tip size and smaller taper, for instance ISO size 35.04 can help to reduce the level of colony-forming units dramatically compared with apical preparation of tip size 25.06. This outcome confirms that by performing a larger tip size apical preparation we can disrupt the biofilm mechanically, thus facilitating the work for the chemicals. Also, such apical preparation will allow for a greater quantity and stable concentration of the irrigating solution, which will therefore better eliminate the organic component and the smear layer from the root canal system walls. The files can clean only parts of the root canal system. They create a reservoir that can hold various irrigating solutions that will access and clean portions of the root canal system, which the instruments cannot reach. The access cavity, having four walls, will create a reservoir for the irrigating solutions to be frequently and continuously refreshed, which can be done safely with the EndoVac system (SybronEndo; Fig. 1) using the Master Delivery Tip for 20 to 30 seconds each time.

In endodontics, the most commonly used irrigating solution is sodium hypochlorite (NaOCl). It has many desirable qualities and properties. It has bactericidal cytotoxicity characteristics and it dissolves organic matter, while providing minor lubrication. However, NaOCl alone is not sufficient for complete cleaning of the root canal system. NaOCl has no effect on the smear layer and its high surface tension does not allow it to clean and disinfect the totality of the root canal system. For this reason, and depending on the specific clinical situation, one has to use other irrigants in combination with NaOCl.

The various irrigants that can be used consecutively and according to the clinical situation are as follows:

- _17% EDTA (SmearClear, SybronEndo);
- _0.2% chlorhexidine;
- _5.25% NaOCl;
- _50% citric acid; and
- _distilled water.

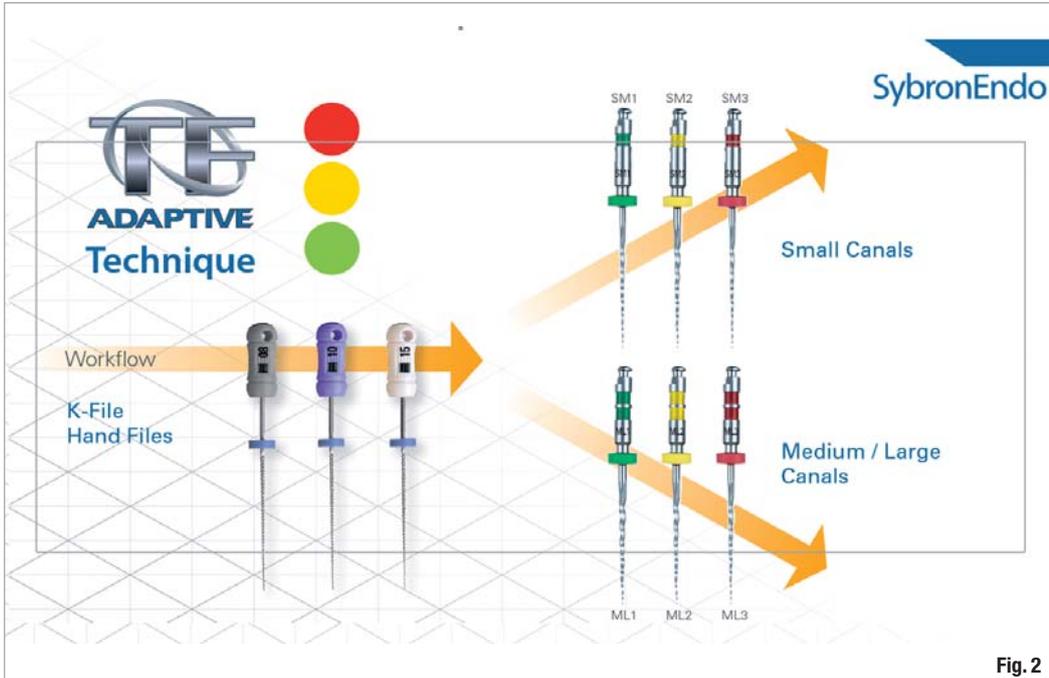


Fig. 2 SM1 file and SmearClear (Sybron Endo).

In general, after preparing the access cavity, an endodontic file is introduced into the root canal. However, when a file is introduced immediately, it spreads bacterial toxins into the root canal system and into the periapical area, which will negatively affect the prognosis of the endodontic treatment owing to the likelihood of a post-operative flare-up. The breakdown and the accumulation of the pulp tissue and its collagen during the initial file penetration may, from the very beginning, create an organic plug within the root canal.

Irrigation sequence during root canal treatment of a vital tooth

In this clinical situation, we have to face the challenge of treating the complexity of the different components of the pulp, and eventually the presence of

bacteria and the smear layer produced during canal enlargement. We suggest beginning the treatment with 30-second irrigation with NaOCl via the Master Delivery Tip to destroy the majority of the pulp tissue inside the access cavity and provide a better view of the canal orifices by controlling bleeding and preventing any collagen plugs from forming. Also, chemical interaction between NaOCl and collagen can help us detect the presence of canals by observing the gas bubbles coming out from the orifice into the access cavity.

A second application of NaOCl and its activation is performed with a K-file (size 8 or 10). This will disorganise the pulpal tissue in both the cervical and middle thirds of the root canal. The M4 handpiece (SybronEndo), with its reciprocating movement of 30 degrees, on the Elements motor can be a great tool

Figs. 3a & b Case 1: Treatment of a maxillary second molar. The patient was referred, since only two canals had been found and the tooth was still symptomatic. It took some time to find the third canal, which shared the same orifice but split off deeper inside (a). The post-op X-ray shows the isthmus filled between those two canals and a lateral exit in the middle of the palatal root that was causing an external infection (b).



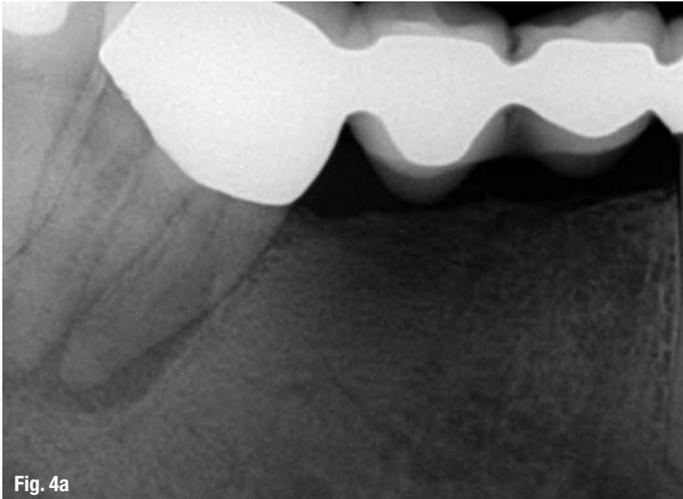


Fig. 4a



Fig. 4b

Figs. 4a & b Case 2: The patient was referred to establish whether it was possible to save the molar (a). As no crack was found, a single-visit treatment was performed, and the six-month follow-up found good healing (b).

for creating a space of lesser resistance in the root canal system, agitating the NaOCl inside it in order to promote chemical interaction and helping dissolve the organic components.

Once the preparation of the canal has begun, with the use of the SM1 file (Fig. 2), or any rotary file, SmearClear (17% EDTA, cetrimide and surfactants) must be used. EDTA is an organic acid that eliminates the mineral component, or the smear layer, formed during the root canal enlargement. The greatest amount of smear layer is produced during the use of rotary files. A surface tension inhibitor will allow for better contact with the dentine and, hence, for a higher efficiency of the product.

It is advised to alternate between EDTA and NaOCl from the beginning of the preparation in order to eliminate the mineral layer before it thickens and becomes condensed inside the canal system, closing access to lateral and accessory canals and dentinal tubules, which would altogether mean that by the end of the preparation the system would be blocked with only the main canal open. I like to compare this technique to cleaning out the snow during a week-long snowstorm: if we do not clean the snow from our door daily, we will be blocked off inside by the end of the storm and it will take a great deal of effort to remove the snow afterwards to open the door.

Ultrasonic activation of the irrigating solution with a small-diameter file is recommended for more efficient chemical preparation. However, we need to ensure that the tip stays at least 5 mm away from the working length to avoid pushing any chemical outside the root canal and into the periodontal ligament and supporting bone. Each time a rotary file is used, an irrigating solution must be present inside the canal, and this should be EDTA. The use of EDTA early in the sequence facilitates the flow of the other irrigants, especially NaOCl or chlorhexidine, into the lat-

eral canals, isthmuses and the whole root canal system, allowing for proper chemical preparation of the root canal system. Also, 17% EDTA plays an important role in the reduction of inflammatory reaction by inhibiting the affinity of macrophages to the vasoactive peptides in the pulpal tissue. The total exposure time of 4 to 5 minutes for EDTA inside the canal must not be exceeded.

After using the SM1 file (TF Adaptive sequence, SybronEndo), we need to neutralise the acidity of the EDTA in order to avoid a chemical interaction between the acid and the base. (As a general rule, one should always avoid any kind of chemical interactions inside the root canal. Saline or distilled water can be used to wash out the previous chemical prior to the use of a different one.) Specifically, an acid and a base interaction leads to the formation of gas bubbles, which can create the so-called dead water zone, or vapour lock, not only at the end of the main canal or at the entry to a lateral canal, but also anywhere inside the root canal system. The interaction can also form a small protective layer of air bubbles on the surface of the collagen fibres, preventing their good contact with NaOCl for a better dissolving action.

Irrigation with NaOCl for 30 seconds is performed with the Master Delivery Tip, followed by rinsing with saline or distilled water prior to the next application of EDTA and the use of the SM2 file. Once the file has been used, the acid is neutralised, and EndoVac's MacroCannula is used to remove and deeply neutralise the previous chemical. Then, another 30-second irrigation with NaOCl is performed in each canal prepared with the SM2 file with the MacroCannula. The idea is to create an area of negative pressure inside the root canal system to draw the NaOCl delivered into the access cavity deeper into the system safely, thus creating a current of fresh irrigant inside the root canal system for a more efficient chemical interaction and organic tissue dissolution.

