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Endo vs Implant: What is your hierarchy in the decision-making process?

One of the most controversially debated topics of modern dentistry has been whether to retain a tooth with endodontic treatment, or to just extract it and replace it with an implant.

In the 1980s, implant dentistry became the mainstream treatment modality, with the purported promise of a maintenance free, definitive and long-term solution for a compromised tooth. It seems that the promise of the ‘80s has not materialised as expected, and times have certainly changed!

Endodontic treatment is regaining favour as the primary strategy for saving a tooth for a number of reasons. Despite the fact that endodontic treatment can be difficult to perform because of the complex anatomy of root canal systems, research has shown that the survival rate of endodontically treated teeth is at least as effective as dental implants, with the added benefit of maintaining the natural dentition. It’s been well documented that implants are more predisposed to both biological and technical complications, which may require more remedial treatment overall. That said, implants offer an important next line option for patients where endodontic options have been exhausted.

The risk factors that may affect implant prognosis are plentiful. General risk factors may include, but not limited to: patients who have diabetes; immunosuppressive conditions; poor oral hygiene; history of periodontal disease; and, of course, those who smoke. Local factors may include, but not limited to: faulty implant placement technique; faulty ridge augmentation procedures; restorative failures; and deep peri-implant pocketing.

Plaque-related disease is more commonplace with implants than with the natural dentition. It is important to educate patients of this issue in order to maximise long term success rates of implants. One must also consider the reason why the patient lost their natural dentition in the first place, necessitating the need for extraction and subsequent replacement. Behavioural change, especially in high risk patients is of paramount importance.1

Dental imaging has made leaps and bounds with the advent and use of cone beam computed tomography (CBCT) enlightening us to the complexities of the root canal system, and thereby necessitating 3-D disinfection and obturation.

High magnification in the form of the dental operating microscope has enabled many practitioners to treat complex root canal anatomic variations more thoroughly and to tip the balance in favour of healing.

Although the hierarchy of treatment planning in the early days first looked at implants as the pinnacle of treatment compared to retaining the natural dentition with endodontic/restorative treatment, this has dramatically changed as increasing reports have come to light regarding the complications now associated with implants. The priority in recent years has seemed to revert back to maintaining the natural compromised teeth through remedial endodontic and restorative procedures.

Dr Gary Glassman
Guest Editor

Reference:
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Success evaluation of N2 treated teeth with open apical foramen—
A retrospective study

Authors: Dr Anette Joschko, Dr Robert Teeuwen & Prof. Jerome Rotgans, Germany

Abstract

95 teeth with open foramen were identified in a general dentist practice during the years 1985—2006, 75 of which could be followed-up by X-ray after an average time of 70 months (follow-up X-ray). 40 teeth were subject to vital extirpation (VitE), 28 teeth to vital amputation (VitA), and seven teeth with necrotic pulp underwent conservative root canal treatment (RT). Apexification success rate amounted to 85.3 % (VitE 90 %, VitA 85.7 %, non-vital RT 57.1 %). Another 12 % could be judged as partial success in molars, as a certain number of the molar roots showed apexification, however, others not yet. The percentage difference of a successful apexification between vitally extirpated teeth and root canal treatment of non-vital teeth was significant (p = 0.0243). Apexification result was irrespective of the filling level of root canal treated teeth as well as of endodontic success.

Endodontic failures resulted in ten cases (13.3 %). Statistic significance was found regarding failure rate of VitA (7.1 %) and root canal treatment of non-vital teeth (28.6 %, p = 0.0157).

Within the observation period 19 out of the 95 teeth with open foramen (20 %) were extracted. There was a significant difference regarding extraction frequency between the VitE group (14.6 %) and the non-vital group (50 %, p = 0.0169).
Introduction

Endodontic treatment of teeth with incomplete root growth poses a special challenge. In young patients, the necessity for endodontic treatment results from an accident or profound caries. Aside from damage control, this treatment aims at promoting tooth maturation including narrowing respectively closure of the apical foramen (apexification) and possibly root extension (apexogenesis).

According to Zeldow (1967) the following treatment options are commonly used:

- For vital teeth: Pulpotomy (VitA) with subsequent conservative root canal treatment (RT)
- For non-vital teeth:
  - either RT
  - RT in connection with apicoectomy/retrograde root canal filling or
  - inducing of bleeding with root canal filling in the coronal root part only.

Krakow et al. (1977) disapprove of a VitA inevitably following root canal filling. Joschko (2012) points out that the often diverging roots of immature teeth exclude a dense root canal filling, and that open apical foramen promotes overfilling. Some authors, like Kvinnsland et al. (2010) and Rafter (2005), state that the dental papilla may simulate an apical periodontitis in the area of the open apical foramen.

Various methods favouring maturation of the immature teeth are described. Surgical interventions turned out to be less promising (Kreter 1959, Khoury 1992), Herforth (1981) obtained a very high healing rate of apical periodontitis with Jodoform deposits, however the success rate regarding stimulation of hard tissue induction only amounted to 3% versus 83% with calcium hydroxide (Ca(OH)_2). Hermann (1920, 1930) introduced calcium hydroxide as material with osteogenic potential. Frank (1966) was the first to use it as medical dressing in teeth with incomplete root growth. These dressings should be replaced approx. every three months for a time period of six through 18 months. Cvek (1972) and Feiglin (1985), however, do favour a replacement of the dressing only in case of pathology. The long treatment duration—and thus loss of patient compliance—as well as a decrease of fracture resistance (Cvek 1972, Andreasen, Fabrik and Munksgaard 2002, Andreasen, Munksgaard and Bakland 2006, Trope 2006) are regarded as adverse features of the calcium hydroxide method.

As formaldehyde also features an osteogenic potential (Orban 1935), tests with formocresol versus calcium hydroxide were made as well. Within a pulpotomy study, Spedding et al. (1965) judged formocresol as being more appropriate for apexification. Latest literature prefers mineral trioxide aggregate (MTA) over calcium hydroxide (Andreasen et al. 2006, Schwartz et al. 2008, Schäfer 2003, 2004). Shabahang et al. (1999) as well as ElMeligy et al. (2006) made a comparison between mineral trioxide aggregate and calcium hydroxide ending up in favour of MTA.

In a prospective study, Simon et al. (2007) report on 43 one-stage MTA treatments, which were followed up after a control period of at least 12 months (up to 36): 65% of apical lesions were completely healed and an apical barrier could be observed in 11 cases (26%). 78.7% were free from apical periodontitis, whereas apexification took place in only 64 out of 75 cases (85.3%). The time period for control of apical development was clearly longer, though, amounting to 70 months.

![Fig. 2: Time history of the extractions (N = 19).](image)
Aside from the therapy with various medicaments, the ‘revascularization’ therapy was established also (Ham et al. 1972, Hülsmann et al. 2008, Bose et al. 2009, Çehreli et al. 2012, Garcia-Gody and Murray 2011) provoking a light bleeding into the pulp by puncture beyond the apex. Dressing is placed coronally: MTA, calcium hydroxide, formocresol or a triple antibiotic paste. The latter one provided thicker canal walls than calcium hydroxide respectively formocresol. Also the length growth was stronger versus MTA application (Ebeleseder 2004).

Based on the knowledge that formaldehyde preparations have a similar (necrotizing, osteogenic) effect to the pulp like calcium hydroxide, the secondary author of this study as long-time owner of a general dental practice suggested an analysis of his endodontic treatment cases with open apical foramen regarding apexification/apexogenesis, which had been carried out by Joschko (2013) as then doctoral candidate from which this article reports.

**Material and method**

99 endodontic treatments of teeth with open apical foramen were taken from the files of the practice examined in this study in the years 1985 through 2006. Treatment method was the so-called N2 method according to Sargenti and Richter(1954), which meant: no canal rinsing and application of the paraformaldehyde-containing N2. Rubberdam was not used. The N2 powder contained 7% formaldehyde before admission by the EU, afterwards the content was decreased to 5%.

Four cases were excluded:
- A non-vital case where the initial X-ray did not clearly reveal whether the apical radiolucency of both roots were a matter of apical periodontitis or apical papilla.
- A VitA-case was extracted also loco a few days up to 18 months after VitA.
- X-ray was insufficient in the third case, VitE of an upper molar.
- In the fourth case, the patient did not show up again after devitalization of an upper premolar.

Thus, 95 cases to be judged remained, of which only two non-vital teeth were treated in a two-stage therapy. 93 cases were treated in one appointment inclusive definite filling. For root canal filling, the N2 powder was mixed with N2 liquid to a creamy texture, a harder consistency was needed for VitA. N2 application for root canal filling was done by lentulo, for VitA a carrier instrument was used to bring the material into the excavated pulp cavity up to 1–2 mm into the canal accesses.

The 95 anonymous made cases were clinically followed-up without recall at an average of 73 months after treatment. 75 cases underwent X-ray control (follow-up X-ray) after an average of 70 months; 64 cases as single-tooth X-ray in parallel technique and 11 cases as orthopantomogram.
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Judged as endodontic failure were: pain or fistula at treated tooth, development of apical periodontitis, lingering or newly developed apical periodontitis.

Treatment success of the 75 cases was analysed in two modes considering the questions:
· Did apexification/apexogenesis occur?
· Did the apex remain unaffected of apical periodontitis?

In multi-rooted teeth with different apical diagnosis, the worst diagnosis was assumed as being valid for the tooth. A double magnifier served as diagnostic aid. Three persons evaluated the X-rays independently from each other: The doctoral candidate (author AJ), a dentist with ten years of professional experience and the practice owner (author RT). The final diagnosis resulted from the consensus of the three ratings.

Statistic significance was assumed for an error assumption of $p < 0.05$ for comparison of two parameters and calculated by means of the logrank test.

Result

The average age of the patients was 10.7 years (6–25). Most cases (N=64) were attributed to mandibular molars (72%), among these mostly the first lower molars with 48 cases (50.5 % of the cases to be analyzed), followed by nine cases of maxillary incisors. 75 cases were subject to one or—in intervals—multiple follow-up X-rays. 40 teeth (53.3 %) were extirpated vitally, 28 teeth (37.3 %) were amputated vitally and seven non-vital teeth (9.3 %) underwent conservative endodontic treatment. Post-endodontic clinical control averaged at 73 months (12–271), the follow-up X-rays to be evaluated at 70 months (10–228). In 41 cases, X-ray evaluation was done more than 48 months after endodontic therapy.

The longer therapy dated back, the earlier achievement of the treatment aim apexification or apexogenesis could be verified. Two cases featured open apical foramina even 16 respectively 30 months post treatment. In nine molars, the apical foramina of various roots were partly still open, partly already closed after an average of 28 months. Thus their results could only be judged as partial success. An average post-observation time of 71 months was registered in 55 cases with the diagnosis ‘apex closed without lengthening of the root’. A ‘closed apex with root growth’ could be stated in nine cases after an average of 117 months (see case 1). The average age of the nine young patients with root growth amounted to 9.5 years, those without root growth had an average age of 11.2 years.

Overall, an apexification success was found in 64 cases (85.3 %, confidence interval 77.3–93.3 %). In nine other multi-rooted teeth (12 %), the maturation process of the roots was differently distinct: The same tooth featured a root with closed apical foramen, whereas another root still showed an open foramen. Maturation progress of the immature teeth was ob-
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served on the basis of the 49 cases with multiple follow-up X-rays in different intervals. A first follow-up X-ray was available after an average of 34.6 months (4–130). 18 cases (36.7%) featured advancement, whereas the status of the other cases remained unchanged.

