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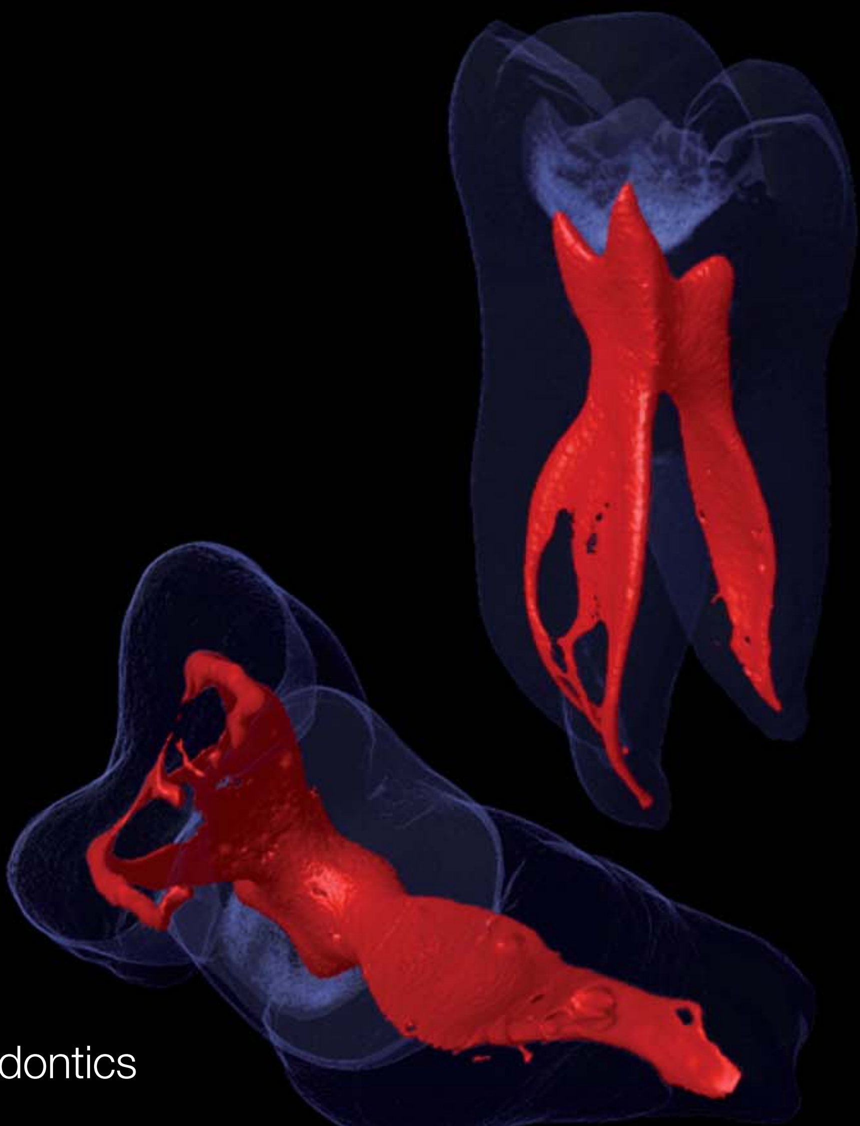

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Dear Reader,

Dr Yoshio Yahata

_The objectives of root-canal preparation are to remove all pulp tissue, bacteria and their by-products and to produce sufficient canal space for disinfection and 3-D obturation. Many techniques have been introduced for proper preparation, one of which is the balanced force technique. This technique uses hand files with alternating clockwise and counter-clockwise motion in an attempt to minimise canal transportation and decrease the amount of stress placed on a file during use.

Recently, on the basis of the principles of the balanced force technique, a new canal preparation technique using rotary NiTi files with reciprocal motion has been advocated. Previous studies have demonstrated that by using asymmetric reciprocal motion, the technique is capable of canal-centring when preparing root canals, especially in curved canals. Furthermore, working time, over-instrumentation, apical extrusion of debris and incidence of file fracture can be significantly lower using NiTi files with reciprocal motion than with conventional continuous rotation.

As has been indicated by numerous studies, fracture of NiTi files is still a major concern. File fracture occurs in two ways: fatigue or torsional failure. Fatigue failure is the result of repeated compression and tension on files, especially in curved canals, while torsional failure occurs when a file tip binds and the remainder continues to rotate. In a clinical setting, these two failures have an influence on one another.

The incidence of NiTi file fracture is reported to be lower with reciprocal motion than continuous rotation. With the newly proposed technique, the file would frequently engage dentine at its tip, but counter-clockwise rotation would immediately disengage the file, resulting in the reduction of deformation and torsional fracture.

As clinicians, we should consider and weigh the advantages and disadvantages of any new technique. Furthermore, it is imperative that we constantly seek better treatment strategies to reduce the risk for the patient. The proposed new system using a single file claims to be a promising method, but few studies have demonstrated the effectiveness of this technique. Therefore, further studies and discussion on this system are necessary.