The same sequence is used for the SM3 file. An EDTA solution is placed during apical preparation with this final rotary file, followed by saline or water, but using EndoVac's MicroCannula, since it fits into the apical area and its lateral holes can create negative pressure (short-term vacuum) exactly at the working length, removing all the air bubbles as well. Then, 30 seconds of NaOCl irrigation in each canal follows, with a small modification: since the MicroCannula holes are small, it needs a bit more time to evacuate fluids from the apical area; therefore, irrigation with the Master Delivery Tip is performed for 10 seconds, followed by a 5-second pause, for three such cycles in each canal.

Finishing the chemical preparation of the root canal system starts first with flushing out NaOCl with saline and drying the space with the MicroCannula. Then, chlorhexidine is introduced into each canal for 10 seconds to inhibit the dentine's matrix metalloproteinases for better stability of the bonding, since we use bonded root canal sealer for obturation. The final and very important step is to flush all the chemicals from the root canal system with distilled water or saline. The reasoning is as follows:

_ Since water is not compressible, using the cannulas to suction the fluids from the root canal system will allow the sealer to enter and seal the system.

_ Any chemical can be toxic and pushing chemicals outside the root itself with the master cone can create some inflammation, which may result in post-operative pain; therefore, it is best to remove all liquids remaining in the canal.

_ Chemicals can interact with the components of some sealers and consequently reduce either their bonding or sealing ability, or even react with some radio-opacifiers, such as bismuth, and cause a chemical reaction that could destroy the obturation material. Oxygen can inhibit bonding, while EDTA can also have a negative effect on the sealer-dentine interaction.

_Irrigation sequence during root canal treatment of a necrotic tooth

The main difference between vital and necrotic teeth is the absence, though partial, of the pulpal parenchyma with the abundance of bacteria present in the latter. For this reason, the irrigation sequence is different. Irrigation should be initiated with either NaOCl (5.25%) for its antibacterial effect or with chlorhexidine (0.02%) for 30 to 40 seconds to eliminate the various bacterial types present in the root canals and dentinal tubules. Distilled water is used to neutralise the effect of each of these irrigants. Then, the same irrigation sequence as described previously for vital teeth is repeated.

_Discussion

Many types of irrigants can be used, such as hydrogen peroxide, anaesthetic solutions, physiological serum, and deionodised water. What is proposed is an irrigation sequence that may be more complex depending on the clinical situation. The alternation between irrigants (NaOCl, chlorhexidine, distilled water, and EDTA) is essential for the cleaning of the root canal system.

The reduced preparation time when using rotary NiTi instruments is balanced by copious irrigation for better cleaning of the root canal system, which will contribute to the increased success rate of endodontic treatment.

The chemical preparation will help us succeed in adequate cleaning of the main canal and its systems. Cleaning is followed by 3-D obturation to fill all the cleansed and prepared canals.

_Conclusion

The irrigation procedure is often dismissed as simple during endodontic treatment; however, it must not be overlooked, since it is crucial to the success of endodontic treatment.

Irrigation, which is too often reduced to a needle on the tray, has to be systematically evaluated in order to become an endodontic entity with a precise time schedule and procedural systematisation.

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PHAST PIPS:

The photoacoustic wave of the future?

Author_ Dr Reid Pullen, USA



_ Photon induced photoacoustic streaming (PIPS) is a low-energy (20mJ) technique based on very short Er:YAG laser-emitted photons introduced into an irrigation solution inside the access of the tooth. This process, which uses the Lightwalker (Lasers4Dentistry), introduces an aggressive and effective photoacoustic streaming or tidal wave of irrigation solution into canals, accessory anatomy and deep into the dentinal tubules of the root canal system. PHAST PIPS can be described as "irrigation on steroids".

The goal of PHAST PIPS is to greatly enhance chemical debridement of the complete root canal system in concert with mechanical instrumentation to reduce the microorganism load to as low as possible.

This article will introduce four PHAST PIPS cases and will discuss why to use PIPS, how to use PIPS and when to use PIPS.

_ Case 1

A 20-year-old female patient presents to the office with instructions from her dentist stating: "Please remove the file and finish the root canal." The patient's dentist initiated root canal treatment on #37 two days prior and separated a rotary instrument in the apical one-third of the distal canal (Fig. 1a).

Clinical testing revealed a temporary crown with percussion and bite sensitivity. Probing, palpation and mobility were within normal limits. Endodontic therapy was initiated on tooth #37 with a diagnosis of previously initiated therapy with symptomatic apical periodontitis.

Upon access, it was noted that the coronal shape was underprepared. The coronal flare was com-



Fig. 2a



Fig. 2b

pleted with a ProTaperSx (DENTSPLY) orifice opener and Gates Glidden #2 and #3. The PIPS irrigation technique with the Lightwalker Er:YAG laser was used for 30 seconds with the access chamber continually flushed with 6 per cent sodium hypochlorite.

After applying this technique in more than 1,500 cases, I have found that "PIPS-ing" after the coronal flare allows easier and quicker negotiation, which then helps the clinician to obtain an accurate working length.

After drying the three canals with the EndoVac Macrocanula, the top portion of the file was visualized. The UT4 (eie2) ultrasonic tip was used in 10-second increments to vibrate the top of the file and create lateral space to allow file movement and escape. After each ultrasonic use, the canals were flushed with sodium hypochlorite and the distal canal was dried with the macrocanula to allow visualization of the file. After the third ultrasonic

increment, the file loosened but did not dislodge. The PIPS technique was used again for 30 seconds, alternating with ultrasonic vibration of the file. On the third PIPS use, the file floated out of the canal.

An accurate working length was established with a Root ZX (J. Morita) and an open glide path created. The canals were shaped with the WaveOne Primary (DENTSPLY) reciprocating rotary file and obturated with a resin-based sealer (Fig. 1b).

Case 2

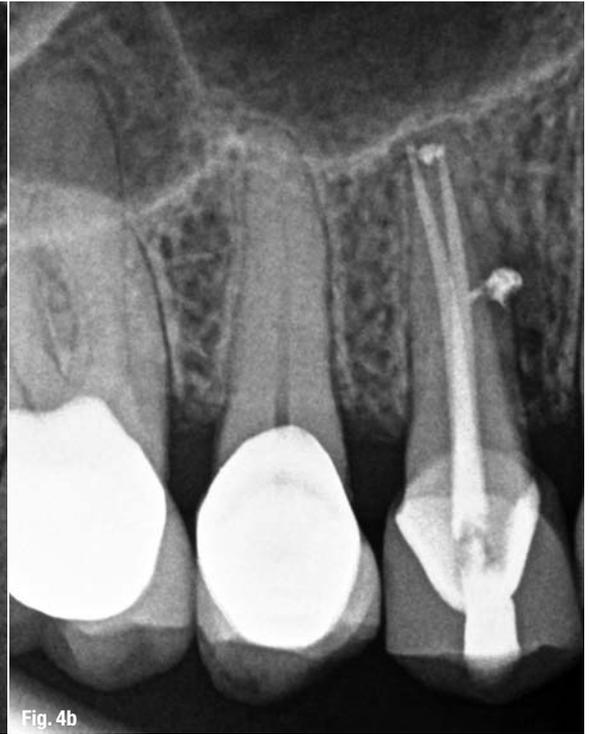
An asymptomatic male patient presents to the office with a referral card with the instructions: "Please remove the separated file, fill and leave post space." The root canal was initiated by his general dentist one week prior. During the procedure, a file was separated in the palatal canal. The dentist was able to shape and obturate the buccal canal. The diagnosis was listed as previously initiated therapy with asymptomatic apical periodontitis.



Fig. 3a



Fig. 3b



The root canal was initiated and the access was opened. A 30-second PIPS cycle with the Lightwalker Er:YAG was completed with 6 per cent sodium hypochlorite to clean out any residual debris. The Endo-Vac Macrocanula was used to remove fluid from the canal. The top of the file was visualized through the microscope.

The UT4 (eie2) ultrasonic tip was used in 10-second increments to help vibrate the top of the file and to create lateral space. The file was slightly loosened after a few ultrasonic uses, but not completely dislodged. Two 30-second PIPS cycles were completed in between and after ultrasonic use. On the third PIPS cycle of the procedure, the file floated out of the canal. (In some cases I was unable to remove a separated file with ultrasonics and PIPS.)

The canal was then properly shaped and obturated with an apical plug of zinc oxide eugenol sealer and gutta-percha using a warm-vertical technique. A post space was left as requested by the general dentist (Figs. 2a & b).

Case 3

A male patient presents to the office with a history of chewing pain and a constant ache on #26 of one-week duration. Clinical tests reveal #26 is percussion, bite-stick and cold-test negative, and a diagnosis is listed as pulp necrosis with symptomatic apical periodontitis.

Root canal treatment was initiated on tooth #26, and four necrotic canals were located. The coronal flare shape was completed, and the PIPS (Lightwalker Er:YAG) irrigation method was used with 6 per cent sodium hypochlorite for 30 seconds. A working length was obtained and an open glide path was achieved with the Path File rotary files (DENTSPLY). An open glide path was difficult to achieve because of length and angulation of the canals.

The shaping procedure commenced with the WaveOne Primary file 0.08/#25 tip (DENTSPLY). The shaping procedure was slow and difficult, and it took five to seven passes (a pass is defined as an entry into the canal, up-and-down shaping, and exiting the canal) with the WaveOne Primary file to fully shape all four canals to working length.

The PIPS technique with 6 per cent sodium hypochlorite was used twice during the shaping procedure to help clear the dentinal debris. Patency was established after every pass with a #10 K file. The final protocol PIPS was completed to help chemically debride the root canal system, and the canals were obturated with a zinc oxide eugenol sealer and gutta-percha using a warm-vertical technique.