Not considering the nine partial successes as mentioned above, an apexification success rate with/without root lengthening of 90% (confidence interval 80.7–99.3%) was determined in the VitE group, the success rate of the VitA group was 85.7% (confidence interval 72.7–98.7%), the non-vital group showed a success rate of 57.1% (confidence interval 20.5–93.8%). The percentaged difference of apexification success VitE versus VitA with a probability of error of p = 0.5893 and VitA versus non-vital group with p = 0.0910 was not significant statistically. A statistic significance could be determined when comparing VitE with the non-vital group (p = 0.0243). Apexification success in root-filled teeth proved not to be depending on the filling level (p = 0.2441).

Ten endodontic failures (13.3%), nine of which radiographically and one clinically due to fistula formation (see case 2), were observed: six following VitE (15%), two following VitA (7.1%) and two following conservative root canal treatment of the seven non-vital teeth (28.6%). Regarding endodontic success/failure of VitE versus non-vital group, a statistic significance revealed (p = 0.0587). A statistic significance could be stated when comparing VitA with the non-vital group (p = 0.0157). Apexification occurred in nine of the ten failures. Patient classification in age groups of younger than 125 months and older than 125 months was not relevant regarding avoidance of endodontic failure (p = 0.448).

19 teeth (20% of the 95 treated teeth) were extracted during the observation period. Seven of these teeth belonged to the VitE group, eight to the VitA group and four to the non-vital group. A statistic significance of extraction frequency existed when comparing the VitE with the non-vital cases (p = 0.0169). Figure 1 shows the three groups’ probability of survival with the aim of no extraction.

Nine teeth (47%) were extracted within the first 50 months after treatment. The time history of all extractions is featured in Figure 2. Main reason for extraction was damage/fracture of the natural tooth crown (42%) or an endodontic failure (31%). 33 of the 48 endodontic treatments of first lower molars had been done prior to the age of ten years. 14 first lower molars (73.7% of all extractions) were extracted, 12 of which prior to the age of 20 years.

Discussion

The present study is a retrospective one with data collected out of a regular dental practice, where endodontic treatments were done according to the Sargenti N2 technique (1954) exclusively, a method not accepted in the established dental doctrine, primarily due to the formaldehyde content in the N2 powder, but also because of elimination of root canal rinsing. 95 cases could be evaluated.

Whereas apexification literature is generally based on front teeth with necrotic pulp, only 10% of the
95 evaluated teeth were non-vital (see case 3). 38% were treated by VitA, 52% by VitE. The first mandibular molars were represented most with 48 cases. Patient recall did not take place. In contrast to clinics, patient loyalty nevertheless allowed a clinical control of all 95 cases, which was done after an average of 73 months. 75 cases were subject to X-ray control. The actually evaluated X-ray had been taken after an average of 70 months. 49 of the 75 cases had more than one follow-up X-ray taken so that X-ray interpretations could have been done for various time intervals thus allowing control of the further apical development. A first control X-ray was generally available after 34.6 months. 18 cases of the more than one follow-up X-rays documented a continuous maturation. For lack of previous X-rays, the result of 31 cases of final apical condition after 34.6 months does not mean that apexitification or apexogenesis could not have been occurred prior to this time, which could have been clarified in a prospective study only. However, the radiographic observation period of 70 months is long compared to other publications. The longest is indicated by Herforth (1981) with 3.9 years after treatment of 541 front teeth, condition after accident, with calcium hydroxide and Jodoform and with four years by Cvek (1972), who evaluated the data of 328 immature luxated/subluxated maxillary front teeth treated with calcium hydroxide by 58 practitioners. 12 months after MTA treatment of 30 single-root, non-vital teeth with open apical foramen Annamalai and Mungara (2010) obtained the following results: apical healing 100%, apexitification 86.6%, root extension 30%. After an observation time of 12–44 months, Holden et al. (2008) determined a success rate of 85% (N=17) for their 20 teeth treated by MTA in several appointments. The healing and apexitification process was not subject to recall interval. However, advanced growth of the apices after N2 application over a period of several years could have been well observed in the present study (average: without extension 71 months, with extension 117 months), possibly due to the different characteristics of MTA versus N2.

The authors Simon et al. (2007) observed 43 single-rooted teeth with open apical foramen that had been one-stage treated with MTA for a time of 12 up to 36 months. They stated a complete healing in 65 %, an incomplete healing in 30 % and an ‘apical closure’ in 26 % of these cases (N = 11). The radiographic diagnosis of the present study is: 78.8 % positively without apical periodontitis, 9.3 % apical periodontitis questionable, 12 % apical periodontitis with 85.3 %

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features ‘apical closure’ and 36.7% root extension. However, a direct comparison between the Simon and the present study is not admissible due to the low number of cases, the different observation periods and the non-coordinated interpretations of the evaluation modalities.

El Meligy et al. (2006) examined 30 pulpotomy cases (15 Ca(OH)$_2$, 15 MTA), 24 of which were first molars, which suggests a comparison with our study. The following assumptions were applied: no clinical problems, radiographically no apical periodontitis, apexification occurred. 13 calcium hydroxide cases (87%), but all MTA cases came up to this.

The three above mentioned therapy groups of this study achieved an apexification success of totally 85.3% by means of the formaldehyde-containing N2: 90% following VitE, 85.7% following VitA, 57.1% following conservative root canal treatment of non-vital teeth. The success rate of 57.1% for non-vital teeth should not be taken too seriously because of the 20.5–93.8% wide confidence interval due to the small number of cases. The percentaged success referred to the respective teeth as a whole. Another 12% referred to some molar roots with partly open, partly closed apices. Sheehy and Roberts (1997) comparatively report on the formation of a hard substance barrier after calcium hydroxide application after 5–20 months in 7–100% of the cases. In contrast, the authors Roberts and Brilliant (1975) considered the interpretation of an X-ray as being unrealistic for determination of a possible apical closure matching the Liang et al. proof of insufficient diagnostics of the periapical X-ray versus digital volume tomography (DVT). 23 teeth were reexamined according to both techniques two years after endodontic treatment. 74% of periapical radiolucencies could not have been visualized with conservative X-ray and 61% with DVT. Despite of the diagnostic deficits to be assumed, X-ray in combination with a clinical examination remains the only practical method. An interpretation bias in this study can be largely eliminated due to the consensus finding of the three X-ray evaluators.

While in short-term studies with low case numbers extractions are not mentioned, this study counted 19 extractions, 14 of which were allotted to the first mandibular molars. Thus the mandibular molars represented 73.7% of all extractions with a 50.5% share in treatments. This relatively high extraction frequency may be due to the fact that these teeth erupt early as the first permanent molars thus having been exposed to tooth-damaging influences for the longest time. Extraction is avoided less in the posterior area versus the anterior areas, as in young patients the gap normally closes the natural way without orthodontic or prosthodontic treatment.

Garcia-Godoy and Murray (2012) made up a survey with hints to deficits in apexification literature. According to this survey, 200 case studies on calcium hydroxide had been published. Reports on unfavourable and long-term effects would be missing. One problem of long-term calcium hydroxide dressings would be an alteration of the mechanical dentine characteristics, which could lead to fractures. Long-term studies regarding MTA would be missing. However, for achieving apexification, mineral-trioxide aggregate would be more effective than calcium hydroxide.

Also regarding regenerative procedures, only case studies and case series would exist. The ‘blood clot’ generated during this therapy should however have no contact to the inserted sealer, as sealers were not biocompatible and featured a cell-toxic effect.

In the present study, pulp tissue, possibly blood as well, had contact to the cell-toxic N2. As the long-term observation showed, this contact had no disadvantageous effect to the respective teeth. Regarding apexification and apexogenesis, a perennial study rather proved that the success rate was at least equal to MTA and calcium hydroxide. Root fracture, as suspected in calcium hydroxide cases, could not have been noticed in any of the cases. One-stage treatment has to be considered as special advantage of N2 application aiming at apexification, which at the same time is a time- and cost-saving method.

Editorial note: A list of references is available from the publisher.

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Canal preparation and obturation: An updated view of the two pillars of nonsurgical endodontics

Author: Dr Ove A. Peters, USA

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

Prior to initiating therapy, a clinician must establish a diagnosis, take a thorough patient history and conduct clinical tests. Recently, judicious use of cone beam computed tomography (CBCT) has augmented the clinically available imaging modalities. Verifying the mental image of canal anatomy goes a long way to promote success in canal preparation. For example, a missed canal is frequently associated with endodontic failures.1

As most maxillary molars have two canals in the mesiobuccal root, case referral to an endodontist for microscope-supported treatment should be considered. Endodontists are increasingly using CBCT and the operating microscope to diagnose and treat anatomically challenging teeth, such as those with unusual root anatomies, congenital variants or iatrogenic alteration. The endodontic specialist, using appropriate strategies, can achieve good outcomes even in cases with significant challenges (Fig. 1).

Preparation of the endodontic space

The goal of canal preparation is to provide adequate access for disinfecting solutions without making major preparation errors, such as perforations, canal transports, instrument fractures or unnecessary removal of tooth structure. The introduction of nickel-titanium (NiTi) instruments to endodontics almost two decades ago2 has resulted in dramatic improvements for successful canal preparation for generalists and specialists. Today, there are more than 50 canal preparation systems; however, not every instrument system is suitable for every clinician and not all cases lend themselves to rotary preparation.

Several key factors have added versatility in this regard, for example, the emergence of special designs such as orifice shapers and mechanised glide path files. Another recent development is the application of heat treatment to NiTi alloy, both before and after the file is manufactured. Deeper knowledge of metallurgical properties is desirable for clinicians who want to capitalise on these new alloys. Finally, more recent strategies such as minimally-invasive endodontics have emerged.3

Basic nickel–titanium metallurgy

What makes NiTi so special? It is highly resistant to corrosion and, more importantly, it is highly elastic and fracture-resistant. NiTi exists reversibly in two conformations, martensite and austenite, depending on external tension and ambient temperature. While steel allows 3 % elastic deformation, NiTi in the austenitic form can withstand deformations of up to 7 % without permanent damage or plastic deformation.4 Knowing this is critical for rotary endodontic instruments for two reasons. First, during preparation of curved canals, forces between the canal wall and...
abrading instruments are smaller with more elastic instruments, hence less preparation errors are likely to occur.

Second, rotation in curved canals will bend instruments once per rotation, which ultimately will lead to work hardening and brittle fracture, also known as cyclic fatigue. Steel can withstand up to 20 complete bending cycles, while NiTi can endure up to 1,000 cycles.4

Recently manufacturers have learned to produce NiTi instruments that are in the martensitic state and even more flexible than previous files. Figure 2 shows how instrument conditions (austenite vs. martensite) are determined in the testing laboratory, using prescribed heating and cooling cycles.5 Heat-treated files with high martensite content typically do not have a silver metallic shade but are coloured due to an oxide layer, such as gold or blue.

It is important to note that CM files frequently deform; however, with a delicate touch, cutting is adequate and often even superior to conventional NiTi instruments.6 It is imperative for clinicians to retrain themselves prior to using these new instruments to avoid excessive deformation and subsequent instrument fracture.

Preparation strategies

Experimental and clinical evidence suggests that the use of NiTi instruments combined with rotary movement results in improved preparation quality. Specifically, the incidence of gross preparation errors is greatly reduced.7 Canals with wide oval or ribbon-shaped cross-sections present difficulties for rotary instruments and strategies such as circumferential filing and ultrasonics should be used in those canals.

Studies found that oscillating instruments recommended for these canal types did not perform as well,4 particularly in curved canals. Specific instruments developed to address these challenges include the Self-Adjusting File (SAF) System (ReDent NOVA), TRUShape (Dentsply Sirona) and XP Endo (Brasseler). However, there is no direct clinical evidence that these instruments lead to better outcomes.