Yours faithfully,

Dr Yoshio Yahata
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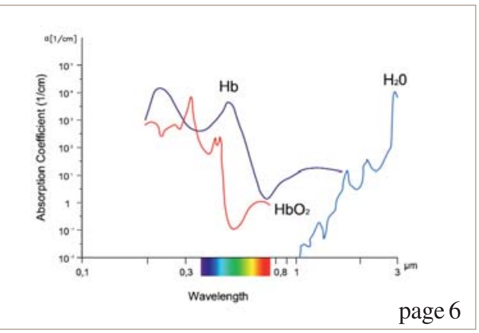

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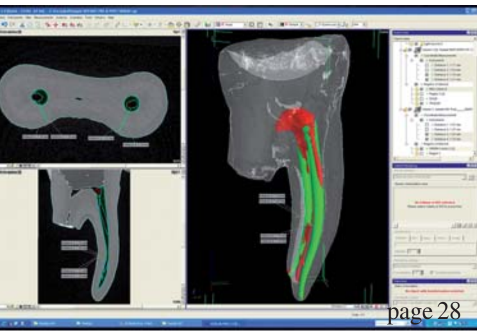
Cover image courtesy of Prof Marco Versiani and Prof Manoel D. Sousa Neto, Ribeirão Preto Dental School, University of São Paulo.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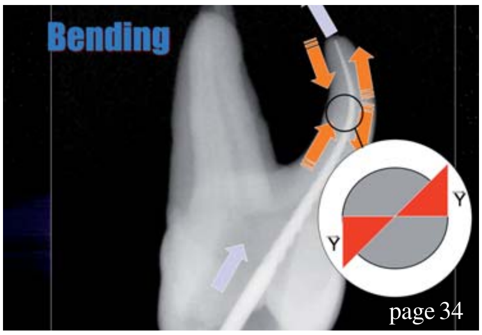

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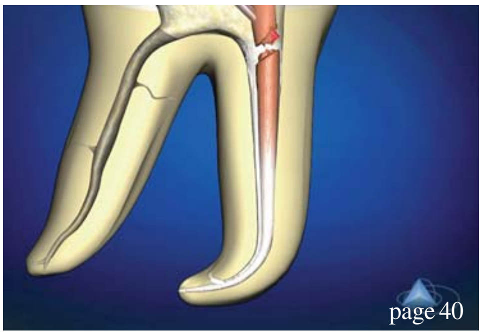
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Laser in endodontics (Part I)

Authors_ Prof Giovanni Olivi, Prof Rolando Crippa, Prof Giuseppe Iaria, Prof Vasilios Kaitsas, Dr Enrico DiVito & Prof Stefano Benedicenti, Italy & USA

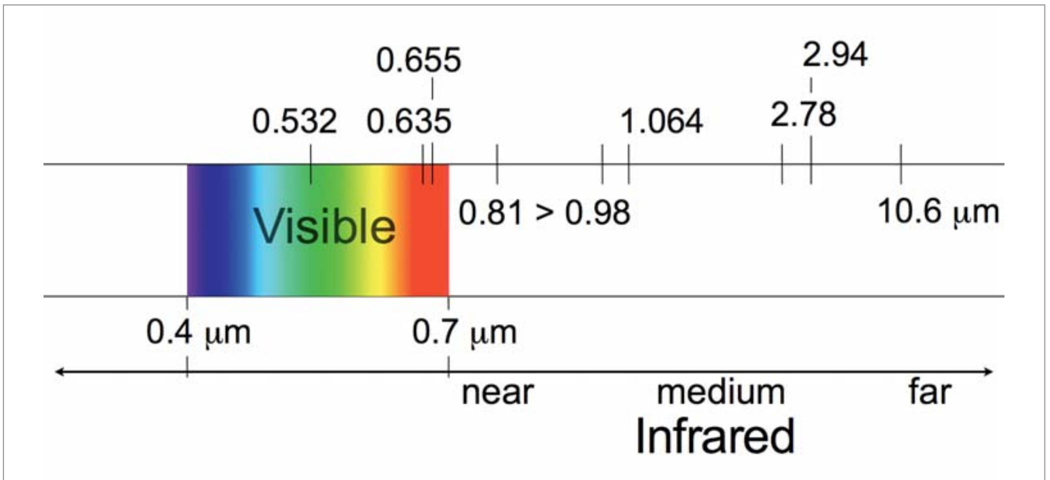

Fig. 1

Fig. 1_Lasers and the electromagnetic spectrum of light.

_**The main goals of endodontic treatment** are the effective cleaning of the root-canal system. Traditional endodontic techniques use mechanical instruments, as well as ultrasound and chemical irrigation to shape, clean and completely decontaminate the endodontic system.

The complexity of the root-canal system is well known. Numerous lateral canals, of various dimensions and with multiple morphologies, branch off from the principal canals. A recent study found complex anatomical structures in 75 % of the teeth analysed. The study also found residual infected pulp after the completion of chemo-mechanical preparation, both in the lateral canals and in the apical structures of vital and necrotic teeth associated with peri-radicular inflammation.[1]

The effectiveness of the debridement, cleaning and decontamination of the intra-radicular space is limited, given the anatomical complexity and the inability of common irrigants to penetrate into the lateral canals and the apical ramifications. Therefore, it appears advisable to search for new materials, techniques and technologies that can improve the cleaning and decontamination of these anatomical areas.