Upon completion it was noted that an accessory canal in the palatal and a lateral canal in the mid-root of the distobuccal canals were filled with sealer (Figs. 3a & b).

Case 4

A male patient presents to the office with an on-and-off toothache of approximately 10 months' duration. Clinical tests reveal a percussion- and bitestick-sensitive maxillary first bicuspid. The tooth does not respond to cold tests. The diagnosis is listed as pulp necrosis with symptomatic apical periodontitis. Radiographs show an apical and lateral radiolucency.

Root canal treatment was initiated on tooth #14, and two necrotic canals were located. The coronal flare or opening was completed, and a 30-second PIPS cycle with 6 per cent sodium hypochlorite was initiated. Working length and glide path were obtained, and the canals shaped with the WaveOne Primary (DENTSPLY) reciprocating file. During the shaping procedure, a 30-second PIPS bleach cycle was completed.

The canals were obturated with a zinc oxide eugenol sealer and gutta-percha using a warm-vertical technique. The post-operative radiographs showed a lateral canal filled with gutta-percha leading to the lateral radiolucency (Figs. 4a & b).

Conclusion

Along with mechanical debridement, the PIPS Lightwalker Er:YAG irrigation technique shows great potential in debridement of the root canal system, including main canals, lateral/accessory canals, isthmuses and dentinal tubules (why to use PIPS). Various studies^{1,2} show that the PIPS technique greatly reduces bacterial flora. As always, ongoing research is needed to show how much the PIPS Lightwalker Er:YAG can really accomplish in debridement.

The PIPS Lightwalker Er:YAG technique works best when the dental assistant irrigates the access continuously while suctioning any excess solution running from the area. The trick is to keep the access chamber full of solution so that the 4 mm unsheathed portion of the PIPS tip stays submerged in fluid. This can be accomplished by the dental assistant moving the surgical suction closer or farther away from the access to allow just the right amount of solution (how to use PIPS).

I recommend using the PIPS Lightwalker Er:YAG technique to enhance chemical debridement after the coronal flare, once during the cleaning and shaping phase and just prior to obturation (when to use PIPS).

I have completed more than 1,500 cases using the PIPS as an irrigation technique. I have kept my endodontic technique nearly the same but added the PIPS Lightwalker Er:YAG to enhance chemical debridement (laser-assisted irrigation). Based on my clinical observation, I feel that I have a decreased post-operative sensitivity, and when I look through the microscope after the final PIPS cycle, the canals are so exceptionally clean that I notice the dust that the paper points give off. As far as a better success rate, the jury is still out. It seems that since I have incorporated the PIPS technique, I have had less post-operative problems and better healing.

In conclusion, PIPS and the photoacoustic wave of irrigant it produces appear to have a bright future in endodontics.

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about the author

roots



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Fifth-generation technology in endodontics: The shaping movement

Authors_ Drs Clifford J. Ruddle, John D. West & Pierre Machtou, USA

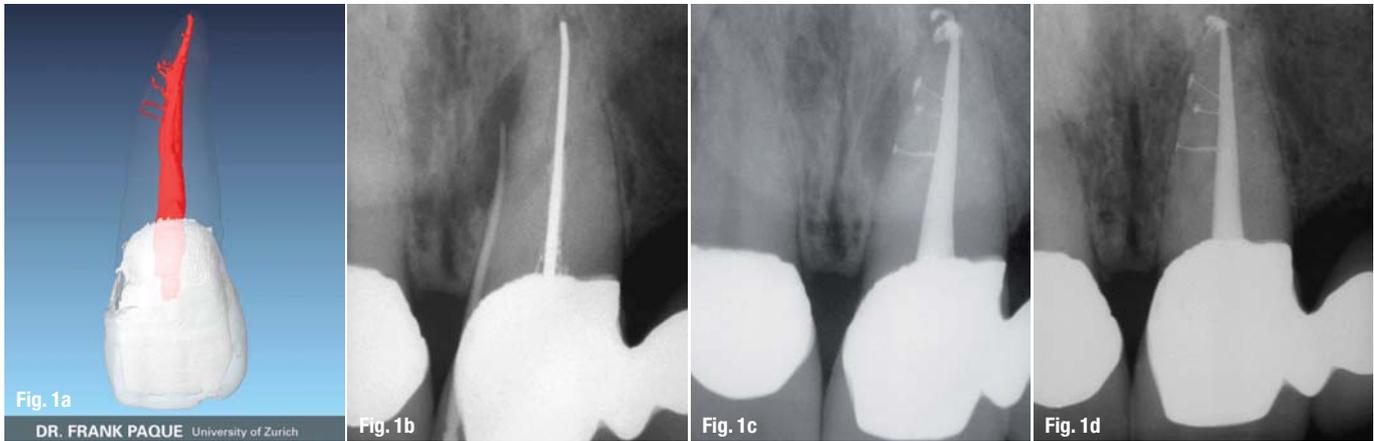


Fig. 1a A μ CT image of a maxillary central incisor demonstrating a root-canal system with multiple portals of exit.

Fig. 1b A pre-op radiograph revealing an endodontically failing anterior bridge abutment with a draining fistula.

Fig. 1c This post-op retreatment image emphasises that shaping canals promotes 3-D cleaning and filling of root-canal systems.

Fig. 1d A 25-year recall radiograph demonstrating osseous healing.

Since the beginning of modern-day endodontics, there have been numerous concepts, strategies, and techniques for preparing canals. Over the decades, a staggering array of files have emerged for negotiating and shaping them. In spite of the design of the file, the number of instruments required and the surprising multitude of techniques advocated, endodontic treatment has typically been approached with optimism for probable success.

The breakthrough in clinical endodontics progressed from utilising a long series of stainless-steel (SS) hand files and several rotary Gates-Glidden drills to the integration of nickel-titanium (NiTi) files for shaping canals. Regardless of the methods, the mechanical objectives were brilliantly outlined by Dr Herbert Schilder almost 40 years ago.¹ When performed properly, they promote the biological objectives for shaping canals, 3-D disinfection, and filling root-canal systems (Figs. 1a-d). The purpose of this article is to identify and compare how each new generation of endodontic NiTi shaping files has helped to advance canal preparation methods. More importantly, it will discuss a new file system and describe a clinical technique that combines the most successful design features from the past with today's innovations.

NiTi shaping movement

In 1988, Walia proposed nitinol, a NiTi alloy for shaping canals, which is two to three times more flexible than SS.² A game-changing feature of files manufactured from NiTi was that curved canals could be mechanically prepared through continuous rotary motion. By the mid-1990s, the first commercially available NiTi rotary files were launched to the market.³ The following overview is a mechanical classification of each generation of file systems. Rather than identify the myriad of available cross-sections, files will be characterised as having either a passive or an active cutting action.

First generation

In order to appreciate the evolution of NiTi mechanical instruments, it is useful to know that first-generation NiTi files in general have passive cutting radial lands and fixed tapers of 4 and 6 per cent over the length of their active blades (Fig. 2).⁴ This generation of technology required numerous files for achieving the preparation objectives. From the mid to late 1990s, GT files (DENTSPLY Tulsa Dental Spe-

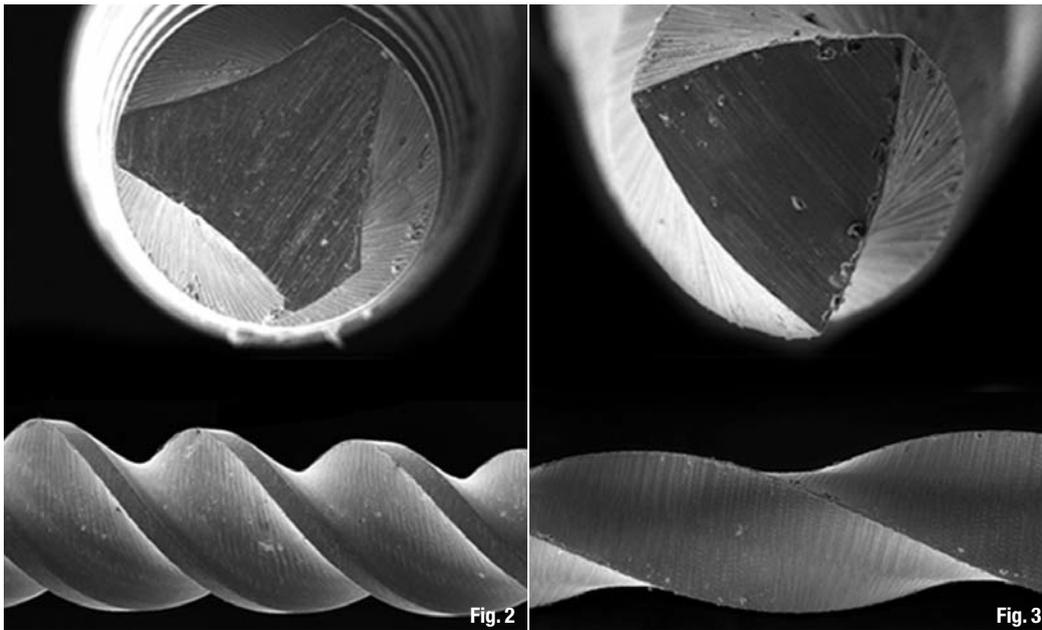


Fig. 2 Two scanning electron microscope images showing the cross-sectional and lateral views of a passively cutting radial-landed file. **Fig. 3** Two scanning electron microscope images showing the cross-sectional and lateral views of an active file with sharp cutting edges.

cialties) became available that provided a fixed taper on a single file of 6, 8, 10, and 12 per cent.⁵ The most important design feature of first-generation NiTi rotary files was passive radial lands, which helped a file to stay centred in canal curvatures during work.

Second generation

The second generation of NiTi rotary files reached dental markets in 2001.⁶ The one feature that distinguished this generation of instruments from previous ones is that they have active cutting edges and thus require fewer instruments to prepare a canal fully (Fig. 3).