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

Almost all current rotaries are non-landed, meaning they have sharp cutting edges, and they can be used in lateral action toward a specific point on the perimeter. This ‘brushing’ action allows the clinician to actively change canal paths away from the furcation in the coronal and middle thirds of the root canal10 but may create apical canal straightening when taken beyond the apical constriction. Circumferential engagement of canal walls by active instruments may lead to a threading-in effect, but contemporary rotaries are designed with variable pitch and helical angle to counteract this tendency.

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

NiTi instrument usage

As a general rule, flexible instruments are not very resistant to torsional load but are resistant to cyclic fatigue. Conversely, more rigid files can withstand more torque but are susceptible to fatigue. The greater the amount and the more peripheral the distribution of metal in the cross-section, the stiffer the file.11 Therefore, a file with greater taper and larger diameter is more susceptible to fatigue failure; moreover, a canal curvature that is more coronal is more vulnerable to file fracture.
Instrument handling has been shown to be associated with file fracture. For example, a lower rotational speed (~250 rpm) results in delayed build-up of fatigue and reduced incidence of taper lock. Material imperfections such as microfractures and milling marks are believed to act as fracture initiation sites. Such surface imperfections after manufacturing can be removed by electropolishing but it is unclear if this process extends fatigue life. Manufacturers’ recommendations stress that rotaries should be advanced with very light pressure; however, the recommendations differ with regard to the way the instruments are moved. A typical recommendation is to move the instrument into the canal gently in an in-and-out motion for three to four cycles, directed away from the furcation, then withdraw to clean the flutes.

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

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

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

Recently, the term ‘minimally-invasive endodontics’ has been used to describe smaller-than-usual apical sizes and, perhaps more importantly, an understanding that the long-term success of root canal-treated teeth will improve by retaining as much dentin structure as feasible. The thought process for this was the finding that most root canal-treated teeth survive ten years and longer. In studies, the reasons cited for the extraction vary but in many cases teeth are either fractured or non-restorable for other reasons.

In consequence, a smaller coronal dimension of rotaries is considered while maintaining apical sizes to support antimicrobial efficacy. There currently is no direct clinical evidence to support this strategy but it is clear that root fractures pose problems in the long-term outcomes of our patients. Another recent development is the emergence of certain specialised rotaries, such as dedicated orifice shapers and so-called glide path files. The orifice shapers have larger tapers, such as .08, which means that they are not flexible and can overprepare at the canal orifice level. Glide path files, for example PathFiles and ProGlider (Dentsply Sirona), are delicate instruments and may fracture when used incorrectly. It is recommended to use a small K-File (size #10) before any rotary instrumentation and to use a delicate touch.

Clinical results

While results from in vitro studies on rotary systems are abundant, clinical studies on these instruments are sparse. Comparing NiTi and stainless steel K-Files, Pettiette et al. found less canal transportation and fewer gross preparation errors such as strip perforations. Subsequently, using radiographic evaluation of the same patient group, they demonstrated better healing in the NiTi group. An earlier outcome study with three rotary preparation paradigms did not show any difference between the three systems with an overall favourable outcome rate of about 87%. The most consistent clinical results are obtained when the manufacturer’s directions are followed.
While these vary by instrument, a set of common rules applies to root canal preparation. Root canal systems are best prepared in the following sequence:

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

Obturation of the endodontic space

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

Basic strategies in root canal obturation

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

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

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

Current developments in root canal obturation materials

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

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

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

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

- Choosing a technique and timing the obturation.
- Selecting master cones.
- Canal drying, sealer application.
- Filling the apical portion (lateral and vertical compaction).
- Completing the fill.
- Assessing the quality of the fill.

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

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

In addition to a solid filler such as gutta-percha, a sealer or cement should be used. Most sealers are toxic in the freshly mixed state, but this toxicity is reduced after setting. When in contact with tissues and tissue fluids, zinc oxide eugenol-based sealers are absorbable, while resin-based materials typically are not absorbed.

Some by-products of sealers may adversely affect and delay healing. Therefore, sealers should not be routinely extruded into the periapical tissues.

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

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

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

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

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

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

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

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

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

- Excessive dentine removal during access and instrumentation.
- Preparation errors such as perforation, ledge formation and apical zipping.
- Presence of an instrument fragment in not fully disinfected canals.
- Obturation material overfill and overextension.

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

Summary and conclusions

Root canal preparation with contemporary instruments is a predictable procedure in most cases for a well-trained clinician following established guidelines. Cases with a recognised high degree of difficulty are best referred to an endodontist. While many cases can be treated successfully in routine practice, the additional training, expertise and technology of endodontists is necessary in cases that are beyond the typical spectrum. The best long-term outcomes are obtained when a correctly planned final restoration is placed as soon as possible after root canal treatment is completed (Fig. 4).

Root canals may be filled through various methods, typically using a combination of a cement and a solid filling material such as gutta-percha. The specific obturation material used appears to have a smaller role on outcomes. Overfills, particularly into the area of the inferior alveolar nerve, have the potential to permanently harm a patient. The absence of gross errors that are associated with persistent presence of bacterial infection and excessive dentine removal during access and canal preparation have the greatest impact on outcomes.

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Editorial note: A complete list of references is available from the publisher and also at www.aae.org/colleagues.

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Dr Peters also earned a certificate in endodontics and MS certificate in oral biology from UCSF and was board certified in endodontics in 2010. He received the Louis I. Grossman Award in 2012. Peters is currently a tenured professor and co-chair of the Department of Endodontics at the Arthur A. Dugoni School of Dentistry at the University of the Pacific, San Francisco, and the director of the Advanced Education Program in Endodontology. His main scientific interests are the performance of root canal instruments assessed by mechanical testing methods, three-dimensional imaging and the efficacy of antimicrobial regimes in root canal treatment. More recently, he became involved in endodontic biology and now runs a dental stem cell biology laboratory.

Dr Peters has published more than 100 papers in peer-reviewed journals and has lectured extensively both nationally and internationally. He has written multiple chapters in leading textbooks and serves on the review panels and editorial boards of high-impact endodontic journals. He may be contacted at opeters@pacific.edu.
Introduction

Radiographic imaging forms an essential part of the diagnosis, treatment planning and follow-up, in modern endodontics. Cone beam computed tomography (CBCT) allows for the visualisation of root canal systems in three dimensions without the superimposition of anatomic structures that occurs with conventional radiographs. CBCT units reconstructs the projection data to produce interrelational images in the axial, sagittal and coronal planes. Due to the higher resolution of limited field of view CBCT units (Fig. 1) their application in endodontics has been expanded. 

High resolution CBCT images are ideal for diagnosis of periapical lesions, identification of root fractures and resorption lesions and for the evaluation of root canal morphology, root length and root curvatures.

The purpose of this article is to demonstrate the benefit of the 3D Endo Software in a complex clinical case that required endodontic treatment. In addition, a different approach to glide path management and root canal preparation for canals that present with multi-planar anatomy will be discussed.

Case report

Preoperative evaluation

The patient, a 25-year-old female, reported with irreversible pulpitis on her maxillary second left molar. The tooth was temporarily restored with Intermediate Restorative Material (IRM, Dentsply Sirona) and the patient complained about continuous food impaction between her maxillary left, first and second molar teeth (Fig. 2). A periapical radiograph revealed that the temporary restoration was not sealing at the gingival margin (Fig. 3). Also, visible on the periapical radiograph was evidence of possible curvatures in the mesiobuccal and distobuccal roots. It was decided, with the consent of the patient, to take a limited field of view CBCT scan to explore the anatomy of this tooth.
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The CBCT scan revealed the presence of three root canal systems when viewed in the axial plane; and in the sagittal plane, evidence of severe root curvatures were present in the mesiobuccal and distobuccal root canal systems. It was decided to do a more in-depth investigation as a result of this complex anatomy, using the 3D Endo Software (Dentsply Sirona).

**3D Endo Software**

The data of the limited field of view CBCT scan was exported as a DICOM file and imported into the 3D Endo Software. The 3-D planning of the case was then completed in five easy steps.

In the first step, ‘Diagnosis and Pathology’, the imported scan was reviewed in the axial, sagittal and coronal planes. The software has the ability to present a 3-D reconstructed view where the transparency of the teeth can be changed (Figs. 4a–d).

The second step, ‘3D Tooth Anatomy’, involved selecting the tooth to be examined and the entire volume was cropped to only leave the data of interest behind (Fig. 5). In the third step, ‘Canal System’, the number of root canals were identified and each root canal was then mapped separately by identifying the orifice and radiographic apical foramen of each root canal (Fig. 6).

With the fourth step, ‘3D Canal Anatomy’, the software made a proposal of the canal anatomy (Fig. 7), but the operator can make corrections according to the canal configuration that can be viewed in different planes in the software. Figures 8 to 10 show the mapping of the palatal, mesiobuccal, and distobuccal root canal systems.

During the fifth step, ‘Treatment Plan’, the software projected ISO size 06 instruments into the canals (Fig. 11), which allowed the operator to visualise the internal anatomy of the canals, check straight line access, and modify the proposed access if necessary. A rubber stop on the files can then be digitally adjusted to a coronal reference point of choice that will then indicate the proposed working length for each root canal system. This view can also be rotated in 3-D to alert the operator of the angle and direction of curvatures in the root canal systems (Fig. 12). The step after ‘treatment plan’ is to select a master file from a preloaded database of endodontic file systems that will most likely result in optimal canal preparation for that specific shape or diameter of a canal. Considering the s-shaped curvatures in all three root canal systems as well as the sharp curvatures in different planes, it was decided to use the Primary WaveOne Gold file (25/07) in the palatal canal and the Small WaveOne Gold file (20/07) for root canal preparation in the two-challenging buccal root canal systems (Fig. 13). The selected instruments were then displayed in the root canal systems and the operator again digitally rotated and visualised the root canal anatomy in 3-D (Fig. 14).
Pre-endodontic restoration
At a following visit, the tooth was anaesthetised, and a rubber dam placed. The temporary filling material was removed, revealing evidence of caries as indicated by caries indicator solution (Fig. 15). The caries was removed and the pulp was exposed (Fig. 16). A pre-endodontic restoration was performed using the Palodent V3 matrix system (Dentsply Sirona; Fig. 17) in combination with SDR bulk fill flowable resin (Dentsply Sirona) and ceram.x SphereTEC one composite resin (Dentsply Sirona; Fig. 18). After the pre-endodontic restoration, an access cavity was prepared and the canals were located under magnification.

Canal negotiation and glide path preparation
The pulp chamber was filled with Glyde (Dentsply Sirona) before the canals were carefully negotiated to full working using pre-curved size 08 K-Files (Fig. 19). Working length measurements obtained from an electronic apex locator reading corresponded with the lengths obtained from the 3D Endo Software. These measurements were also confirmed radiographically (Fig. 20). A reproducible glide path was prepared in each root canal system with the size 08 K-File in an M4 Reciprocating hand piece (Sybron Endo; Fig. 21), followed by making a size 10 K-File ‘super loose’ (Fig. 22). A ProGlider (Dentsply Sirona)
Case report: Treating complex root canal anatomy

A rotary motion was used to expand the glide path in the palatal root canal (Fig. 23). Considering the sharp and severe curvatures in the two buccal canals, it was decided to convert the ProGlider instrument into a manual file to expand the glide path in these tortuous canals with more safety (Fig. 24). The manually adapted ProGlider was used in a balanced force motion up to working length. In addition, to create more safety during the canal preparation of the two challenging buccal root canals, it was also decided to use the reciprocating WaveOne Gold Glider (Dentsply Sirona; Fig. 25) after the ProGlider instrument to further expand the glide path. The WaveOne Gold Glider was used in 4–8 backstroke brushing motions from working length, in the two buccal root canal systems.