The use of lasers in endodontics has been studied since the early 1970s, and lasers have been more widely used since the 1990s.[2–7] In this regard, Part I of this article will describe the evolution of laser techniques and technologies. The second part, which will be published in roots 2/2011, will present the state-of-the-art effectiveness of these instruments in the cleaning and decontamination of the endodontic system and take a look at the future, presenting recent preliminary studies on new methods of utilising laser energy.

_Lasers in endodontics

Laser technology was introduced to endodontics with the goal of improving the results obtained with traditional procedures through the use of light energy by increasing cleaning ability and the removal of debris and the smear layer from the root canals and also improving the decontamination of the endodontic system.

Different wavelengths have been shown to be effective in significantly reducing bacteria in infected canals and studies have confirmed these results *in vitro*.[8] Further studies have demonstrated the efficiency of lasers in combination with commonly used irrigants, such as 17% EDTA, 10% citric acid and 5.25% sodium hypochlorite.[9] The action of the chelating substances facilitates the penetration of laser light, which can penetrate into the dentinal walls up to 1 mm in depth and have a stronger decontaminating effect than chemical agents.[8,9] Other studies have investigated the ability of certain wavelengths to activate the irrigating solutions within the canal. This technique, which is termed *laser-activated irrigation*, has been shown to be statistically more effective in removing debris and the smear layer in root canals compared with traditional techniques and ultrasound.[10–12] A recent study by DiVito *et al.* demonstrated that the use of the Erbium laser at subablative energy density using a radial and stripped tip in combination with EDTA irrigation results in effective debris and smear layer removal without any thermal damage to the organic dentinal structure.[13]

_Electromagnetic spectrum of light and laser classification

Lasers are classified according to their location on the electromagnetic spectrum of light. They can be visible and invisible, near, medium and far infrared laser. Owing to optical physics, the function of the various lasers in clinical use differs (Fig. 1). In the visible spectrum of light, the green light laser (KTP, a neodymium duplicate of 532 nm) was introduced in dentistry in recent years. There have been few studies concerning this wavelength. Its delivery through a flexible optical fibre of 200 µ allows its use in endodontics for canal decontamination and has shown positive results.[14,15]

Near infrared lasers (from 803 nm to 1,340 nm) were the first to be used for root decontamination. In particular, the Nd:YAG (1,064 nm), introduced at the beginning of the 1990s, delivers laser energy through an optical fibre.[5] The medium infrared lasers, the Erbium (2,780 nm and 2,940 nm) laser family, also produced at the beginning of the 1990s, have been equipped with flexible, fine tips only since the beginning of this century and have been used and studied in endodontic applications. The far infrared laser CO_2 (10,600 nm) was the first to be used in endodontics for decontamination and apical dentine melting in retrograde surgery. It is no longer used in this field with the exception of vital pulp therapy (pulpotomy and pulp coagulation). The lasers considered here for endodontic applications are the near infrared laser—diode (810, 940, 980 and 1,064 nm) and Nd:YAG (1,064 nm)—and the medium infrared lasers—Erbium, Chromium:YSGG (Er,Cr:YSGG; 2,780 nm) and Erbium:YAG (2,940 nm). A brief introduction to the basic physics of laser–tissue interaction is essential for understanding the use of lasers in endodontics.

_Scientific basis for the use of lasers in endodontics

Laser–tissue interaction

The interaction of light on a target follows the rules of optical physics. Light can be reflected, absorbed, diffused or transmitted.

_Reflection is the phenomenon of a beam of laser light hitting a target and being reflected for lack of affinity. It is therefore obligatory to wear protective eyewear to avoid accidental damage to the eyes.
_Absorption is the phenomenon of the energy incident on tissue with affinity being absorbed and thereby exerting its biological effects.
_Diffusion is the phenomenon of the incident light penetrating to a depth in a non-uniform manner with respect to the point of interaction, creating biological effects at a distance from the surface.
_Transmission is the phenomenon of the laser beam being able to pass through tissue without affinity and having no effect.

The interaction of laser light and tissue occurs when there is optical affinity between them. This interaction is specific and selective based on absorption and diffusion. The less affinity, the more light will be reflected or transmitted (Fig. 2).

Effects of laser light on tissue

The interaction of the laser beam on target tissue, via absorption or diffusion, creates biological effects responsible for therapeutic aspects that can be summarised as:

_photo-thermal effects;
_photomechanical effects (this includes photo-acoustic effects); and
_photochemical effects.

Fig. 2_Laser–tissue interaction.