In order to prevent taper lock and the resultant screw effect associated with both passive and active fixed-taper NiTi cutting instruments, EndoSequence (Brasseler) and BioRaCe (FKG Dentaire) provided file lines with alternating contact points.⁷ Although this feature is intended to mitigate taper lock, these file lines still have a fixed-taper design over their active portions. The clinical breakthrough occurred when ProTaper Universal (DENTSPLY Tulsa Dental Specialties) utilised multiple tapers of an increasing or decreasing percentage on a single file. This revolutionary, progressively tapered design limits each file's cutting action to a specific region of the canal and affords a shorter sequence of files to produce deep Schilderian shapes safely (Fig. 4).⁸ During this time, manufacturers began to focus on other methods that could increase the resistance to file separation. Some manufacturers, for example, electropolished their files to remove surface irregularities caused by the traditional grinding process. However, it has been observed clinically and reported scientifically that electropolishing dulls the sharp cutting edges.

As such, the perceived advantages of electropolishing were offset by the undesirable inward pressure required to advance a file to length. Excessive inward pressure, especially when utilising fixed-taper files, promotes taper lock, the screw effect and excessive torque on a rotary file during work.⁹ In order to offset deficiencies in general, or inefficiencies resulting from electropolishing, cross-sectional designs have increased and rotational but dangerous speeds are advocated.

Third generation

Improvements in NiTi metallurgy became the hallmark of what may be considered the third generation of mechanical shaping files. In 2007, some manufacturers began to focus on using heating and cooling methods for the purpose of reducing cyclic fatigue in and improving safety with rotary NiTi instruments

Fig. 4 The ProTaper shaping files cut dominantly in their coronal and middle one-thirds, whereas the finishing files cut primarily in their apical one-thirds.



Fig. 4



Fig. 5

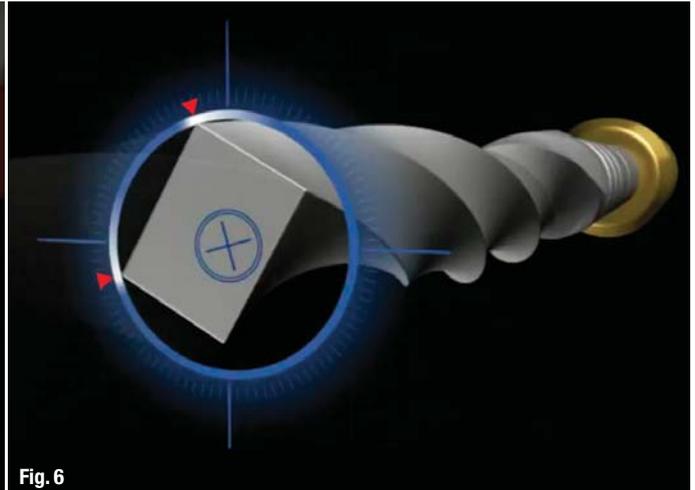


Fig. 6

Fig. 5_ A WaveOne reciprocating file utilises unequal CCW and CW angles to improve efficiency, inward progression and removal of debris from the canal.

Fig. 6_ A cross-section of a ProTaper Next file. Note that an offset mass of rotation desirably reduces file engagement, provides greater space debris, and improves flexibility.

used in canals that are more curved.¹⁰ The intended phase-transition point between martensite and austenite was identified as producing a more clinically optimal metal than NiTi. This third generation of NiTi instruments significantly reduced cyclic fatigue and, hence, broken files. Some examples of brands that offer heat treatment technology are Twisted Files (SybronEndo), HyFlex (Coltène/Whaledent), and GT, Vortex, and WaveOne (all DENTSPLY Tulsa Dental Specialties).

ment are M4 (SybronEndo), Endo-Express (Essential Dental Systems), and Endo-Eze (Ultradent). Compared with full rotation, a reciprocating file requires more inward pressure to progress and will not cut as efficiently as a rotary file of the same size. It is also more limited in removing debris from the canal. Based on these experiences, innovation in reciprocation technology led to a fourth generation of instruments for shaping canals. This generation of instruments and its related technology have fuelled the hope again for a single-file technique.

Fourth generation

Another advancement in canal preparation procedures was achieved with reciprocation, a process that may be defined as any repetitive up-and-down or back-and-forth motion. This technology was first introduced in the late 1950s by a French dentist. Recent brands that use equal clockwise (CW) and counter-clockwise (CCW) degrees of rotation in their move-

ReDent Nova introduced the Self Adjusting File. This has a compressible open-tube design that is purported to exert uniform pressure on the dentinal walls, regardless of the cross-sectional configuration of the canal. It is mechanically driven by a handpiece that produces both a short 0.4 mm vertical amplitude stroke and vibrating movement with constant irrigation.¹¹ Another emerging single-file technique is One

Fig. 7_ The five ProTaper Next files. Most canals in posterior teeth can be optimally shaped using two or three instruments.

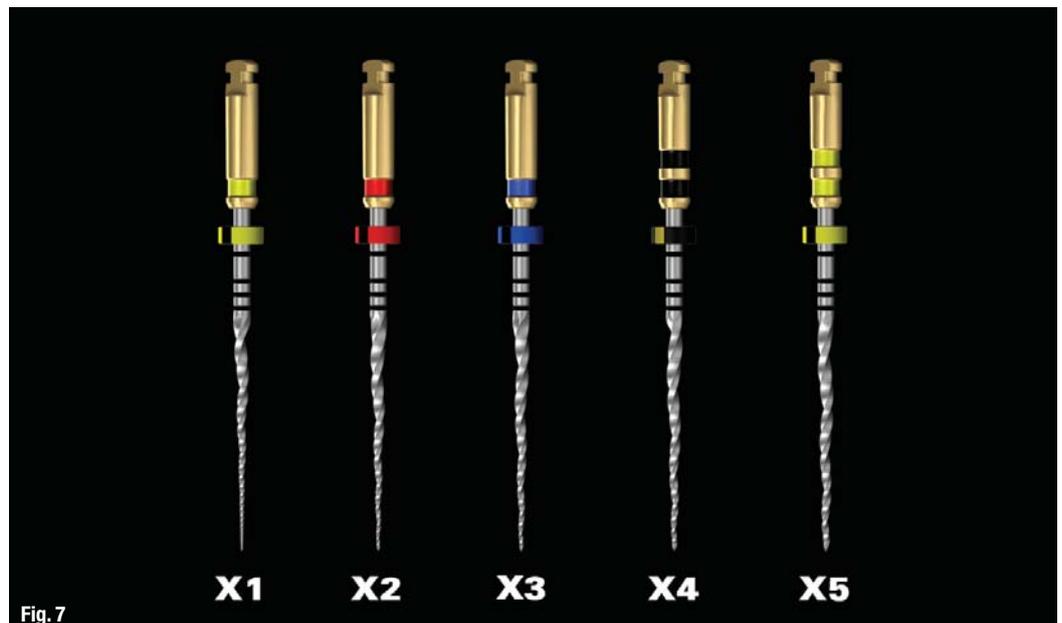


Fig. 7

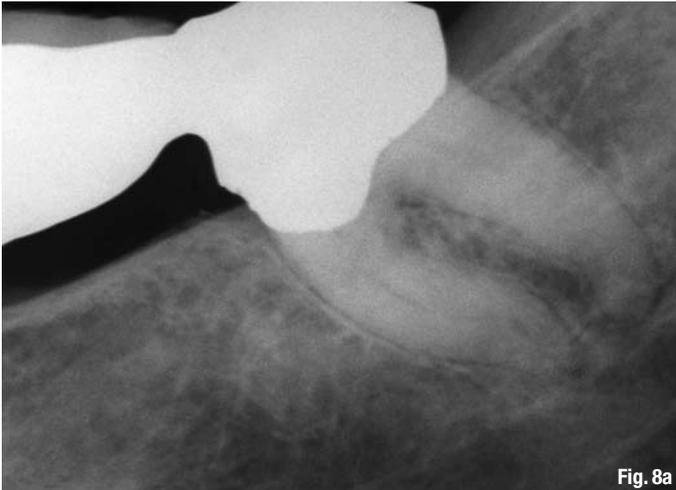


Fig. 8a

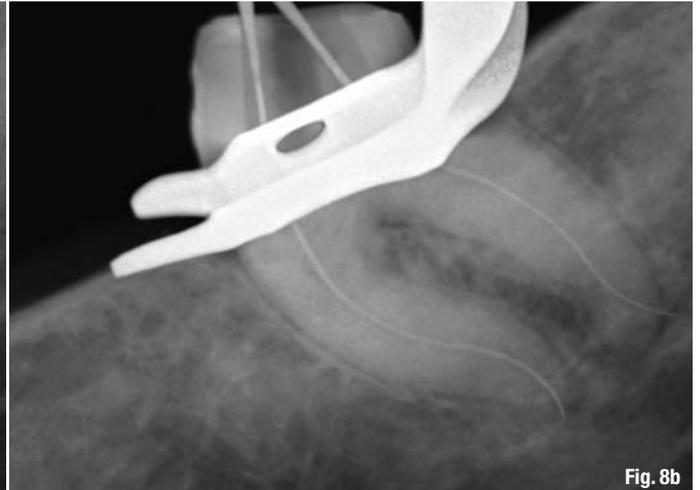


Fig. 8b

Shape (MICRO-MEGA), which will be mentioned again in the section on the fifth generation of instruments.