Root canal preparation, irrigation, and obturation

As mentioned before, WaveOne Gold files (Dentsply Sirona) were selected for root canal preparation. The palatal canal was prepared with the reciprocating, Primary WaveOne Gold instrument (Fig. 26), and the two buccal root canals with the Small WaveOne Gold file up to working length (Fig. 27).

After canal preparation, the canals were flooded with 17% EDTA solution (Ultradent) and the solution activated for 1 minute with the EDDY Endo Irrigation Tip (VDW) driven by an air scaler (SONICflex LUX 2000L, KaVo). Thereafter, final disinfection was achieved by activating 3.5%, heated sodium hypochlorite for three minutes, again activated with the EDDY Endo Irrigation Tip.

The canals were dried with paper points and obturated using matching gutta-percha points, Pulp Canal Sealer (Kerr) and the Calamus Dual Obturation Unit (Dentsply Sirona). Figure 28 shows the final result after obturation.

Discussion

According to the European Society of Endontology’s position statement, the use of CBCT in endodontics should only be considered if additional information from the reconstructed three-dimensional images will potentially aid in the diagnosis and/or enhance the management of the tooth with an endodontic problem. A limited field of view CBCT scan should be considered as the imaging modality of choice for teeth with the potential for extra canals and suspected complex root canal morphology.

The 3D Endo Software that was used in this case report not only allowed the operator to scroll through the tomographic slices in the coronal, axial and sagittal planes, but facilitated a 3-D image of the root canal anatomy prior to treatment. Only after visualising the severe curvatures and their projection in the buccal palatal direction was the complexity of this case realised. This information was vital for the treat-
ment-planning phase of this case. According to the information obtained from the 3D Endo Software, the authors could select the ideal instruments for canal negotiation, glide path and canal preparation, irrigation and obturation. According to Tchorz (2017), the option to plan endodontic cases in 3-D before treatment is a significant gain for modern endodontics, and can help to prevent procedural errors, especially in complex cases.10 It is important to note that in this case report the working length measurements obtained from the 3D Endo Software and the apex locator correlated with each other. However, it always advised to verify the software readings with an apex locator, as several parameters such as the access cavity design and position, the amount of coronal pre-flaring and the choice of reference point can have an influence on the working length measurement.10

The most challenging clinical aspect of this case was to negotiate the canals to patency, to create reproducible micro glide paths, and to expand the glide paths to a level where the maximum safety could be secured before introducing the root canal preparation instruments. The glide path preparations were managed with manual K-Files, K-Files in the reciprocating M4 handpiece followed by expanding the glide paths with the ProGlider and the WaveOne Gold Glider instruments.

In 2006, West recommended using K-Files with an initial watch winding motion to remove restricted dentine in very narrow canals, followed by a vertical in and out motion with a 1 mm amplitude and gradually increasing the amplitude as the dentine wall wears away and the file advances apically.11 Several authors have described the use of a small K-Files driven by a reciprocating hand piece for initial glide path preparation, especially in very constricted or curved canals.12, 13 The main advantages of using the reciprocating M4 hand piece is to reduce the glide path preparation time, hand fatigue, and to secure the canal in narrow, multi-planar root canals faster compared to the conventional manual technique.14 Securing the two multi-planar buccal root canal systems in this case, with a size 08 K-File in the M4 reciprocating handpiece, facilitated further glide path enlargement.

The ProGlider, a single file rotary glide path instrument was the first instrument used to expand the glide paths. This file is manufactured from M-wire NiTi alloy that shows more flexibility and resistance to cyclic fatigue compared to conventional NiTi alloy. It has a semi-active tip, size ISO 016 (D0) with a 2% taper that progressively increase up to 8% (D14; Fig. 29). The cross section of the ProGlider instrument is square and the file is used in a continuous rotary motion at 300 rpm and a torque setting of 2–4 Ncm.14 Considering the severe curvatures in different planes of the buccal root canal systems, the ProGlider instrument was first used in a manual mode up to working length in these two canals. It was also then decided to further expand the glide path in these canals by using the WaveOne Gold Glider, also a single, reciprocating glide path file designed for glide path enlargement. Here, a second glide path instrument was used because the cutting envelope of the WaveOne Gold Glider is more than the ProGlider instrument (Fig. 30).
The rationale for this double file approach for glide path expansion was to enhance safety for the preparation files that followed.

The file tip of the WaveOne Gold Glider at D0 has a ISO 015 tip size with a 2% taper, and the taper progressively increase up to 6% (D16; Fig. 29). The file has a semi-active tip and a parallelogram shaped cross-section. The WaveOne Gold Glider is manufactured using NiTi wire subjected to a post-manufacturing thermal process, whereby a new phase-transition point between martensite and austenite is identified to produce a file with super-elastic NiTi metal properties.15 This process gives the file a gold finish with enhanced flexibility and resistance to cyclic fatigue compared to conventional NiTi and M-wire alloys. The WaveOne Gold Glider was driven by the X-Smart motor, on the WaveOne setting. The file was taken up to working length in the already secured and expanded glide path and the glide path was further expanded by using a 4–8 backstroke brushing motions, until the file felt completely loose in the challenging canal systems.

The WaveOne Gold Primary and Small files were selected for root canal preparation in this case. These
files are manufactured with the same technique as described above for the WaveOne Gold Glider, to produce a file with super-elastic NiTi metal properties. The WaveOne Gold Primary file (Dentsply Sirona) is 50% more resistant to cyclic fatigue, 80% more flexible, and 23% more efficient than the conventional WaveOne Primary instrument.16–18

This unequal clockwise (CW) and counter-clockwise (CCW) reciprocating motion of the WaveOne Gold system has the following advantages over continuous rotation systems:

- Binding of the instruments into the root canal dentine walls is less frequent, reducing torsional stress.19
- Reduction of the number of cycles within the root canal during preparation results in less flexural stress on the instrument.20
- Improved safety, as the CCW disengaging angle is designed to be less than the elastic limit of the instrument.17
- There is decreased risk of instrument fracture.19, 21
- It allows the file to easily progress towards working length without using potentially dangerous inward pressure.17, 21

WaveOne Gold files are characterised by a parallelogram (with two 85 degree cutting edges), off-centred, cross-section.18 According to Ruddle, this design limits the engagement between the file and the dentine to only one or two contact points at any given cross-section.17 This will subsequently reduce taper lock and the screw-in effect, improve safety, and cutting efficiency.16, 17

The newly designed files is also manufactured with an ogival, roundly tapered and semi-active guiding tip to ensure that the files progress safely along canals with a secured and confirmed reproducible glide path.17, 18

**Conclusion**

The preoperative planning stage using the 3D Endo Software provided the authors with vital information regarding the complex root canal anatomy that influenced the choice of materials and techniques in this case report. Because the root canal anatomy could be visualised in 3-D preoperatively, the authors realised that there would be a high risk of either losing working length or instrument fracture during canal preparation. It was therefore very important to secure the canals by means of glide path preparation and enlargement prior to root canal preparation._

**References**


**Fig. 23:** A ProGlider was used in a rotary motion to expand the glide path in the palatal root canal.

**Fig. 24:** A ProGlider, converted to a manual file, was used to expand the glide paths in the two buccal root canals.

**Fig. 25:** A WaveOne Gold Glider was used in a reciprocating motion to further expand the glide paths in the two buccal root canals.

**Fig. 26:** The Primary WaveOne Gold file (25/07) was used to complete canal preparation in the palatal root canal.

**Fig. 27:** The Small WaveOne Gold file (20/07) was used to complete canal preparation in the two buccal root canal systems.

**Fig. 28:** Periapical radiograph showing the result after obturation. Note the evidence of an additional canal loop in the mid-root area on the mesiobuccal root canal system that was obturated.
Fig. 29: Comparison between ProGlider and WaveOne Gold Glider.

Fig. 30: Cutting envelope of the ProGlider and WaveOne Gold Glider.


[16] Dentsply Maillefer Engineering and testing. Ballaigues, Switzerland. 2014.


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The effect of partial vacuum on the chemical preparation of the root canal system:

The Sleiman sequence

Authors: Prof. Philippe Sleiman & Dr Alfredo Iandolo, Lebanon/Italy

Introduction

From the early 20th century, when Walter Hess and Ernest Zürcher1 demonstrated root canal anatomy with an unprecedented visual clarity, its complexity has fascinated researchers armed with ever better imaging tools—from blue dyes to CT, from CBCT to confocal microscopy, from clear tooth preparations to micro-CT2–4, to name just a few. Thanks to rigorous research and discussion, the diverse intricacy of root canal morphology is well understood and accepted today. However, the question of how to best prepare this space to restore homeostasis remains open to debate, which is conducted both in the scientific and, unfortunately, commercial domains. Our task as scholars and clinicians is to investigate which approaches would be practical and applicable to bring teeth and periodontium back to health in accordance with evidence-based endodontics and principles of minimally-invasive dentistry.

As yet another array of new file systems are launched in the market, we seem to share an understanding that files do not have the ability to clean root canal space, only preparing, i.e. shaping it, while it is the irrigation process that provides a level of cleanliness that can, hopefully, create conditions for the body to heal. Thus, given that the shaping is acceptable (i.e. the files used remove the bulk of the pulp and/or infected dentine without blocking the system with debris as well as maintain the original shape of the canal without any micro-crack formation), it is the chemical preparation that is responsible for treating the system in all its complexity.

For a long time, irrigation remained a somewhat mystical part of the process, with a general agreement that a good rinse is necessary, but without a standardised sequence of irrigation. While various tools for irrigation and activation of solutions were studied extensively, the first sequence was suggested only in 2005,5, 6 and it made clinicians aware that alternating solutions could be as beneficial as the use of negative pressure in order to achieve a clean root canal space and diminish postoperative pain.

Below you will find descriptions and outcomes of several studies that led to a suggested protocol of irrigation that is presented in the conclusion of the present publication.
Investigating irrigation today

The fact that during root canal shaping the system may get blocked by debris led to the question of how to best conduct the chemical preparation so that the dentinal tubules remain open to allow for a better cleaning and, consequently, sealing of the system. Drawing from clinical experience and improved outcomes, Jaramillo et al. have formulated an experimental irrigation sequence based on Sleiman's 2005 suggestions, and added a negative pressure device to see if it may have added benefits. 7

Scanning electron microscopy used to evaluate the cleanliness of dentinal tubules at three different levels of the canals demonstrated that our experimental sequence—alternating the use of 6% NaOCl and 17% EDTA with water in between—had shown a significantly better ability to keep the entrances of dentinal tubules open and avoid the blockage of dentinal tubules by the smear layer and debris during the cleaning and shaping procedure compared with the use of 6% NaOCl or 17% EDTA alone. The results emphasised the importance of the early use of 17% EDTA and not only as a final rinse.

This sequence allows us to use the standard endodontic irrigants during chemical root canal preparation and prevents any chemical interaction between them thanks to the use of distilled water at strategic times. Depending on the pH levels and the nature of the solutions, such chemical interactions may have a variety consequences, from brown (and in some instances, carcinogenic) precipitation to dentine modification, potentially affecting general health and/or quality of the dentine inside the root canal system, which, in turn, may influence the longevity of the link between the sealer and the dentine, thus changing the outcome of the root canal treatment in general.