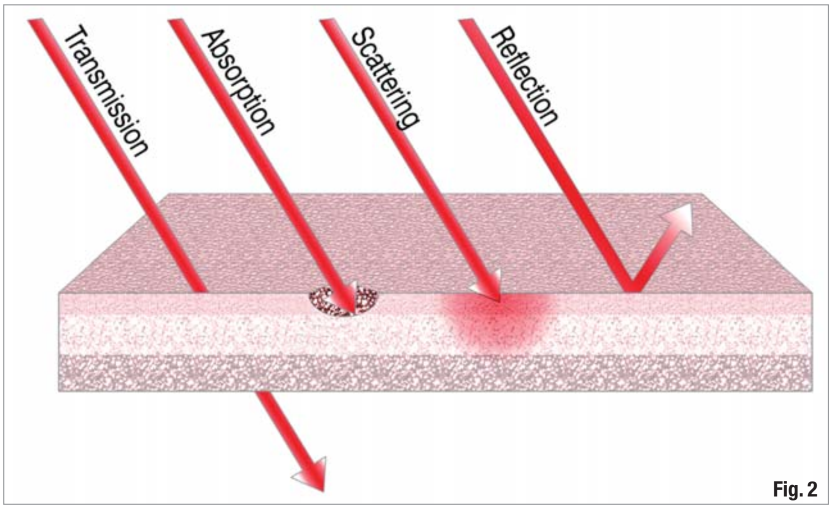

Fig. 2

P	power (in W)
E	energy (in J)
R	pulse repetition rate (in Hz)
Pd	power density or density of power (in W/cm²)
F	fluence or density of energy (in J/cm²)
P(W)	average power = E x R
PP(W)	peak power = E; length of single pulse (in seconds)

Table I

Table I_Laser light emission parameters.

The diode laser (from 810 nm to 1,064 nm) and the Nd:YAG (1,064 nm) belong to the near infrared region of the electromagnetic spectrum of light. They interact primarily with soft tissue by diffusion (scattering). The Nd:YAG laser has a greater depth of penetration in soft tissues (up to 5 mm), while the diode laser is more superficial (up to 3 mm). Their beam is selectively absorbed by haemoglobin, oxyhaemoglobin and melanin, and has photo-thermal effects on tissue. Therefore, their use in dentistry is limited to the vaporisation and incision of soft tissue. They are also used for dental whitening with a laser beam, by thermal activation of the reagent. In endodontics, they currently represent the best system for decontamination, owing to their ability to penetrate the dentinal walls (up to 750 µ with the 810 nm diode laser; up to 1 mm with the Nd:YAG)[8] and for the affinity of these wavelengths with bacteria, destroying them through photo-thermal effects.[16]

The Erbium lasers (2,780 nm and 2,940 nm) belong to the medium infrared region and their beam is primarily absorbed superficially by soft tissue between 100 and 300 µ and up to 400 µ by the dentinal walls.[8,17]

The chromophore target is water, which is why their use in dentistry extends from soft to hard tissue. Owing to the water content of the mucosa, gingiva, dentine and carious tissue, Erbium lasers vaporise and affect these tissues thermally. The explosion of the water molecules generates a photomechanical effect that contributes to the ablative and cleaning process (Fig. 3).[18–20]

Parameters that influence the emission of laser energy

Laser energy is emitted in different ways with various instruments. In diode lasers, the energy is emitted in a continuous wave (CW mode). A mechanical interruption of the energy emission is possible (properly called 'gated' or 'chopped' and improperly called 'pulsed'), allowing for better control of thermal emission. The pulse duration and intervals are in milliseconds or microseconds (time on/off).

The Nd:YAG laser and the Erbium family emit laser energy in a pulsed mode (also called free-running pulse), so that each pulse (or impulse) has a beginning time, increase and an end time, referred to as a Gaussian progression. Between pulses, the tissue has time to cool (thermal relaxation time), allowing for better control of thermal effects (Fig. 4).

The Erbium lasers also work with an integrated water spray, which has the double function of both cleaning and cooling. In the pulse mode, a string of

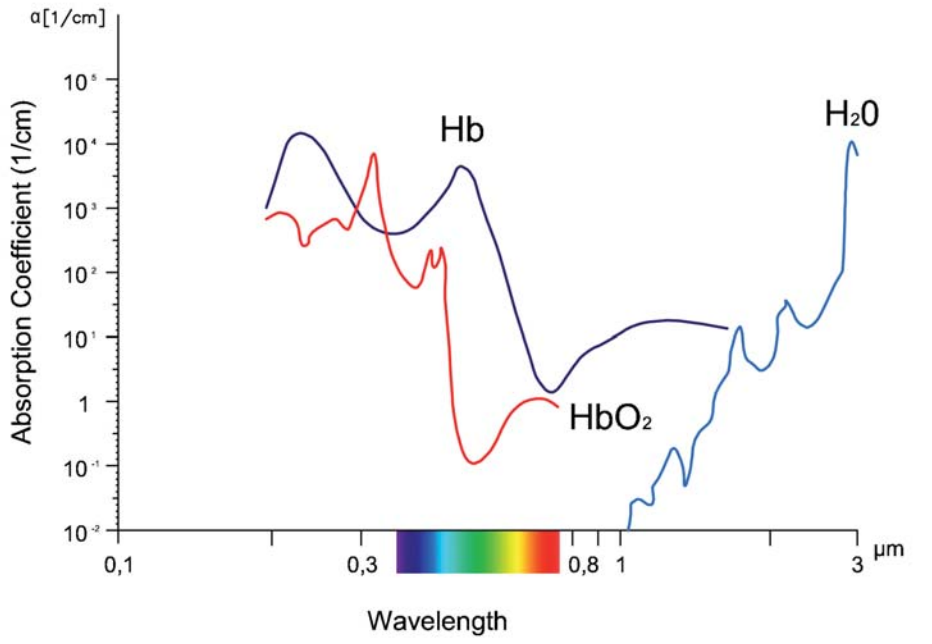

Fig. 3

Fig. 3_Coefficients of tissue absorption.

pulses is emitted with a different pulse repetition rate (improperly called 'frequency') referred to as the Hertz rate (generally from 2 to 50 pulses) per second. The higher emission repetition rate acts in a similar way to the CW mode, while the lower repetition rate allows for a longer time for thermal relaxation. The emission frequency (pulse repetition rate) influences the average power emitted, according to the formula shown in Table I.