By far the most popular single-file concepts are DENTSPLY's WaveOne and RECIPROC (VDW). WaveOne combines the best design features of the second and third generation of files, complemented by a reciprocating motor that drives any given file in unequal bidirectional angles. The CCW engaging angle is five times the CW disengaging angle and was designed to be lower than the elastic limit of the file. After three CCW and CW cutting cycles, the file will have rotated 360 degrees, or one full circle (Fig. 5). The reciprocating movement allows a file to progress more readily, cut efficiently, and remove debris from the canal effectively.¹²

Fifth generation

The latest generation of shaping files have been designed in such a way that the centre of mass or the centre of rotation, or both, are offset (Fig. 6). When in rotation, files that have an offset design produce a mechanical wave of motion that travels along the active length of the file. Like the progressively percentage tapered design of ProTaper files, this design minimises the engagement between the file and dentine.¹³ In addition, it enhances the removal of debris from a canal and improves flexibility along the active portion of the file. The advantages of an offset design will be discussed later in this article. Commercial examples of file brands that offer variations of this technology are Revo-S, One Shape (both MICRO-MEGA) and ProTaper Next (DENTSPLY Tulsa Dental Specialties/DENTSPLY Maillefer). Currently, the simplest, safest, and most efficient file systems combine the most proven design features with the most recent technological advancements. The following will offer a brief technical overview of the ProTaper Next rotary file system.

ProTaper Next

There are five ProTaper Next (PTN) files in different lengths available for shaping canals: X1, X2, X3, X4 and X5 (Fig. 7). These files have yellow, red, blue, double black, and double yellow identification rings on their handles, corresponding to sizes 17.04, 25.06, 30.07, 40.06, and 50.06. The tapers are not fixed over the active portion of the files. Both the X1 and X2 files have an increasing and decreasing percentage taper on a single file, whereas the X3, X4, and X5 files have a fixed taper from D1 to D3, then a decreasing percentage taper over the rest of their active portions.

PTN files are the convergence of three significant design features, which include a progressive percentage taper on a single file, M-Wire technology, and the fifth generation of continuous improvement, the offset design. As an example, the X1 file has a centred mass and axis of rotation from D1 to D3, whereas it has an offset mass of rotation from D4 to D16. Starting at 4 per cent, the X1 file has ten increasing percentage tapers from D1 to D11, whereas there are decreasing percentage tapers from D12 to D16 to enhance flexibility and conserve radicular dentine during shaping.

PTN files are used at 300rpm and a torque of 2–5.2Ncm, based on the method used. However, the authors prefer a torque of 5.2Ncm, as this level of torque has been validated as profoundly safe if clinicians perform meticulous glide path management procedures and utilise a deliberate outward brushing motion as they progressively shape canals.¹⁴

ProTaper Next shaping technique

In the PTN shaping technique, all files are used in exactly the same way, and the sequence always follows the ISO colour progression and is always the same regardless of the length, diameter, or curvature of a canal. The PTN shaping technique is extraordi-

Fig. 8a A radiograph showing an endodontically involved posterior bridge abutment. Note the orientation of the prosthesis to the underlying roots.

Fig. 8b A working image showing coronal disassembly, isolation and #10 files traversing through canals that exhibit curvatures and recurvatures.

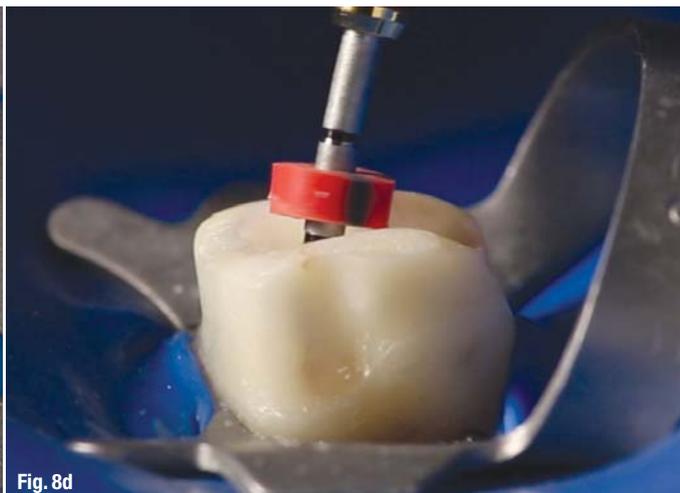


Fig. 8c

Fig. 8d

Fig. 8c_A video grab image showing a mechanical wave of motion travelling along the active portion of a PTN X1 shaping file.

Fig. 8d_A video grab image showing a PTN X2 file at length in the mesiobuccal root-canal system.

rarily safe, efficient and simplistic when attention is focused on access preparation and glide path management. As required for any shaping technique, straight-line access to each orifice is emphasised. Attention is directed to flaring, flattening, and finishing the internal axial walls. For radicular access, the original ProTaper system offers the auxiliary shaping file SX, which is used in a brushing motion on the outstroke to pre-flare the orifice, eliminate triangles of dentine, relocate the coronal-most aspect of a canal away from external root concavities, or produce more curvature if desired.

Perhaps the greatest challenge in performing endodontic treatment is to find, follow, and predictably secure any given canal to its terminus. Negotiating and securing canals with small manual files requires a mechanical strategy, skilful touch, patience and dedication.

A small hand file is used initially to scout, expand, and refine the internal walls of the canal. Once the canal can be reproduced manually, a dedicated mechanical glide path file may be used to expand the working width in preparation for shaping procedures.¹⁵ For clarification, a canal is secured when it is empty and has a confirmed, smooth, and reproducible glide path. With an estimated working length and in the presence of a viscous chelator, a #10 file is inserted into the orifice. Then it is determined whether the file moves towards the terminus of the canal easily. In shorter, wider, and straighter canals, a #10 file can usually be inserted to the desired working length. Once a #10 file has been confirmed to be loose at length, the glide path may be further enlarged with either a #15 hand file or dedicated mechanical glide path files, such as PathFiles (DENTSPLY Tulsa Dental Specialties). The glide path just described confirms that sufficient existing space is available to initiate mechanical shaping procedures with the PTN X1 file.

In other instances, certain endodontically involved teeth have roots with canals that are longer, narrower and more curved (Fig. 8a). In these situations, often a #10 file will not go to length initially. Generally, there is no need to use #6 and/or #8 hand files in an effort to reach the terminus of the canal immediately. Rather, the size #10 hand file simply has to be worked gently within any region of the canal until it is completely loose. PTN files can be used to shape any region of a canal that has a smooth and reproducible glide path. Regardless of the glide path and shaping sequence, the objective is to negotiate the entire length of the canal, establish working length, and confirm apical patency (Fig. 8b). The canal is secured and a glide path is verified when a #10 file is loose at length and can reproducibly slip, slide and glide over the apical one-third of the canal.

Once the canal has been secured, the access cavity is flushed voluminously with a 6% solution of NaOCl. Shaping can then commence, starting with the PTN X1 file. It should be noted that PTN files are never used with an inward pumping or pecking motion. Rather, they are used with an outward brushing motion. This method will enable any PTN file to move inward passively, follow the glide path and progress towards the working length. The X1 file is carried through the access and inserted passively into a pre-flared orifice and secured canal. Before encountering resistance, deliberate brushing on the outstroke has to begin immediately (Fig. 8c). Brushing creates lateral space and enables this file to progress a few millimetres inward. A brushing action serves to improve contact between the file and dentine, especially in canals that exhibit irregular cross-sections or deviations off their rounder parts.

Progression with the PTN X1 file through the body of the canal has to be continued. After every few millimetres of file progression, the mechanical shaping file has to be removed to inspect and clean its flutes.

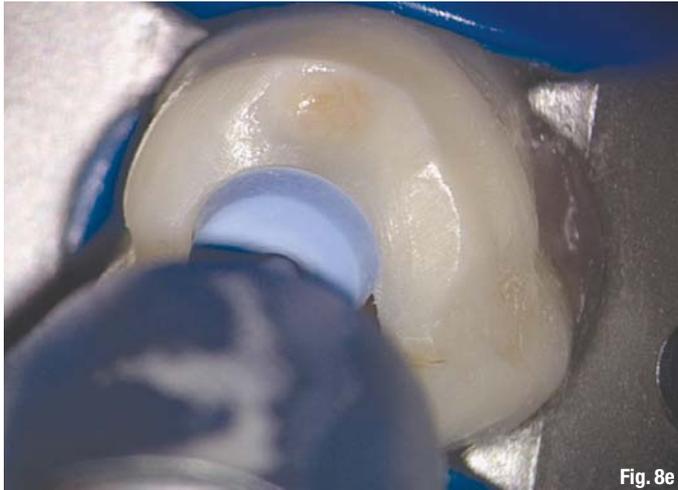


Fig. 8e

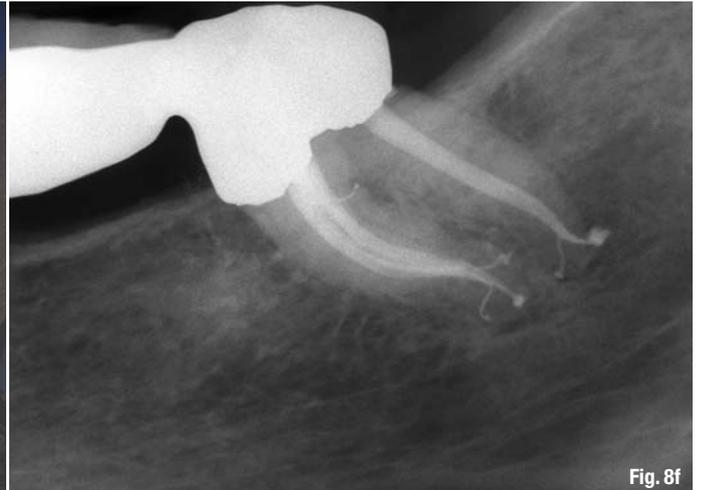


Fig. 8f

Before reinserting the X1 file, it is critical to irrigate and flush out gross debris, recapitulate with a #10 file to break up residual debris and move the debris into solution, then re-irrigate to liberate this debris.

In one or more passes, progression with the X1 file should be continued until the working length is reached. In order to promote the mechanical objectives, clinicians are advised to always irrigate, recapitulate and then re-irrigate after removing any mechanical shaping file. The PTN X2 file then has to be selected and used to begin to advance inward. Before encountering resistance, it has to be brushed against the dentinal walls, which will enable the X2 file to advance inward passively and progressively. The X2 file will follow the path of the X1 file easily, shape progressively, and advance incrementally towards the working length. If this file becomes stuck and ceases to move inward, it has to be removed and cleaned. Flutes have to be inspected as well before irrigation, recapitulation and re-irrigation. Progression with the X2 file is continued until the working length is reached. It may take one or more passes, depending on the length, width, and curvature of the canal (Fig. 8d).