Another finding of the study that echoed positive clinical outcomes related to the use of negative pressure in combination with the experimental irrigation sequence; the irrigation protocol that included both the Sleiman sequence (alternating between sodium hypochlorite, water, and EDTA) and a negative pressure irrigation device was proven to be the most efficient in opening dentinal tubules and maintaining them open. It may be posited that the negative pressure allows for a formation of a temporary partial vacuum force, which first draws the liquids from the

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root canal preparation

Using the macro- and micro-cannulas of the negative pressure irrigation unit in, correspondingly, the coronal-middle and apical parts of the root canal system, leads to the creation of a vacuum, or a partial vacuum, to be more specific, inside the root canal space. Though its main role is to attract solutions deeper and deeper into the system and safely remove them from within, the partial vacuum created by the negative pressure has a number of other important benefits as Sleiman-Iandolo testing has shown.

First of all, it can eliminate the airlock (better known in endodontics as vapor lock) inevitably resulting from bubbly chemical reactions between irrigating solutions and the content of the root canal space inside the main canal—mainly in the apical part—as well as inside lateral canals and dentinal tubules and preventing the irrigants from reaching these areas and performing their best (Figs. 1a & b). Secondly, once the access cavity into the root canal system and then suctions them out of the system.

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Sleiman–Iandolo testing used freshly extracted premolars, removed due to periodontal pathology, impregnated with methylene blue dye in a centrifuge; this resulted in pushing the dye deeply into the dentinal tubules (Fig. 2a). To compare commonly used irrigant delivery techniques, a negative pressure irrigation unit was used (EndoVac) as well as a lateral-vented needle, manual activation of the solution, and passive ultrasonic irrigation in combination with the Sleiman irrigation sequence. EndoVac + Sleiman sequence was shown to be the only approach that allowed for a complete removal of the methylene blue dye from the entire root canal system and dentinal tubules over the total time of 25 minutes, while the other approaches failed to achieve a completely clean system (Figs. 2b & c).

The Sleiman sequence goes beyond using water as an intermediate between the two alternating solutions and as the final irrigant (water cooled to between 2.5°C and 4°C and used for postoperative pain control or in a cryotheraphy modality also suggested by Sleiman and investigated by Vera et al.)—it also stipulates that when using the macro- or the micro-cannula of the negative pressure irrigation unit for chemical preparation, every five seconds a two-to-three-second pause should be made when no irrigant is added. It is during this pause that the partial vacuum is created by the cannula, which will

Fig. 2c: Sleiman–Iandolo testing. Results of the dye removal with PUI (left) and a negative pressure irrigation unit used at the intervals suggested as part of the Sleiman sequence (right). Note the extreme cleanliness of the deepest recesses of the dentinal tubules in the image on the right.
draw out all the fluids, residues and gases from all the root canal system. Once the system has been drained, the partial vacuum established inside the root canal system in its entirety can attract a fresh portion of irrigant for a faster and cleaner preparation of the root canal system.

Clinical cases

In the images above, we present some of the typical cases demonstrating the cleanliness of the root canal system achieved as shown by the lateral and/or accessory canals visualised upon 3-D warm vertical condensation (Figs. 3–6).

The case of a failing root canal treatment with apical infection and an internal resorption in the apical area was referred to us (Fig. 7). After removing the previous filling, chemical preparation was performed, with the help of the partial vacuum inside the system the chemicals were able to clean the resorption area without an aggressive effect on the periodontal ligament; this has led to a truly three-dimensional obturation. The 4-month follow-up image (Fig. 8) confirms a fast healing of both the apical area and the area of the resorption lesion.

Conclusions

Realising that a 100% disinfection of the root canal space remains unattainable, we continue to strive for perfection in our attempts to develop viable clinical protocols that would allow to lower the inflammatory and/or bacterial load so that our patients' bodies can heal. Based on the supporting research and testing as well as on a history of sustainably high treatment outcomes for both primary endodontic treatment and retreatment of vital and non-vital teeth, we would like to propose our irrigation protocol as a fast, safe, and, most importantly, evidence-based technique of chemical preparation.

The Sleiman irrigation protocol requires 6% (or 5.25%, if the 6% concentration is not available) NaOCl, 17% EDTA, distilled water or normal saline. For the best results it is recommended to use a negative pressure irrigation unit to introduce and remove the solutions in order to benefit from the partial vacuum force; however, it must be said that using other introduction techniques in combination with the Sleiman sequence of irrigants will also improve chemical preparation results and lead to a cleaner root canal space.

Access cavity; manual files to locate orifices; manual files for initial scouting—NaOCl
· $H_2O$
· Machine files for root canal preparation—EDTA
· $H_2O$
· In between machine files—NaOCl
· $H_2O$ (cold for cryotherapy)
· Drying the root canal system—EndoVac

The whole irrigation procedure should follow the '5 sec introducing solution + 3 sec pause' guideline to achieve the best effect of the partial vacuum...

Editorial note: A complete list of references is available from the publisher.

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In 1967, Schilder had postulated that the final objective of endodontic procedures should be the total three-dimensional filling of the root canals and all accessory canals, in addition to the elimination of all organic debris, bacteria, and bacterial toxin. Therefore, the ability of filling lateral canals has been regarded as a measure of the endodontic treatment quality.

Nevertheless, the substantive need for filling lateral and accessory canals is still a controversial issue among clinicians. Kasahara et al. reported the incidence of accessory canals in the maxillary central incisors to be over 60%, and Dammaschke et al. showed 79% of molars had lateral/accessory canals. Large numbers of lateral/accessory canals exist in the roots, but the frequency of periapical lesions related with these ramifications is not as high as anticipated. The answers for these clinical observations are still not clarified. The differences in size between main apical foramen and lateral/accessory foramen might explain why the apical lesions were observed more frequently than lateral lesions. The amount of bacteria existing in the small ramifications might not be sufficient to raise inflammation which can be detectable on radiographs. Occasionally, the lateral lesion is healed without lateral canal filling because simple canal treatment could stop the diffusion of bacterial products from the main canal which might reach periodontal ligaments through lateral/accessory canals maintaining vitality. However, if periapical lesions originate from bacteria surviving in some spaces derived from lateral canals and irregularities of root canals, such as isthmuses, ramifications, deltas, then the treatment seems to be particularly challenging for clinicians.

Since it is unlikely to kill all pathogens in entire root canals, Buchanan suggested that the embedding of remaining bacteria with filling materials can achieve the same results as from complete disinfection in the canal systems. Thermo-plasticised gutta-percha filling techniques have been considered preferable means to achieve this goal due to remarkable frequency of lateral canal filling based on case reports and in vitro studies. Two major concerns for using thermoplastic techniques would be the periodontium damage by temperature increase and overextension of root canal filling materials, especially gutta-percha. The application of lasers in endodontic treatment is an attempt to minimise these potential risks.

The investigation of laser applications in endodontics was first reported in the early 1970s. Among a variety of conceivable uses, most researches emphasised the efficiency of debridement and the possibility of shaping the root canal by laser. It seems that the disinfection and cleaning of the root canals would be the most practical use of laser devices in endodontic
The maximum disinfecting effects in root canals can be achieved by laser-activated irrigation with NaOCl solution due to the pulsation of laser output and the easy access to root canals by an optical fibre. The acoustic streaming, caused by the collapse of laser-induced bubbles, was identified as an effective mechanism for dentin debridement in the apical portion of root canals. The pressure produced by the pulsation of laser beam in a narrow space like a root canal is a unique feature of laser devices.

No study addresses the application of laser pulsation on canal filling so far. This report documents three cases of traditional endodontic treatment that were supplemented with the use of the Nd:YAP laser which resulted in the radiographic identification of sealer in apical ramifications.

Material and methods

Three patients of this case report received root canal treatment necessitated by carious exposure of the pulp or apical periodontitis. Endodontic treatment consisted of the following procedures: access opening, canal preparation by hand and rotary instruments, canal irrigation, and canal filling. The canals were enlarged conservatively providing adequate proximation of the optic fibre to the apical third of the root canal. Three-percentage NaOCl solution and EDTA paste (RC-Prep, Premier) were used during instrumentation; saline was used between application of NaOCl and EDTA. Gutta-percha cones (Gutta Percha Points, Meta Biomed) and zinc-oxide eugenol-based sealer (ZOB Seal, Meta Biomed) were used for canal obturation.

The exposure to the Nd:YAP laser (Lokki YAP, Lokki), using 220 µm optical fibre (Fig. 1) with 160 mJ/pulse and 30 Hz, was conducted during canal irrigation. The optical fibre was put into a root canal 2–3 mm short of working length as a starting point for pulsed radiation. Radiation of the laser was followed with upward movement of the optical fibre against the canal wall and stopped when the optic fibre was close to the orifice. Laser irradiation was repeated throughout all canals as mimicking circumferential filing until no debris was noted in the pulp chamber followed by drying of the canals with paper points. The 220 µm optical fibre with the mode of 180 mJ/pulse and 5 Hz was chosen for canal filling. After root canals were filled with sealer by using a lentulo spiral, a single pulse of laser beam was radiated at a position 2–3 mm short of working length at first, and then another two single pulses of laser beam were emitted in the middle of the root and at a location 2–3 mm below the orifice consecutively. Cold lateral condensation was accomplished with the placement of a master gutta-percha cone followed by accessory cones for complete obturation. Periapical X-ray films were taken to evaluate the quality of the root canal obturation. No medications were prescribed during treatment or postoperatively for patients.
Case presentation

Case 1 (Figs. 2a–e)
A 45-year-old woman sought treatment for severe pain associated with a mandibular left canine. Clinically there was severe vertical mobility and cuspal interference existed when the patient moved her mandible in lateral excursion. Radiographic examination revealed a radiolucent lesion extending along the mesial aspect of the root. Before beginning access opening, the canine was splinted to the mandibular left, lateral incisor and first premolar, and the occlusion was adjusted to eliminate lateral interference. Purulent exudate was drained not only from the periodontal pocket, but also from the canal orifice after the chamber was opened. An accessory canal mimicking a bifurcated apical canal was sealed. At the ten-month recall, bone density was increased around the root and no inflammatory signs were observed in the periodontal pocket.

Case 2 (Figs. 3a & b)
A 46-year-old woman with missing restorations on the mandibular right first and second premolars complained of toothache. The fracture of the crowns was a result of secondary caries at the cervical portion of premolars. A large apical lesion was observed around the root of the first premolar. A prosthetic treatment of splinted crowns on the mandibular right first and second premolars with crown lengthening and cast posts was planned due to the patient’s desire to retain teeth. All symptoms subsided after endodontic treatment was completed. There was radiographic evidence of sealer in the apical ramifications.

Case 3 (Figs. 4a–c)
A 40-year-old woman sought treatment for a labial sinus tract related to the maxillary right first premolar. Extensive pulpal calcification was noticed on the periapical radiograph. The gutta-percha cone indicated that the labial sinus tract which appears to originate from a lateral canal. A dilaceration of the apical third and calcification of the canal made access difficult, resulting in a perforation on the mesial aspect of the root. The working length was adjusted and the canal was obturated to this point. A lateral canal was filled with sealer on the distal aspect of the root. The patient returned for follow-up in two weeks. The sinus tract healed and she was asymptomatic.