Another important parameter to consider is the 'shape' of the pulse, which describes the efficiency and the dispersion of the ablative energy in the form of thermal energy. The length of the pulse, from microseconds to milliseconds, is responsible for the principal thermal effects. Shorter pulses, from a few microseconds (< 100) to nanoseconds, are responsible for photomechanical effects. The length of the pulse affects the peak power of each single pulse, according to the formula in Table I. Dental lasers available on the market today are free-running pulsed lasers, the Nd:YAG with pulses of 100 to 200 µs and the Erbium lasers with pulses of 50 to 1,000 µs. Furthermore, diode lasers emit energy in CW that can be mechanically interrupted to allow the emission of energy with pulse duration of milliseconds or microseconds depending on the laser model.

Effects of laser light on bacteria and dentinal walls

In endodontics, lasers use the photo-thermal and photomechanical effects resulting from the interaction of different wavelengths and different parameters on the target tissues. These are dentine, the smear layer, debris, residual pulp and bacteria in all their various aggregate forms.

Using different outputs, all the wavelengths destroy the cell wall due to their photo-thermal effect. Because of the structural characteristics of the different cell walls, gram-negative bacteria are more easily destroyed with less energy and radiation than gram-positive bacteria.[16] The near infrared lasers are not absorbed by hard dentinal tissues and have no ablative effect on dentinal surfaces. The thermal effect of the radiation penetrates up to 1 mm into the dentinal walls, allowing for a decontaminating effect on deeper dentine layers.[8] The medium infrared lasers are well absorbed by the water content of the dentinal walls and consequently have a superficial ablative and decontaminating effect on the root-canal surface.[8,16]

The thermal effect of the lasers, utilised for its bactericidal effect, must be controlled to avoid damage to the dentinal walls. Laser irradiation at the correct parameters vaporises the smear layer and the organic dentinal structure (collagen fibres) with characteristics of superficial fusion. Only the Erbium lasers have a superficial ablative effect on the dentine, which appears more prevalent in the intertubular areas richer in water than in the more calcified peri-tubular areas. When incorrect parameters or modes of use are employed, thermal damage is evident with extensive areas of melting, recrystallisation of the mineral matrix (bubble), and superficial microfractures concomitant with internal and external radicular carbonisation.

With a very short pulse length (less than 150 µs), the Erbium laser reaches peak power using very low energy (less than 50 mJ). The use of minimally ablative energy minimises the undesirable ablative and thermal effects on dentinal walls while the peak power offers the advantage of the phenomena of water molecule excitation (target chromophore) and the successive creation of the photomechanical and photoacoustic effects (shock waves) of the irrigant solutions introduced in the root canal on the dentinal walls. These effects are extremely efficient in cleaning the smear layer from the dentinal walls, in removing the bacterial biofilm and in the canal decontamination, and will be discussed in Part II.[10–13] _

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

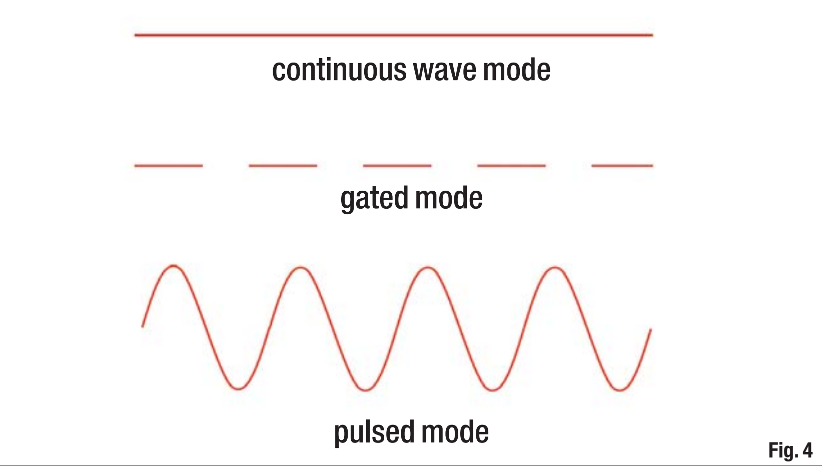

Fig. 4

Fig. 4_Methods of laser light emission.