Once the PTN X2 file has reached the working length, it is removed. The shape may be confirmed as finished when the apical flutes of this file are visibly loaded with dentine. Alternatively, the size of the foramen may be gauged with a 25.02 NiTi hand file. When the #25 hand file is snug at length, the shape is finished. If the 25.02 hand file is loose at length, it simply means that the foramen is larger than 0.25 mm. In this instance, the foramen may be gauged with a 30.02 NiTi hand file.

If the #30 hand file is snug at length, the shape is finished. However, if the #30 hand file is short of the working length, proceed to the PTN X3 file, following the method just described for the PTN X1 and X2 files.

The vast majority of canals will be optimally shaped after using either the PTN X2 or X3 files (Fig. 8e). The PTN X4 and X5 files are primarily used to prepare and finish larger-diameter canals. When the apical foramen is determined to be larger than a 50.06 X5 file, other recognised shaping methods may be utilised to finish these larger canals, which are typically less curved and more straightforward to prepare. It is important to appreciate that meticulously secured canals promote shaping, 3-D cleaning, and filling of root-canal systems (Fig. 8f).

Discussion

From a clinical standpoint, the PTN rotary system is a convergence of the most proven and successful generational designs, coupled with the most recent advances in critical path technology. This brief discussion will consider the influence of design on performance.

The most successful generational design is the mechanical concept of utilising a progressive percentage taper on a single file. The patent-protected ProTaper Universal NiTi rotary file system utilises an increasing or decreasing percentage taper on a single file. This design feature serves to minimise the contact between a file and dentine, which decreases the risk of taper lock and the screw effect while increasing efficiency.⁸ Compared with a fixed-taper file of similar size, a decreasing percentage taper design, strategically improves flexibility, limits the shaping in the body of the canal, and conserves two-thirds of coronal dentine.

Following this mechanical design, PTN also features progressive tapers on a single file. This design has contributed to the ProTaper system becoming the top-selling file in the world, the file choice of endodontists, and the leading system taught to undergraduate students in dental schools internationally.¹⁶

Fig. 8e_A video grab image showing a PTN X3 file at length in the distal root-canal system.
Fig. 8f_A radiograph showing the provisional bridge, flowing shapes, and the importance of treating root-canal systems.

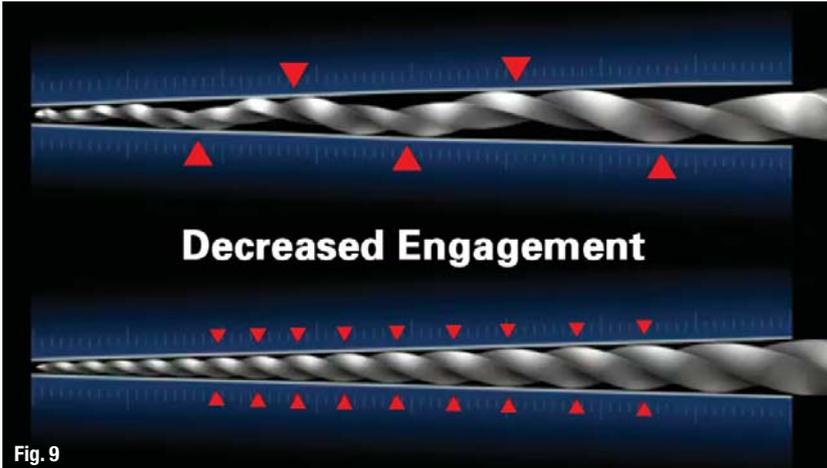


Fig. 9

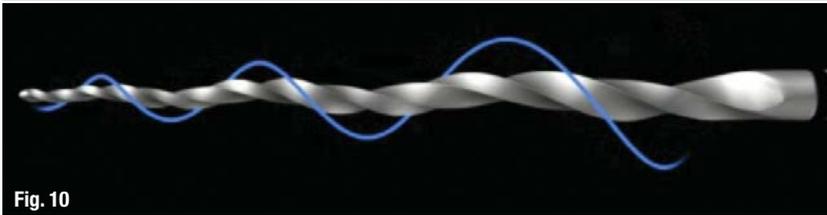


Fig. 10

Fig. 9 A PTN file has a progressively tapered and offset design. These features minimise engagement, maximise debris removal and improve flexibility. In contrast, the bottom image shows a fixed-taper file with a centred mass and axis of rotation.

Fig. 10 Similar to a sinusoidal wave, a rotating PTN file produces a mechanical wave of motion, or a swaggering effect, along its active portion.

Another critical design feature that is intended to benefit certain brand lines of mechanical shaping files is metallurgy. Although NiTi files have been shown to be two to three times more flexible than SS files of the same size, additional metallurgical benefits using heat treatment have been identified. Research and development has focused on heating and cooling traditional NiTi, either pre- or post-machining. Heat treatment aims to create a more optimal phase-transition point between martensite and austenite.

It should be appreciated that the best transition point is dependent on the cross-section of the file. Research has shown that M-Wire, a metallurgically improved version of NiTi, reduces cyclic fatigue by 400 per cent when comparing files of the same D0 diameter, cross-section, and taper.¹⁷ This third-generational advancement is a strategic improvement to the overall clinical safety and performance of the PTN rotary file system. The third design feature of PTN is related to its offset cross-sectional design. There are three major advantages when the mass of rotation of a continuously rotating file is offset:¹³

1. An offset design generates a travelling mechanical wave of motion along the active portion of a file. This swaggering effect minimises the engagement between the file and dentine compared with the action of a fixed-taper file with a centred mass of rotation (Fig. 9). Reduced engagement limits taper lock, the screw effect, and torque with any given file.
2. A file with an offset design affords more cross-sectional space for enhanced cutting, loading and removal of debris from a canal compared with a file with a centred mass and axis of rotation (Fig. 10).

Many instruments break as a result of excessive debris packed between the cutting flutes over the active portion of a file. More importantly, an offset file design decreases the probability of laterally compacting debris and blocking the root-canal system (Fig. 6).

3. A shaping file with an offset mass of rotation will generate a mechanical wave of motion analogous to the oscillation along a sinusoidal wave (Fig. 10). Owing to this design, any PTN file can cut a larger envelope of motion compared with a file of similar size with a symmetrical mass and axis of rotation (Fig. 6). The clinical advantage of this is a smaller and more flexible PTN file that can prepare the canal to the same size as a larger and stiffer file with a centred mass and axis of rotation can (Fig. 9).

Conclusion

Each new generation of shaping files was intended to offer improvements on previous generations. Being a fifth-generation system, PTN was designed to bring together the most proven performance features and the most recent technological advancements. The system should simplify rotary shaping procedures by eliminating the number of files typically used to shape canals and through the so-called hybrid techniques. Clinically, PTN files fulfil the three sacred tenets for shaping canals, which are safety, efficiency and simplicity. Scientifically, further evidence-based research is needed to validate the benefits of this system.

Acknowledgement

The authors would like to recognise Dr Michael J. Scianamblo for his work in the field of critical path technology, which led to the development of ProTaper Next.

Editorial note: This article originally appeared in Dentistry Today in April 2013. A list of references is available from the publisher. Drs Ruddle, Machtou, and West have a financial interest in the products they design and develop, which includes the ProTaper Universal system.

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The rationale and use of electronic apex locators

Author_ Dr L. Stephen Buchanan, USA

Electronic apex locators (EALs) are my best friend when performing a root canal. Of all the devices I use in practice, my RootZX-mini (Fig. 1) is the most indispensable. This is borne out by the fact that most endodontists use an EAL to determine length in every root canal they treat.

The rationale for using an EAL in every single canal you treat? A short review of the anatomy literature reveals conventional radiography to be no greater than 80 per cent accurate for length determination, vs. 97 per cent accuracy with EALs. One of the worst endo concepts—ever—has been the procedural recommendation that we treat root canals a certain distance from the root apex—a strategy based on the average position of root canal foramina.

Unfortunately, none of our patients is average. Every single root canal you enter for the next 35 years of practice will be different than the one before. So how is it going to work when we arbitrarily assign apical preparation sizes based on averages? Not so good, actually. When we decide all small canals should be enlarged to a #35 file size at the end of the prep, we will often have one of two untoward outcomes: apical damage or incomplete preparation.

Fig. 1_ The RootZX-mini.



Fig. 1

So it is with length determination.

With an EAL, you will know immediately when you reach the end of root canals with the smallest, first negotiating files – data that is so critical to controlling our use of these instruments and preventing apical damage. Without an apex locator, you will never know where you are in a root canal until you have horsed a #15 KF to estimated length and have taken an X-ray; in small curved molar canals, this can be disastrous. Working initial negotiating files short in error invites apical blockage and ledging, while working them erroneously long invites ripping apically curved canals straight, outcomes that happen more often than most of us realize.

Yet the majority of general dentists do not use EALs. Why? Many have been unsuccessful in first use—no surprise; EALs are technique-sensitive to use.

Here are the technique touch points I consider when using an EAL:

Condition of the EAL

Confirm a good condition of the EAL, its batteries, its cords and its file probes (Fig. 2). These are sensitive electronic devices with boards inside that can break when drop-kicked in an operatory. Be gentle with them. When their signal shows halfway, replace the batteries with fresh ones. When EAL cords have been autoclaved repeatedly, they may develop tarnish that inhibits conduction at the cord connections and at the end of the file probe where it touches the shank of the file being used. Using a bur brush here will take care of the tarnish.

Ideally, use a straight file probe that has been gold plated (this prevents oxidation) at its business end. These work the best of all EAL probe designs I have used (Fig. 3).