Discussion

Microbial infection is considered a major cause of endodontic failure. Several studies reported that periapical lesions did not develop without bacteria, although pulp tissue had been devitalised; therefore, thorough disinfection is strongly recommended before obturation is performed. The complexity and variability of the root canal system make it difficult to achieve ideal goals of endodontic treatment. A laser system which transmits energy through a flexible and...
small-diameter optical fibre can provide convenient access to root canals. Consequently, direct and indirect disinfection by laser possibly takes place while irradiating the inside of root canals. De Andrade AK et al.24 reported laser disinfection is an effective way to decrease bacterial colonies when the mean power of laser exposure was over 3 Watts. The energy of the Nd:YAP laser is powerful enough to eliminate microbes because the average output of the Nd:YAP laser is 10 Watts and the peak power may reach 2.6 kW. Only 0.00015 seconds of laser energy is emitted for every pulsed irradiation;25 so the fleeting moment of emission minimises the risk of overheating tissue and has bactericidal effects by direct contact. Two possibilities may explain the indirect disinfection of laser. When the mode of 30 Hz is used in narrow space such as a root canal filled with irrigation solution, shock waves may occur repeatedly and be transmitted into dentinal tubules to kill bacteria. Pulsed irradiation causes vibrations in narrow spaces similar to ultrasonic devices.26 This laser energy caused by high frequency emission of the Nd:YAP laser help maintain the integrity of the root because it is not necessary to eliminate excessive contaminated dentin of canal wall. Minimal enlargement is sufficient, if the space can allow 220 µm optical fibre to move passively through the canal. The laser energy also causes temperature of the NaOCl solution to rise resulting in increased efficiency of dissolving organic debris and disinfection in canals.26 This enhanced cleanliness gains space in apical ramifications for sealer placement.

In the clinical practice, the warm vertical condensation technique is widely used to obturate the canal, but keeping a gutta-percha cone warm enough to obtain favourable sealing in the ramifications may cause lasting discomfort because of thermal damage to periodontal tissues.27,28 On the other hand, the mechanism of sealer placement by the Nd:YAP laser is different from thermoplastic techniques. Sealer is placed in the canal with a lentulo spiral followed by application of the Nd:YAP laser to disperse the sealer into ramifications by the fleeting pressure of laser beam. Although the pressure causes slight discomfort, the post-filled sensation is not overt and dissipates clinically within a few hours. In most cases, there was radiographic evidence of sealer being forced into lateral/accessory canals. Puffs of sealer from the periapical foramen are considered an evidence of tight seal.1 Zinc-oxide and eugenol-based sealer was chosen in this case report because working and setting time are conducive to completion of the entire obturation process before the sealer sets. The heat from laser irradiation induces fast setting and burning of epoxy resin-based sealer; these types of sealers are not recommended with this technique. Taking periapical films during obturation is recommended to confirm whether the sealer is placed into canal adequately.

Another advantage of using the Nd:YAP laser is that the need for analgesics/antibiotics after treatment can be decreased. The Nd:YAP laser has a strong antibacterial effect and an excellent potential for promoting tissue healing induced without a more invasive procedure29,30; therefore, using the Nd:YAP laser may be more efficient in disinfection and obturation of the root canal system resulting in a higher success rate of non-surgical root canal treatment. Based upon personal experience and observation for four years in laser application, Nd:YAP laser-assistant endodontic treatment is less technique sensitive and easy for general practitioners to acquire the skill and follow this method.

Further histological analysis is needed to verify the significance of laser disinfection and sealer placement with the use of the Nd:YAP laser. These additional investigations will hopefully add to the store of knowledge relative to canal disinfection and the benefits of adequate obturation of auxiliary canals.

Conclusion

Obturation of lateral canals and apical ramifications were observed on postoperative radiographs. This indicates enhanced canal cleanliness and sealing of these small ramifications. The Nd:YAP laser can be utilised as adjuncts to disinfection, canal irrigation and canal filling to improve the quality of obturation in the canal system. The efficiency of Nd:YAP laser-assistant endodontic treatment could simplify the procedure of root canal treatment without purchasing additional equipment to provide an advanced level of treatment.

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Using the AdvErL Evo laser for endodontic treatments

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Introduction

I used a laser in a dental treatment for the first time in 1991. I was completing my residency and my superior had ordered a Nd:YAG laser to conduct PAR therapies in his practice. But, truth be told, my very first contact with a laser had actually taken place a couple of years previously. In 1988, when I was still a student at the University of Mainz, we were shown a laser made by ADL and told that it was considered to be the future of dental medicine. I was ambivalent about that as I could not see the much praised advantages of using lasers because, contrary to the promises made about the equipment, treatments were neither completely painless nor was the long-term quality of the treatments better.

As a matter of fact, it was evident that treatments using lasers in periodontology and dental surgery took significantly longer than conventional treatment methods. The only positive aspect I was able to discern was faster wound healing.

In my opinion, this justified neither the high purchase price nor operating costs; and, so, I put the question of using a laser in dental medicine to rest as far as my own practice was concerned. And nothing caused me to change my opinion for the next 20 years. The much promoted revolution did not come about, the ever so innovative laser quickly descended to esoteric marketing for dental practices, whose only argument for a laser’s raison d’être was that it conveyed the image of being a modern dentist.

My only points of contact with the medium were limited to reading endodontic studies within the scope of my own specialised endodontic practice. For the most part, the abstracts confirmed a reduction in bacteria; however, this reduction was not better in practical terms, perhaps even worse, than that achieved with such fundamental measures as irrigating with NaOCl.

Moreover, the side effects of using a laser were mentioned as well, e.g. those caused by an excessive application of heat. All in all, I had no reason to concern myself with the use of lasers in endodontics for more than two decades, not to mention investing a considerable amount of money in this type of equipment.

Endodontics, by comparison, experienced enormous progress during this period of time.

The use of nickel-titanium (NiTi) as a material for mechanical root canal instruments revolutionised the preparation procedure and smoothed the path for warm filling techniques. Electrical length measurements, dental microscopes and cone beam computed tomography (CBCT) became established, as did the use of ultrasound for irrigation, preparation of the primary and secondary access cavities, as well as pin/fragment removal. Nonetheless, a critical point throughout this time was the cleaning quality of our preparation methods, which remained an unsolved problem in root canal treatments.
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The Morita laser AdvErL Evo

At the annual conference of the German Society for Endodontology and Traumatology (DGfE) in Hamburg in 2014, David Jaramillo spoke about the so-called PIPS method using an Er:YAG laser. It displayed outstanding results regarding the cleaning of root canals and dentinal tubules. This type of laser application, which uses an Erbium:YAG laser with an effective wavelength of 2,940 nm, is no longer based on a direct thermal effect. Instead, endodontic irrigants are activated by small gas bubbles that form at the tip of the laser due to heat. As they move away from the tip, they cool down and collapse quickly. In this way, up to 50 bubbles per second are formed in quick sequence, forming a chain of bubbles that stream through the irrigant, pressing it into the branches of the root canal system and the dentinal tubules. Up until now, this had not been possible in an adequate manner, irrespective of whether activation was initiated with the help of sound, ultrasound or the SAF system.

The micro-explosions are the key element of this new treatment method. Micro-explosions occur when the laser energy is absorbed by water and the volume suddenly increases 800 to 1,000 times. This causes the formation of very small bubbles, microbubbles, which collapse again just fractions of seconds later. The thermal effect, which is obligatorily presupposed when a fluid acting as medium, is limited to a micrometer-thin layer on the root canal surface. Therefore, the exposure of tooth substance to excessive thermal effects that has been observed and feared with other laser applications is excluded.

I have been working with the Morita AdvErL Evo (Fig. 1) in my practice since 2015. This laser also is based on the principle of Laser-activated irrigation (LAI) and uses the formation of microbubbles to activate the irrigants, even if the term PIPS is not used for reasons of patent law.

In the course of time, the Morita AdvErL Evo has become an obligatory part of our treatment protocol, especially for the following procedures:

1. Cleaning the access cavity, representation of the root canal entrances.
2. Opening root canals, obtaining patency.
4. Cleaning the root canals, removing the smear layer.
5. Removing calcium-hydroxide, removing any foreign bodies.

Although the manufacturer offers a large selection of laser tips, two different tips have proven particularly well suited for endodontic treatments and are used as part of my workflow (Fig. 2) in every endodontic treatment. The P400FL tip (Fig. 3) is designed for cleaning the trepanation cavity. Furthermore, in view of its diameter of 0.4 mm, length of 13 mm and curved attachment, it allows instrumentation of the coronal and, if necessary, middle sections of the root canal. The R300T tip (Fig. 4), which has a diameter of 0.3 mm and a length of 16 mm, can be used for accessing deeper areas of the root canal after preparation has been completed.

Clinical workflow of LAI within the scope of endodontic treatments

Below I would like to describe in detail a clinical workflow:

1. Cleaning the access cavity, representation of the root canal entrances

After the initial dental trepanation, the P400FL tip with 25 pps and 70 mJ is used. Dentine splinters, which are pressed into the innumerable cracks and pores during the preparation of the access cavity and cannot be removed by conventional irrigation methods, can be removed in this way.
seconds, the laser will have cleaned the access cavity (Figs. 5 & 6). Any denticles will be detached from the soft tissue surrounding them and rinsed out, any soft- and hard-tissue will be removed from occult canal entrances, making them visible and penetrable.

2. Opening root canals, obtaining patency
Using Morita’s AdvErL Evo will prove its worth particularly in very narrow canals, which involve a high risk of iatrogenic blockage. Morita’s AdvErL Evo will rinse out the canals. Whereas the P400FL tip (25 pps, 50 mJ) is used before the initial opening, the R300T tip (25 pps, 50 mJ) is used for 20 seconds respectively after the coronal preparation of root canals. In this way, it will become significantly easier and foreseeable to open root canals completely with thin manual instruments or mechanical glide-path instruments up to the foramen apicale within the meaning of the ‘patency’ concept. If the irrigation solution exhibits slightly red colouring, this indicates that there may be a patency. If there is stronger bleeding, even if it stops on its own just a short time after the laser instrument is used, the energy parameter should be reduced from 50 to 30 mJ. In the same way, periapical sensations of pain, which may occur sporadically to a minor degree, can be considered a sign that patency has been achieved and the energy parameter should be reduced to 30 mJ.

3. Removal of blockages
If there are any blockages, as can frequently be the case in revisions of the root canal filling, the P400FL and R300T tips are used at 25 pps and 70 mJ and, if necessary, with several irrigation cycles of 20 seconds respectively.

4. Cleaning the root canals, removing the smear layer
Following the initial opening of the root canals and the use of mechanical nickel–titanium instruments to complete the root canal preparation, if necessary also intermittently during the preparation, Morita’s AdvErL Evo laser is used to remove the smear layer analogous to conventional irrigation of the root canals with irrigation solutions, ultrasound or sound-activated irrigation.

Then the R300T tip with 25 pps and 50 mJ is used. The cloudiness of the irrigation solution after activation and the removal by rinsing of suspended particles clearly demonstrates the efficiency of the measures taken. This is particularly impressive if the conventional irrigating methods mentioned above were applied for the recommended duration in the root canal and, nonetheless, the laser still removes a smear layer from the root canal when it is applied afterwards. The cloudiness of the irrigation solution is a good indication for determining the duration of irrigation, which can be ended when the irrigation solution that is transported out of the root canal seems to be clear. As a rule, this should be the case after about 15–20 seconds.

In the event of bacterial infections, 3 % NaOCl is used for the LAI; in the case of vital extirpation, 17 % EDTA should be used.

5. Removing calcium-hydroxide, removing any foreign bodies
As helpful as calcium hydroxide may be when it is used as an agent for disinfecting bacterially infected root canals, it is also difficult to completely remove
this pasty material from root canals. Within the scope of endodontic treatments, I insert calcium-hydroxide in the root canals as a medicinal filling after the mechanical preparation has been completed but before the root canal filling is inserted. It remains there for several days; in the case of large apical bright spots, it may stay 12 to 16 weeks so that we can verify by means of X-rays that reossification, a visible sign of healing, has started before we fill the root canal.

Before filling the root canal (Figs. 7–9), the calcium-hydroxide has to be removed from the root canals. To this end, the mechanical apical master file is used to proceed up to 1 mm before reaching the working length to be able to remove as much of the pasty calcium-hydroxide as possible by using the instrument’s spiral-shaped teeth like a screw conveyor.