_contact roots

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Root-canal anatomy of the permanent mandibular first molar—Clinical implications and recommendations

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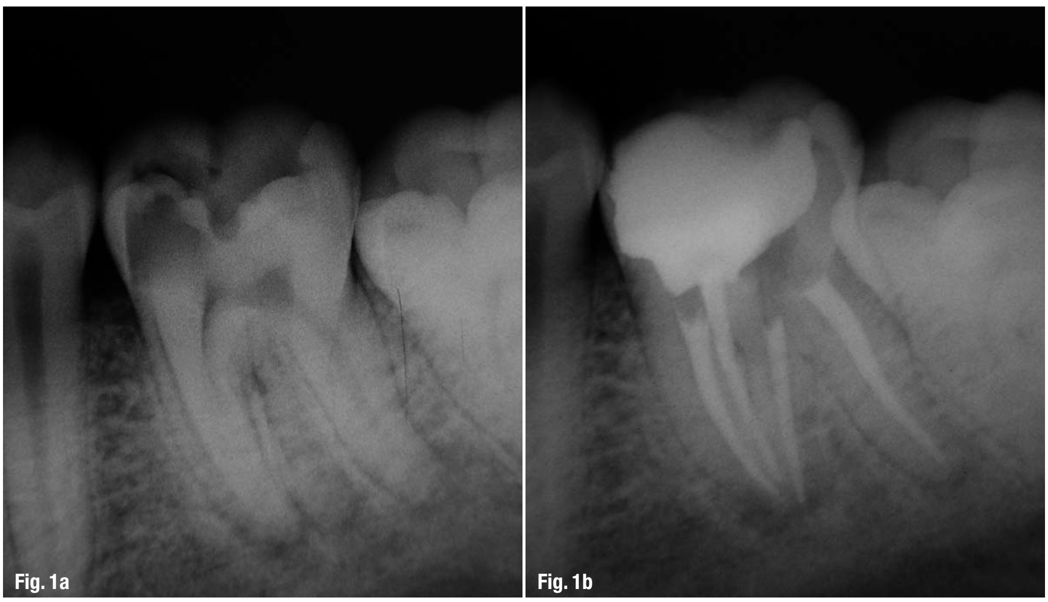
_The world of endodontics has incorporated new technologies, instruments and materials in the past decade, such as operating microscopes, digital radiography, CBCT, NiTi rotary shaping files, sonic and ultrasonic instruments, and new irrigation delivery systems. However, despite all these improvements, the overall outcome, especially of non-surgical endodontics, has not increased significantly.[1–8]

Why? If we consider this critically, we can determine that there are two important factors directly related to prognosis that have limited our advancement: predictable eradication of microorganisms and access to the full anatomy of the canal system in which they might be harboured.

The mandibular first molar (MFM) is the more frequently endodontically treated tooth.[9–11] In a study by Swartz *et al.*, the success rate of endodontically treated teeth was 87.79 %, with a significantly lower success rate of 81.48 % for MFMs.[12] It is well accepted that a unique cleaning and shaping technique is not suitable for all cases. Therefore, the endodontist should be able to fully understand the tooth morphology and root-canal configurations in order to select the most appropriate treatment modality for a particular case,[13] thereby increasing the healing rate.[14–16]

Based on the above information, our group recently published a systematic review on root anatomy and canal configuration of the permanent MFM with reference to 41 studies and a total of 18,781 teeth.[17] A summary of the data obtained is presented in Table I. This review provided significant information directly related to our clinical procedures.



Figs. 1a & b_Root-canal treatment on a three-rooted MFM: pre-op radiograph (Fig. 1a); post-op radiograph (Fig. 1b).

Number of roots					
Number of molars studied	18,781		3-rooted molars in %		13 % (2,450)
Total number of canals					
Number of molars studied	4,745		61.3 % 3 canals	35.7 % 4 canals	0.8 % 5 canals
Number of canals in mesial root					
Number of mesial roots studied	4,535		3.3 % 1 canal	94.2 % 2 canals	2.6 % 3 canals
Mesial and distal roots. Canal system configuration					
		Type I (1-1)	Type II (2-1)	Type IV (2-2)	Type VIII (3-3)
Number of mesial roots studied	4,331		35 %	52.3 %	0.9 %
Number of distal roots studied	2,992	62.7 %	14.5 %	12.4 %	
Number of foramina in mesial and distal roots					
			1 foramen	2 foramina	3 foramina
Number of mesial roots studied	4,817		38.2 %	59.2 %	1.6 %
Number of distal roots studied	3,378		77.2 %	22.2 %	
Intercanal communications. Type V isthmuses					
			Mesial root		Distal root
Number of molars studied	1,615		54.8 % middle & apical 1/3		20.2 % middle 1/3

Table I

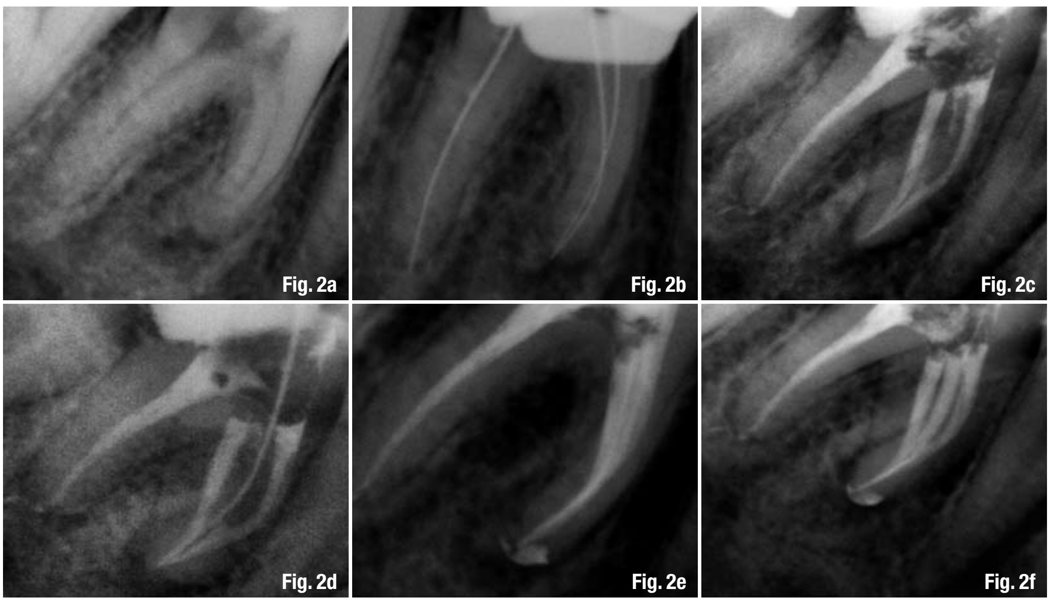
Table I_Results of mandibular first lower molar systematic review (Valencia de Pablo *et al.*, 2010).