My least favorite is the spring-loaded test file leads that most dentists attach to their files. They are too



Fig. 2 Make sure your EAL is in good working condition by checking its batteries, cords and file probes.

Fig. 2

wide to fit them between the rubber stop and handle in canals longer than 22 mm. Test leads attached to files during negotiation dampen tactile feedback, increasing the risk of damaging tortuous apical anatomy.

The straight probe can be temporarily set on an alcohol gauze, located on the patient's bib, as the assistant places the lip clip under the rubber dam—on the opposite side of the tooth being treated, with the EAL display nearby. When estimated length is approached, it is then very convenient to simply retrieve the file probe from under the patient's chin, touch its thin, V-cut end to the file shank, between the rubber stop and the handle (Fig. 4).

The file in hand is then advanced into the canal until the display meter pegs to the farthest red "Apex" indication, and the instrument is turned slowly in a counter-clockwise direction until the meter is only lit up to the simulated "0.5 mm" mark and the green bar opposite that mark stops blinking and holds steady for a couple of seconds.

Lead sets typically need replacing in my office every six to 12 months. Not autoclaving EAL cords and probes is not good, and the temperature and steam fatigues the insulation, so accept this and pop for a new cord set every now and then.

Access cavity

Cut a nice access cavity. I am often asked how I use EALs when working next to metallic restorations, as it can be difficult to avoid shorting the signal. My first consideration is to make sure the line-angles of the access cavity have been cut so that files may drop smoothly, without hitch, into each canal without significant flexure of their shank ends.

A well-cut access cavity will allow files to be easily held away from an adjacent metal crown or alloy

restoration. To do so, get a finger rest, look carefully as you center the file in the access prep, then direct your attention to the EAL display as you turn the file back and forth until the meter arrives at a reproducible length measurement.

If you still have trouble keeping files from shorting, cut heat-shrink tubing (RadioShack) into 9 mm lengths and place them on your initial negotiating files and the procedure can go on. A little practice and this will no longer be necessary. Not to brag, but I don't have any greater difficulty using EALs through metallic restorations or crowns and would rather do that than work on teeth devastated by caries.

Use of lubricant

Use a lubricant such as RC Prep or ProLube instead of NaOCl during electronic length determination. This is the second requirement for working successfully through access cavities with adjacent metal. In fact, doing all initial negotiation procedures through an access cavity filled with lubricant will smooth out all EAL use as it helps eliminate the apical blockage so common in vital cases. Not only has there been no evidence-based research proving NaOCl is helpful for negotiation procedures, all of our clinical experience shows lubricants to be the ideal solution to have in the pulp chamber as initial negotiating files are taken into small curved canals. When sufficiently small first files are used in a bath of lubricating solution, apical soft tissue blockage can be totally avoided.

Plus, all EAL readings are more stable with lubes, and most erratic with bleach. Lose the bleach, until later in the procedure.

File size

Increase file size when EAL readings are erratic. Simply using one or two larger sizes of negotiating file

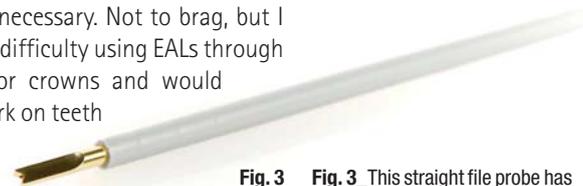


Fig. 3 This straight file probe has been gold plated at its business end to prevent oxidation.

Fig. 4 When estimated length is approached, it is then convenient to simply retrieve the file probe.



works virtually every time when first or second files taken to length return an erratic, jumpy signal. Going to a larger size file with a lubricant during EAL use will solve erratic signals for most brands of apex locators.

Of all the unnecessary obstacles to success with EALs, this one was my *bête noir* for years until Johan Masrelleiz twiggged me to the use of lubricants during EAL use.

Use an EAL often

Use an EAL in every canal you treat, and you will become proficient. Pulling the office EAL from the back of a dusty closet once every two months—when radiographic length determination isn't working—and expecting immediate success requires a rich fantasy life. Conversely, when I have an apex locator, I can be on a dental mission in an underserved region and do a pretty nice RCT with no X-ray machine. Get one, if you don't already have one, and use that sucker every time, and you will have way more fun doing RCT.

Length determination radiographs

Stop taking length determination radiographs—take this recommendation to heart, and soon you will be ready for the EAL homerun. If you are able to accept gifts from heaven and are looking for a way to be more efficient when delivering RCT, eschew length determination radiographs. Remember 80 per cent vs. 97 per cent? So what do we accomplish when we stop everything to capture a length determination X-ray? To see files as they exit molar root structure, multiple X-rays are usually required, so why are we doing this?

Furthermore, curved canals change length as they are worked. When you use an EAL for each negotiating file, it is common to observe the loss of 1/4 to 1/2 mm of canal length just going from the 08 KF to the 10 KF, as the original irregular canal path is smoothed. So do we capture a second length determination X-ray, after negotiation, and a third after shaping?

Rather than spend the time to capture a radiographic record of a length that will change almost immediately after, consider using today's rotary instrumentation. I can literally cut an initial shape, a final shape, gauge the terminus and fit a gutta-percha cone in less time than it usually takes to capture a well-angulated X-ray image of a #15 KF at length. Then, when I take an X-ray image with the cones in place and be certain that the length represented will be stable to the completion of the case. If you want to eliminate working films altogether, use a lubricant and an EAL during apical gauging procedures and you will know exactly where to fit the cone.

I know this works; I practiced for three years (including live demonstrations) without taking a working film after canal location—and my apical accuracy improved.

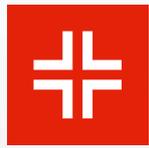
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Electronic length determination has become the gold standard over the last few years. The Deutsche Gesellschaft für Zahn-, Mund- und Kieferheilkunde (German association for dental, oral and maxillofacial surgery) confirmed in a statement that this technique is superior to working length determination with a conventional radiograph. However, 3-D radiography (CBCT) provides an additional method for determining the endodontic working length.

A study conducted at the University of Granada in Spain evaluated the accuracy of working length determination based on these modern methods. For this purpose, 150 extracted teeth were randomly divided into five groups. The working length was determined electronically with the RAYPEX 6 apex locator in four groups, under dry conditions¹ or in the presence of three different irrigating solutions.²⁻⁴ The working length of the fifth group was determined radiologically with a CBCT scan.⁵ Measuring points were the major foramen and the apical constriction.

The results obtained by electronic measurement were more reliable than by CBCT scan, in particular regarding the determination of the major foramen. The study therefore confirmed that RAYPEX 6 measures the working length with more accuracy and reliability than CBCT does.

The study and a complete list of references are available online at <http://onlinelibrary.wiley.com/doi/10.1111/iej.12140/abstract>

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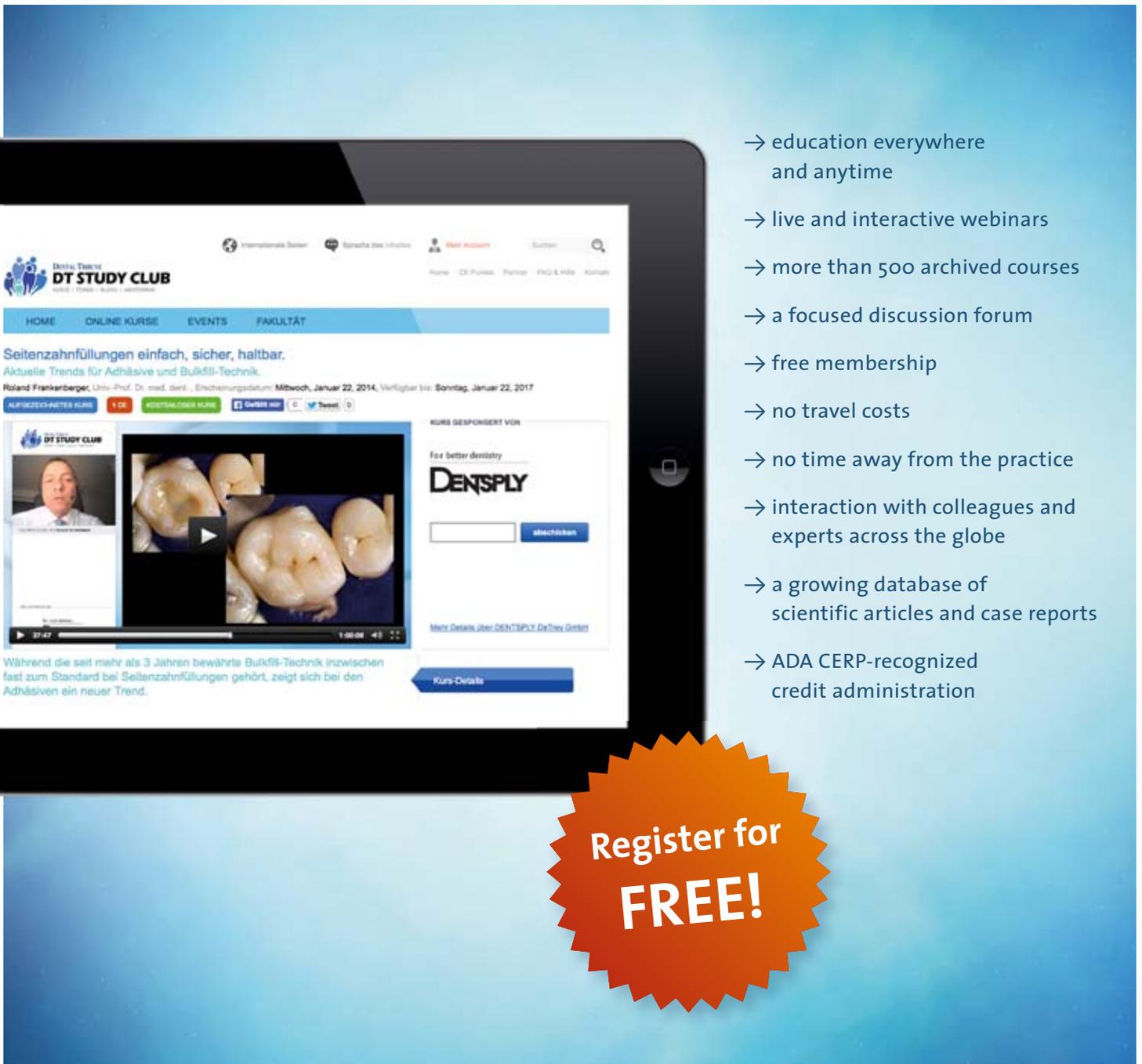
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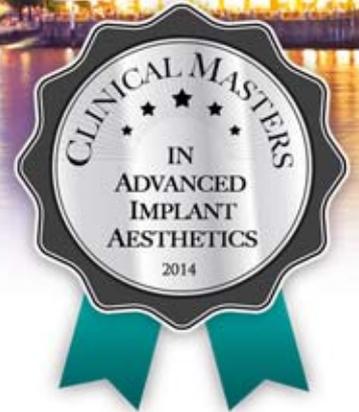


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American Association of Endodontists organised Root Canal Awareness Week for the seventh time

During its seventh annual Root Canal Awareness Week, which was held from 17 to 23 March, the American Association of Endodontists (AAE) aimed to dispel myths surrounding root canal treatment and encourage general dentists to involve endodontists in case assessment and treatment planning to save patients' natural teeth.