This is followed by a sound-activated irrigation using an EDDY attachment (VDW). Each root canal is rinsed for one minute with EDTA irrigation solution and sound activation. Afterwards, an XP-endo shaper instrument (FKG Dentaire) is used up to 1 mm before reaching the working length; however, the instrument is used less for preparation than for cleaning the walls of the canals mechanically. It seems reasonable to expect that there would be no more calcium hydroxide after such a time- and material-intensive manner of proceeding. So, it is highly impressive when Morita’s AdvErL Evo laser transports a surprisingly large quantity of remaining calcium hydroxide out of the root canals. It is equally impressive to see that irrigating with Morita’s AdvErL Evo laser may, in certain cases, even bring to light fractured foreign bodies such as fragments of instruments or irrigation tips as well as old filling material hidden in the depths of the root canals.

Summary and evaluation

Progress in endodontics can be measured by the circumstance whether procedures are simplified or more cost-effective than previously. Or whether one can do something better. The Morita AdvErL Evo laser helps us improve our treatment in the different stages of a root canal procedure described above. Although I still take a negative standpoint towards many statements made about the use of lasers, I have a positive opinion about using an Er:YAG laser for LAI.

Critical aspects are the purchase price and the operating costs. The Morita AdvErL Evo laser is equipped with comparably fracture-proof attachments; although this property is desired for the product, it is not necessarily a matter of course in view of the alternatives that are available. Nonetheless, it must be borne in mind that the laser attachments, being the tools that they are, are subject to wear and, hence, have a limited service life. For this reason, the purchase price, operating costs and time involved, need to be taken into consideration when putting together a viable economic concept. Unfortunately, private health insurance schemes frequently refuse to pay for LAI treatments, even though German legislation added such innovative measures to the Schedule of Fees for Dentists. Of course, this is nothing new. For years, private health insurance companies refused to assume the material costs for disposable mechanical NiTi instruments or the costs for using a dental microscope within the scope of endodontic treatments. We can only hope that legislation will support the use of LAI in the near future. Irrespective of that, the practical benefits provided by Morita’s AdvErL Evo laser are evident. For this reason, using the Morita AdvErL Evo laser for LAI has proven its worth as a meaningful and, hence, indispensable treatment measure in all different phases of root canal treatments and my endodontic work.

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Introduction

Due to progresses in scientific knowledge, endodontic treatments now provide highly predictable results. However, such results are closely tied to the respect of a number of steps that are nowadays clearly identified as key elements for endodontic treatment success. Notably, the filling of root canals is one of them. In clinical applications, it requires both knowledge and thoroughness (Ray and Trope 1995).

Sterilising and obtaining a root canal free of bacteria, following disinfection, is, so far, impossible to obtain (Siqueira et al. 1997). Apart from disinfecting, obturation is responsible for trapping residual bacteria, filling the predisinfected space and ultimately sealing it, in order to avoid any bacterial leakage into the periapical area.

Modern techniques for filling root canals are based on the association of gutta-percha (the core of the filling) and a sealer. The latter acts as a sealing material and, because of its fluidity, it is able to spread into any free space, notably those which were not enlarged during the mechanical root canal preparation.

Depending on the technique used by the practitioner, the gutta-percha is compacted differently: laterally when used with cold lateral condensation or vertically when used with a warm vertical compaction. Both techniques provide good long-term results, as the root canal is filled with a high proportion of gutta-percha with a small volume of sealer. The quantity of the latter needs to be minimal, as being degradable, it may lead to canal bacterial contamination over time.

The single cone technique is still very popular among practitioners, being quick and easy to perform. This technique consists in employing a single cone with a large amount of sealer, which acts as a filling material. Unfortunately, the currently used sealers are prone to dissolution. As a consequence, with time, the canal is again contaminated with bacteria, leading to treatment failure and the growth of an apical lesion.

Thereby, although being easy to accomplish, the single cone technique is not recommended for root canal filling (Beatty 1987, Pommel et Camps 2001).

However, the single cone technique may be re-opened and provided new reliability with new proposed biomaterials based on bioceramics, developed in the last few decades and launched on the market as root canal sealers.

Bioceramics properties

Bioceramics are specifically designed for medical and dental use with the prefix ‘bio’, referring to their biocompatibility. In the orthopaedic field, inert bioceramics are used for prosthetic devices, while the active and re-absorbable ones are applied in endodontics.

Bioceramics are composed of alumina, zirconia, bioactive glass, glass ceramics, coatings, composites, hydroxyapatite, resorbable calcium phosphates and radiotherapy glasses (Dubock 2000, Best et al. 2008). Among them, calcium phosphate–based materials are used for filling bone defects. Calcium silicates and bio-aggregates (Mineral Trioxide Aggregate for example) were introduced for apical plug-in apexification procedures, but also for coronal/root repair in case of perforations (Trope and Debelian 2014, Koch and Brave 2009). Three basic types of bioceramics must be distinguished: (1) bio-inert high strength ceramics (alumina, zirconia and carbon); (2) bioactive ceramics which form direct chemical bonds with the bones or soft tissues of a living organism (bioglass and glass ceramics); and (3) biodegradable/soluble/re-absorbable ceramics (calcium phosphate based ceramics) that actively participate in the metabolic processes of an organism.

According to the manufacturers, such sealers could be used alone or combined with a gutta-percha point using a single cone technique in the context of an endodontic treatment or retreatment (Koch and Brave 2009). These sealers are mainly composed of tricalcic silicate, calcium phosphate monobasic, cal-

BioRoot RCS a new biomaterial for root canal filling

Author: Prof. Stéphane Simon, France
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BioRoot RCS is a mineral-based root canal sealer designed to be used by mixing the powder part and the liquid part by simple spatulation: there is no need for a mixing machine. The working time is around 15 minutes and the setting time is less than 4 hours in the root canal. In addition, BioRoot RCS displayed a tight seal with the dentine and the gutta-percha (Xuereb 2014) and an appropriate radiopacity. The paste is of smooth consistency with good flow and adequate adhesion to instruments in order to enable an optimal placement in the root canal.

Thanks to the use of Active BioSilicate Technology, which is monomer free, there is no shrinkage of BioRoot RCS during setting for reaching a tight seal of the root canal.

Despite the similar composition in terms of viscosity and texture with a sealer, BioRoot RCS must be considered as an adhesive root filling material. A fitted gutta-percha point is used as a plugger-like carrier to facilitate the flow of BioRoot RCS into the canal space. Indeed, BioRoot RCS is also recommended for facilitating the obturation removal in case of retreatment.

**A new concept of obturation**

To achieve root canal filling and prevent any bacterial or fluid leakage, practitioners were always told to associate a core material with a sealer in order to fill the canal space. So far, gutta-percha is the most used material because it is a non-resorbable and well biotolerated. Unfortunately, gutta-percha has no intrinsic adhesive properties to dentine. Thereby, in order to ensure the seal of the final filling, the use of a sealer is required. The latter is also used for filling voids, flowing into anatomical irregularities, notably the ones that were not enlarged by mechanical preparation (i.e. isthmus, lateral/accessory canals).

Nevertheless, sealers are subjected to shrinkage, degradation over time and have no chemical sealing ability to dentine. As a consequence, the use of a large amount of core material with the thinnest layer of sealer is recommended to improve the quality of the filling.

Among the obturation techniques, cold lateral and warm vertical compaction are the best ones. Indeed, they are both capable of pushing the sealer into the non-instrumented spaces, where residual bacteria may persist. However, the first technique leaves excessive cold sealer inside the canal irregularities (instead of leaving gutta-percha) and the second one requires the placement of a plugger within 4 mm of the apex. Furthermore, with the warm lateral compaction, a large volume of coronal dentine needs to be removed, causing concerns among practitioners as it may possibly weaken the tooth structure (Trope and Debelian 2014).

Moreover, these techniques are time consuming, highly operator-dependent and require the use of...
visual aids to ensure the best chances of success. As a matter of fact, most of the general practitioners still use the single cone technique, as it is easy and quick to perform. Due to the introduction of nickel-titanium tapered instrumentation, gutta-percha cones fitting in taper and apical diameter with the last file used of a given system are now commercialised. The apical sealing ability of a single cone placed inside the root canal is achieved in such condition in the apical third, because of the concordance of the last file used and the gutta cone design. However, because of the non-circular shape of the canal section on the median and coronal thirds, the cone does not perfectly fit into an ovoid canal. Hence, the remaining space is filled with sealer or voids (Angerame et al. 2012, Schäfer et al. 2013, Somma et al. 2011). On this basis, the single cone technique cannot be considered as reliable, since it provides an imperfect sealing.

Bioceramic sealers may be considered as an interesting solution to make the obturation steps reliable and easier to achieve, potentially replacing the ZnO-eugenol based sealers. In this context, they might provide a tight and durable seal all along the entire length of the root canal without the need of any compaction procedure. Used in combination with an adjusted gutta-percha point and due to its excellent wettability and viscosity, the bioceramic could spread into any root canal irregularity and non-instrumented space. Furthermore, its adhesive properties to dentine and the reduced need of excessive coronal tissue removal would provide an improved resistance to root fracture over time. This new class of materials could finally simplify the obturation stage, making it reproducible in every practitioner’s hands with a reduced learning curve. Above all, such technique could provide equivalent clinical results, if not even better, when compared to the gold standards. Notably among them, BioRoot RCS is one of these new bioceramic materials. The purpose of the present article is to describe its properties and introduce a new way of considering this biomaterial, not as a sealer but as a true root canal filling material. If this material can be considered as reliable, we may assist in a true paradigm shift in the field of endodontics.

**Description of the technique and case reports**

From an operational point of view, the procedure is very similar to the single cone technique. However, few indispensable differences justify the reliability of BioRoot RCS with such technique. Notably, the single cone technique seals a cone alone. Instead, here the cone is employed as a carrier, which is left in place to allow for material removal in case of retreatment. Indeed, it must not be considered as the core of the filling. The obturation is made by BioRoot RCS itself.

**Case 1**

A pulp necrosis was diagnosed on tooth #16 of a 35-year-old female patient associated with chronic periapical disease (Fig. 1). The patient had experienced chronic sinusitis for over two years and received unsuccessful medical treatments.

After having shaped the root canal and obtained an appropriate tapered preparation, the canal was disinfected with a 3 % sodium hypochlorite solution activated with mechanical agitation (Irrigatys, ITENA). A final rinse with 17 % EDTA and a final flush with sodium hypochlorite were completed before fitting the gutta-percha cones.

The canals were dried with paper points. The BioRoot RCS was mixed, following manufacturer recommendations and injected into the root canals with a spiral used with a low speed of rotation (800rpm). Each gutta-percha point was poured into the mixed material to largely cover the surface of the cone. Afterwards, it was gently inserted into the root canal space until reaching the working length.

The cone was cut at the entrance of the root canal with a heat carrier, and a slight plug was created with a hand plugger. The second and the third canal were filled in the same way (Fig. 2).

The patient was referred to the general practitioner who restored the tooth with a bonded...
overlay. She was recalled at 6 and 12 months after treatment. She no longer experienced a sinusitis and the tooth was asymptomatic. The 12-month recall showed complete healing of the periapical lesion (Fig. 3). Thereby, the treatment may be considered as successful.

Case 2

A 32-year-old female was referred to our endodontic department by her general practitioner for treatment on tooth #47 (Fig. 4). The patient reported a long painful dental history on this tooth. Root canal treatment had been initiated six months before, and several practitioners tried to complete the root canal treatment, unsuccessfully.

The patient complained about severe pain, numbness and loss of sensitivity of the mandible each time the access cavity was closed with a temporary filling.