_Number of roots

A literature review revealed a strong correlation between the presence of a third root in 13 % of teeth and the ethnicity of the patients, particularly Asians, Mongolians and Eskimos.[18]

In order to determine the presence of additional roots visually, several radiographic exposures are required. Initial off-angle radiographs are essential during MFM treatment (Fig. 1a).[19,20] Initially, a file located in the extra root, may give the appearance of a perforation.[21] If radiographic findings are not definitive, information provided by electronic foramen locators provides reliable readings to make a differential diagnosis and confirm the presence of the additional canal. Walker and Quackenbush conclude that simple analysis of bitewings allows for the detection of disto-lingual (DL) roots in 90 % of cases.[18]

In 1990, Carlsen and Alexander reported on a study of 398 permanent mandibular molars with a lingually located supernumerary root.[22] This macrostructure, the radix entomolaris, presents high variation in regards to shape and curvature. When the position of this third root is buccal, it is called the radix paramo-



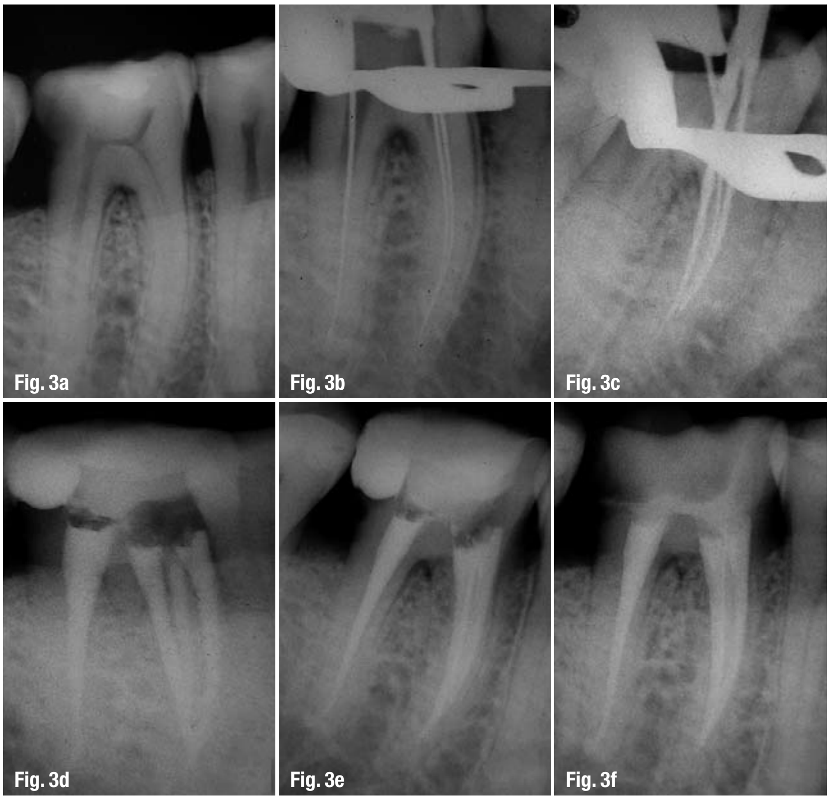
Figs. 2a–f_Root-canal treatment on an MFM: pre-op radiograph (Fig. 2a); working length radiograph (Fig. 2b); post-op radiograph demonstrating a fine projection of sealer between MB and ML (Fig. 2c); working length radiograph of middle mesial canal (Fig. 2d); post-op, ortho-radial radiograph (Fig. 2e); post-op, off-angle radiograph demonstrating three canals treated on mesial root (Fig. 2f).

laris. Its shape and curvature are highly variable (Fig. 1b).[23–25] Typically, the axis of the root faces the buccal aspect of the molar. Therefore, it could be easier to select the disto-buccal cusp as a reference point, instead of the typical DL. The combination of the slope present at the orifice and the buccal curvature at the apical third results in a highly complex canal to be instrumented and irrigated. To prevent mishaps, it is advisable to choose a small and highly flexible instrument when treating the apical portion.

Diagnosis, access and proper treatment of the third root within the complex canal system are essential in order to achieve successful endodontic treatment. In cases of endodontic surgical procedures, the third root will be a significant challenge.[19] In a recent publication, Tu *et al.* report high DL root prevalence amongst the Taiwanese population.[26] The authors found that the inability to recognise and treat this extra root was directly correlated to treatment failure, leading to tooth extraction.