"Ninety-four per cent of general practitioners agree that endodontists are partners in delivering quality dental care," said AAE immediate past President Dr James C. Kulild. "By working together, general dentists and endodontists can treat patients comfortably and save their natural teeth."

Endodontists' enhanced training, combined with high levels of expertise, use of cutting-edge technology and impressive success rates are the main reasons patients trust dental specialists, according to an AAE survey. By partnering with endodontists, general dentists can ensure the highest quality of care while helping patients feel less anxious. In fact, 89 per cent of patients report being satisfied after root canal treatment by an endodontist.

In order to encourage collaboration between general dentists and endodontists, the AAE offers several free resources available for download from its website:

Treatment Options for the Compromised Tooth: A Decision Guide includes case examples with radiographs of successful endodontic treatment in difficult cases and encourages general dentists to assess all possible endodontic treatment options to save the natural dentition.

The case difficulty assessment and referral form offers guidance to help evaluate a patient's condition and assess risk factors that may affect the outcome of treatment.

The *ENDODONTICS: Colleagues for Excellence* newsletter highlights clinical topics of interest to dentists who perform their own endodontic treatment, and benefit from coverage of best practices and the latest advancements in the specialty.

Endodontists: Partners in Patient Care is a video that explains what an endodontist is and how specialists work with general dentists to provide the highest levels of patient care. It is a great resource to show patients and general dentists when a referral to a specialist is needed.

By using these tools during Root Canal Awareness Week and throughout the year, general dentists ensure they are developing the best treatment plans to save natural teeth and keep patients satisfied. Additional clinical resources are available at www.aae.org

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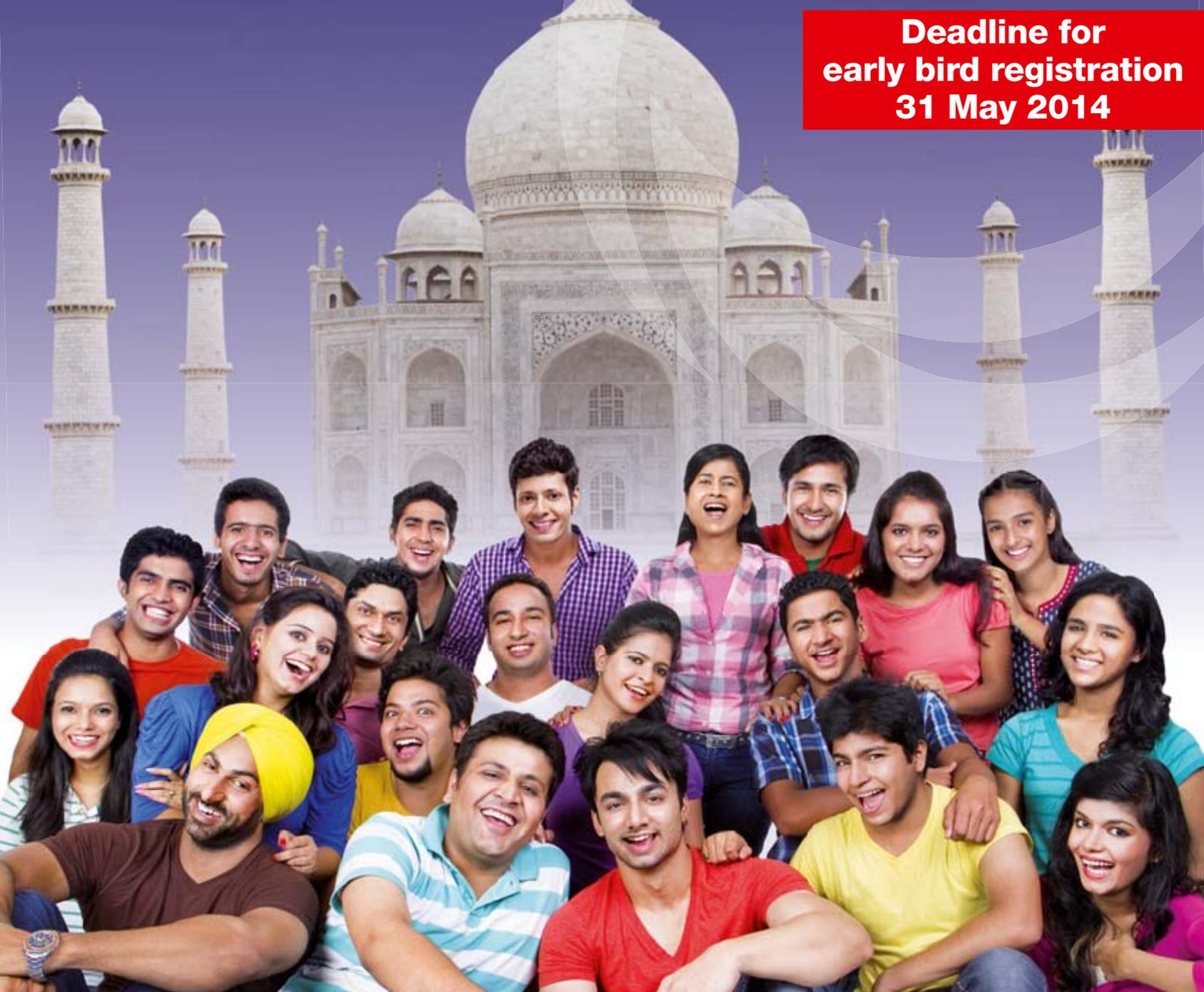
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International Events

2014

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30 April – 3 May, 2014
Washington, USA
www.aae.org

DGET Spring Meeting

9–10 May, 2014
Witten, Germany
www.dget.de

SFE Congress

12–14 June 2014
Nice, France
www.endodontie.fr

Asia Pacific Dental Congress (APDC) Improving quality of life through better dental care

17–19 June 2014
Dubai, UAE
www.apdentalcongress.org

18th World Congress on Dental Traumatology

19–21 June 2014
Istanbul, Turkey
www.iadt-dentaltrauma.org/2014conference/index.html

2014 AAE/AAP/ACP Joint Symposium

Teeth for a life time: Interdisciplinary Evidence
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www.perio.org/meetings/joint-symposium2014.htm

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Italian Academy of Endodontics (AIE)

22nd National Congress
2–4 October 2014
Montecatini Terme, Italy
www.accademiaitalianaendonzia.it

155th ADA Annual Session

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San Antonio, USA
www.ada.org

Digital Dentistry Show

16–18 October 2014
At the International Expodental Milano, Italy
www.digitaldentistryshow.com

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7–9 November 2014
Chennai, India
www.rootssummit2014.com

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submission guidelines:

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- _ all the image (tables, charts, photographs, etc.) captions;
- _ the complete list of sources consulted; and
- _ the author or contact information (biographical sketch, mailing address, e-mail address, etc.).

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Article lengths can vary greatly—from 1,500 to 5,500 words—depending on the subject matter. Our approach is that if you need more or less words to do the topic justice, then please make the article as long or as short as necessary.

We can run an unusually long article in multiple parts, but this usually entails a topic for which each part can stand alone because it contains so much information.

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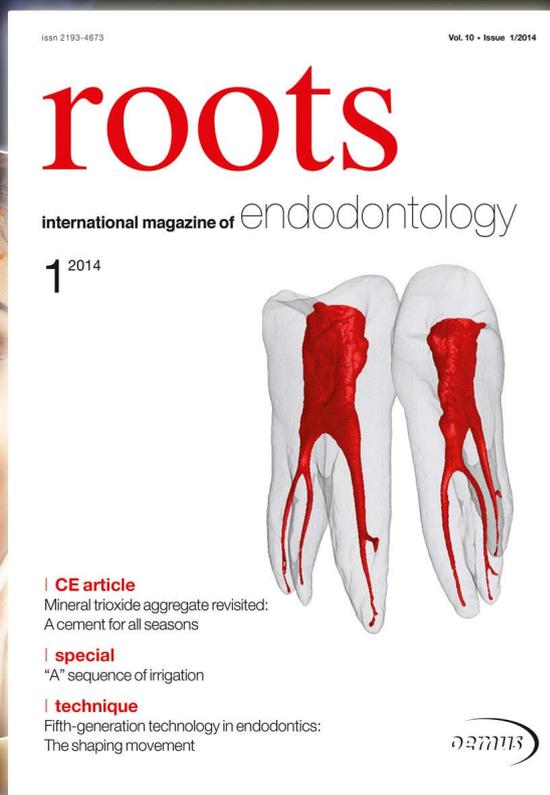
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