An intraosseous injection (one cartridge articaine + 1/100,000 epinephrine (Septodont) was completed and root canals were shaped and disinfected with a large volume of sodium hypochlorite activated with Irrigatys (ITENA). The canals were dried, and temporary filled with a calcium hydroxide-based medication. Access cavity was filled with a temporary filling and the crown was drilled for occlusal reduction.

At the second visit, the root canal treatment was completed. Because the proximity of the inferior dental nerve, everything was done to avoid any extrusion of dental material. Because of its excellent biotolerance and non-toxicity, BioRoot RCS was considered as the material of choice for filling the root canals.

The root canals were rinsed again with sodium hypochlorite and 17% EDTA, and then dried. BioRoot was placed inside each canal with a spiral (800 rpm) and gutta-percha points were poured into the material and gently placed inside the canals up to the working length (Fig. 5).

The coronal restoration was completed on a third visit with a CAD/CAM bonded overlay (Figs. 6–8).

The patient never complained of any pain, neither discomfort. The six-month recall radiograph confirms the complete healing of the apical lesions (Fig. 9).

Case 3

A 31-year-old female patient was referred for a root canal retreatment on tooth #46 (Fig. 10). This tooth had already been retreated twice recently, but the patient still complained about pain and abscesses since the tooth had been restored with a post placed into the distal root.

Because the post was not visible on the preoperative radiograph, it was assumed that it might be a fibre post. The shape of the interradicular lesion let us suspect a zipping perforation into the interradicular area.

Root canal retreatment was completed in one visit. The fibre post of distal root and root canal filling material were removed with rotary and manual instruments. The four root canals were then reshaped and disinfected with 3% sodium hypochlorite with mechanical activation and 17% EDTA. During the retreatment process, an interradicular perforation (mesial side of the distolingual root canal) was highlighted (Fig. 11).
In the past, this type of disease would have been completed into two steps. The first step involves filling the root canal up to the level of the perforation, taking care to avoid any extrusion of materials through the perforation, and the second step involves filling the last third of the canal with a silicate-based material such as Biodentine (Septodont).

Because BioRoot is a tricalcium silicate-based filling material, it was decided to combine the two steps in one by filling the canals and the perforation in the same time.

Just as the two previous cases, the root canals were dried with paper points, BioRoot RCS was injected into the canals with a spiral used at low speed (800 rpm) and gutta fitted gutta-percha points were inserted into each canal up to the working length (Fig. 12). A small extrusion of material is visible on the postoperative radiograph, as a confirmation of perforation closure (Fig. 13).

The tooth was restored with a bonded overlay (Figs. 14 & 15) and the patient was recalled at six months after the treatment (Fig. 16).

The tooth is asymptomatic and functional; the peridontal probing is normal, and the six-month recall radiograph confirm the bone healing of the interradicular lesion.

These cases are used to illustrate some specific situation in which we used BioRoot RCS because its valuable properties. These are three of a large number of cases we have completed in the last 18 months. Before the launch of this product, 22 clinical cases were completed in the frame of a randomised clinical trial comparing the success of an endodontic treatment using warm vertical compaction of gutta-percha versus the above described BioRoot RCS. The RCT registration number is NCT01728532 and the full protocol is available online (https://clinicaltrials.gov).

The results are, at the time of writing, under analysis and very encouraging, which allows us to consider this technique as reliable enough to be described here.

### Conclusion

Endodontics is continuously under evolution. In the last 20 years, instrumentation research and development have been very active. Currently, disinfection and irrigation procedures are the two most focused on aspects of endodontic research.

The shaping procedures and root canal disinfection have been considerably simplified. Thereby, every practitioner interested in endodontics is now able to complete any easy/middle difficulty root canal treatment with reproducible results without any issue. Obturation, the final step of the procedure, is usually the most difficult and time-consuming aspect. However, with this new approach of root canal filling, this milestone may be overcome. Considering the fluidity of BioRoot RCS as a filler and not only as a sealer, this represents a true paradigm shift. The preliminary results of the randomised clinical trial are very encouraging. More clinical investigations will be necessary in the future to confirm this new vision of a simpler root canal obturation.

Editorial note: A list of references is available from the publisher.

BioRoot RCS is a registered trademark of Septodont.

Prof. Stéphane Simon acts as a scientific consultant for Septodont company.

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How can dentists create glide paths more easily and efficiently? In the past, dentists used hand instruments, which is often a laborious and unsafe task and requires multiple stages, particularly when it comes to curved and calcified canals. During the International Dental Show in Cologne this year, German-based endodontic expert VDW introduced R-PILOT, the first and only motor-driven glide path instrument with reciprocating motion available. Since its launch, endodontists have called it a major advancement in glide path creation and the first step towards full working length in more difficult cases.

R-PILOT is made of nickel-titanium M-wire, which is also used in VDW’s established RECIPROC system. The material has a higher resistance to cyclic fatigue, while being more flexible. For dentists who require additional safety in the formation of a glide path in certain cases, R-PILOT seems to set a new standard in reciprocating glide path management.

Dental Tribune International talked to Dr Bogdan Moldoveanu, an endodontic specialist based in Cluj-Napoca, Romania. Besides owning a practice specialising in endodontology and leading the educational platform “Endodontie cu pasiune”, he also lectures extensively on microscopic endodontics and surgical endodontics at the universities of Cluj-Napoca, Romania, and Turin, Italy, the latter from which he graduated with excellence. Dr Moldoveanu is an expert in mechanical glide path management and has consistently been using R-PILOT since March 2017. In the interview, he gives recommendations on the use of reciprocating motion, explains the benefits of mechanical glide path techniques and explains the beauty of endodontics.

Dental Tribune: Over 90 per cent of root canal preparations are still conducted with manual glide path management. What are some of the uncertainties that occur when using hand files for glide path creation?

Dr Bogdan Moldoveanu: From my perspective, using manual files for the glide path procedure is something that should be done only by an expert and under very specific conditions—mostly retreatments. The mechanical glide path procedure has opened up a new dimension, especially for general practitioners, who are now able to perform a difficult procedure in a matter of seconds.

Most of the mistakes that occur during the shaping phase of the root canal treatment take place during the initial stages of the therapy, namely, when one is managing the glide path. One of the most common mistakes encountered is the improper use of instruments and the main causes of
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this problem are a lack of knowledge and a lack of patience. The mechanical glide path technique solves these issues by reducing human error. Therefore, the knowledge required to perform an adequate mechanical glide path is reduced to a minimum and the time it takes to do it correctly is dramatically reduced. With a procedure that only presents benefits, I cannot understand why anyone would not want to switch from manual to mechanical glide path management.

Glide path management and reciprocating motion—do they work well together?

I believe so. We now have huge amounts of literature regarding the benefits of reciprocating motion, so it was just a matter of time until the first reciprocating instrument, designed exclusively for glide path, was introduced. If you think about the mechanics of the reciprocating motion, then you can understand why a glide path instrument that uses reciprocating motion is very effective for the task at hand, making the ‘taper lock’ issue a thing of the past.

When would you use files such as R-PILOT for glide path creation?

I will always choose mechanical glide path for any necrotic or vital tooth. On the other hand, I think a manual glide path is particularly necessary for retreatment cases, where you have to battle huge ledges, false paths, perforations and so on. So, I would not say it is a matter of middle or coronal third, but more a matter of adequate case selection. If we want to talk about the proper tools (instruments) for the proper job, I believe we should keep in mind that endodontics is a beautiful field because it is very diverse. Every case must be analysed and the procedure planned only afterwards. I rarely mix things up when it comes to the glide path procedure, so either I am doing everything manually or everything mechanically.

Thank you very much for the interview.
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Swiss quality in dentistry

Produits Dentaires expands in endodontics

Produits Dentaires stands for Swiss quality in dentistry. In more than 100 countries, the company offers dentists a wide range of high-quality products for use in endodontics, restorative dentistry, prophylaxis, prosthetics and periodontology. At the recent International Dental Show (IDS), Dental Tribune International had the opportunity to learn more about the Swiss company’s future business strategies and portfolio.

“We are a family business that has been operating in dentistry for 77 years now. However, this is a special IDS for us because we are entering a new phase. What we’ve been presenting here is our vision for the future,” Yann Gehrig, Co-Executive Director of Produits Dentaires, along with his brother Nicolas told Dental Tribune International on-site. “Our portfolio has been very broad in the past. Now, our focus is on one particular area: endodontics.”

The company’s well-established MAP (Micro-Apical Placement) System, for example, is a unique method for effectively placing root canal repair materials. This high-end product for specialists has been manufactured for more than ten years. With MAP One, Produits Dentaires now offers general practitioners performing endodontic work a useful, cost-effective and easy-to-use version of the MAP System. “With this new product, for instance, we are able to give a much wider audience access to our products. This is an important aspect of our vision and we’ll
continue in this direction," stated Michel Ruffieux, Sales and Marketing Director at Produits Dentaires.

Over the past several years, Produits Dentaires has built up an extensive distribution network of agents, wholesale dealers and dental suppliers, making its products easily available worldwide. "With regard to meeting our partners and establishing new business relations, IDS is key for us. It is the only truly global exhibition," Ruffieux commented.

Another key element of Produits Dentaires’ business strategy is education. The company provides information and support worldwide through a national and international expert team of dentists, dental hygienists and other specialists from the medical field, with whom it also regularly organises workshops and conferences. In addition, several research projects are running in close cooperation with universities and colleges in Switzerland and worldwide.

"Through our collaborations, we seek to create something new—products with added value. We feel that innovations need to be explained not only to the distributors but to the users too. We don’t want to just put the products in a catalogue; we want to make sure that training for our products is done correctly," said Gehrig. "Our overall mission is to make dentistry simpler and more accessible for everybody," he concluded.

To this end, the company organised a workshop area at its booth this year for the first time at IDS. Every day during the show, Produits Dentaires offered free lectures and workshop sessions, which were presented by key opinion leaders from Style Italiano, for instance, and very well attended and received.

More information about the company can be found at www.pdsa.ch.
Online registration for the next ROOTS SUMMIT, the premier global discussion forum dedicated to endodontic dentistry, is now open. The event, featuring lectures and workshops, will be held at the European School of Management and Technology (ESMT) in Berlin from 28 June to 1 July 2018. Approximately 500 visitors are expected at next year’s ROOTS SUMMIT, which is again being organised in collaboration with Dental Tribune International.

Although the 2018 ROOTS SUMMIT will mainly feature presentations on the latest techniques and technologies in endodontics, the organisers are inviting dental professionals in all fields, as well as manufacturers in the industry, suppliers of endodontic products and anyone involved in the practice of endodontic treatment, to attend.

It has been announced that foremost opinion leaders, including Drs Frederic Barnett, Gergely Benyócs and Elisabetta Cotti, will be speaking at the conference next year. There will also be the opportunity to participate in hands-on workshops, speak to industry professionals on-site and engage with new equipment, procedures and protocols in endodontic dentistry. A number of dental companies specialising in endodontics, including Meta Biomed and FKG Dentaire, have already confirmed their participation.

The ROOTS SUMMIT, which started as a mailing list of a large group of endodontic enthusiasts in the 1990s, has grown significantly over the last few years. With currently more than 24,000 members from over 100 countries, the ROOTS SUMMIT evolved into one of the most prominent global learning forums in the dental industry.

Previous conferences have been held in Canada, the US, Mexico, Spain, the Netherlands, Brazil and India. The 2016 ROOTS SUMMIT took place in the UAE and was one of the most important events in endodontics, drawing over 300 dental professionals to Dubai. These meetings have been known for their strong scientific programmes.

An early bird discount of 20 per cent is being offered and dental students too will be granted a 20 per cent discount. Additional information and online registration can be found at www.roots-summit.com. Dental professionals are invited to like the ROOTS SUMMIT Facebook page to view the latest updates.
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Questions?

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