Table I summarises the findings of a systematic review compiling data on 4,745 MFMs.[17] On average, three canals were present in 61.3 % of cases, followed by four canals in 35.7 % of cases and five canals in almost 1 % of cases. *In vivo* studies performed by endodontists demonstrated the presence of four canals in 45 % of the treated cases.[27–30] Five canals were found in 0.8 % of the samples, while case reports have demonstrated the possibility of six- and even seven-root canals.[31,32]

Figs. 3a–f_Root-canal treatment on an MFM: pre-op radiograph (Fig. 3a); working length radiograph (Fig. 3b); working length off-angle radiograph after location of three canals on mesial root (Fig. 3c); post-op, off-angle radiograph demonstrating three canals treated on mesial root (Fig. 3d); post-op, ortho-radial radiograph (Fig. 3e); final restoration control (Fig. 3f).



_Mesial root morphology

A systematic literature review of studies concerning more than 4,000 mesial roots confirmed the presence of two root canals in 94.2 %.[17] These canals merge in a common apical foramen (type II) in 35 % of cases or remain independent with separate apical foramina in 52.3 % of cases (type IV of Vertucci's classification; Table I). A clinical approach to identifying the internal canal configuration should include evaluation of the distance between the main orifices. The short distance between mesiobuccal (MB) and mesiolingual (ML) orifices often leads to confluence and termination in a common foramen. An increased distance is directly correlated to type IV configuration with two separate foramina.[33]

When facing a type IV configuration (2-2), the clinician should treat the canals independently. For merging canals, Castellucci explains that initially the canals should not be instrumented to working length, thus preventing unnecessary removal of dentine.[34] In addition, full instrumentation of both canals to working length will create an hour-glass preparation, with the narrowed area at the junction and widening canal space apical to the junction. The 3-D obturation in this case is much more complicated and poses a risk of extrusion, as well as leaving some empty space in the most apical divergent zone.[29] It is clinically safer and easier to instrument the ML canal to working length and the MB to the level of the confluence, since the latter is the closest to the outer surface of the root and also presents more severe curvatures than the ML.[35,36]

Marroquin *et al.* report that the average size of the maximum diameter is 0.31 mm when the apical foramen is common.[37] In contrast, the average maximum diameter does not exceed 0.25 mm when two separate foramina are present. This data suggests that treating a type IV configuration could allow a more conservative apical preparation. Nevertheless, canal preparation must always be correlated to the anatomy and the microbiological status of the canal. While vital cases should be treated more conservatively, infected canals may require larger apical preparations to allow efficient irrigation and disinfection.[38,39]

Several publications report the presence of three canals in the mesial root.[40,41] Our systematic review reports an incidence of 2.6 % (Figs. 2 & 3).[17] In order to localise it, access modifications are required. Briefly, once the main canals have been localised and their access instrumented, small burs or ultrasonic tips are used to remove the dentinal bridge that connects both entries, providing a direct view of the angle formed by the mesial wall and the floor of the pulp chamber, exposing the developmental groove between the two main canals. An endodontic explorer is then used, followed by negotiation with small files. Additionally, the use of operating microscopes further improves the possibility of finding and treating this accessory canal.[42] Taking into consideration the distal concavity of the mesial root, instrumentation of the third medial canal must be done carefully using small instruments to avoid stripping perforations.[27] The middle mesial is an entirely independent canal in up to 25 % of cases.[17]

_Distal root morphology

Gulabivala *et al.* evaluated 139 MFMs and found that 74.8 % of the distal roots had a flattened MD morphology.[21] They also noted that conical distal roots frequently presented a single canal, while the vast majority had more complex configurations. Therefore, routine access openings should be modified in search of a second or a ribbon-shaped canal. The access design has evolved from the classic triangular to a rectangular shape shifted to the MB.[27,43]

Martinez-Berna and Badanelli were the first to report a third canal in the distal root and termed it the disto-central (DC) root canal.[44] A literature review sets the incidence of DC at 1 %.[21,31,39,45–50]

_Intercanal communications

The morphology and buccolingual width of the mesial root allow for intercanal communications and isthmuses (Fig. 4). An isthmus (anastomosis) is defined as a pulpal passageway that connects two or more canals in the same root.[51] In young patients, we should expect to find large canals with wide isthmuses. As secondary dentine is deposited throughout the maturation of the tooth, these large communications are divided into smaller ones and, eventually, its frequency decreases after age 40.[52]

Of the 1,615 MFMs reviewed, 50 % of the mesial and 20 % of the distal roots presented isthmuses of type V. Type V is recognised as a true connection or wide corridor of tissue between the two main canals.[53] Therefore, the presence of isthmuses should be considered the rule rather than the exception when treating young MFMs.

Given the extreme difficulty in disinfecting these inaccessible spaces,[54] our efforts should be focused on improving our irrigation protocols with the more efficient systems available today. The clinical importance of recognising, treating and disinfecting isthmuses was recently pointed out by Von Arx, who identified complete cross-anastomosis in 29 % of cases of failed root-canal therapies requiring apical surgery.[55]

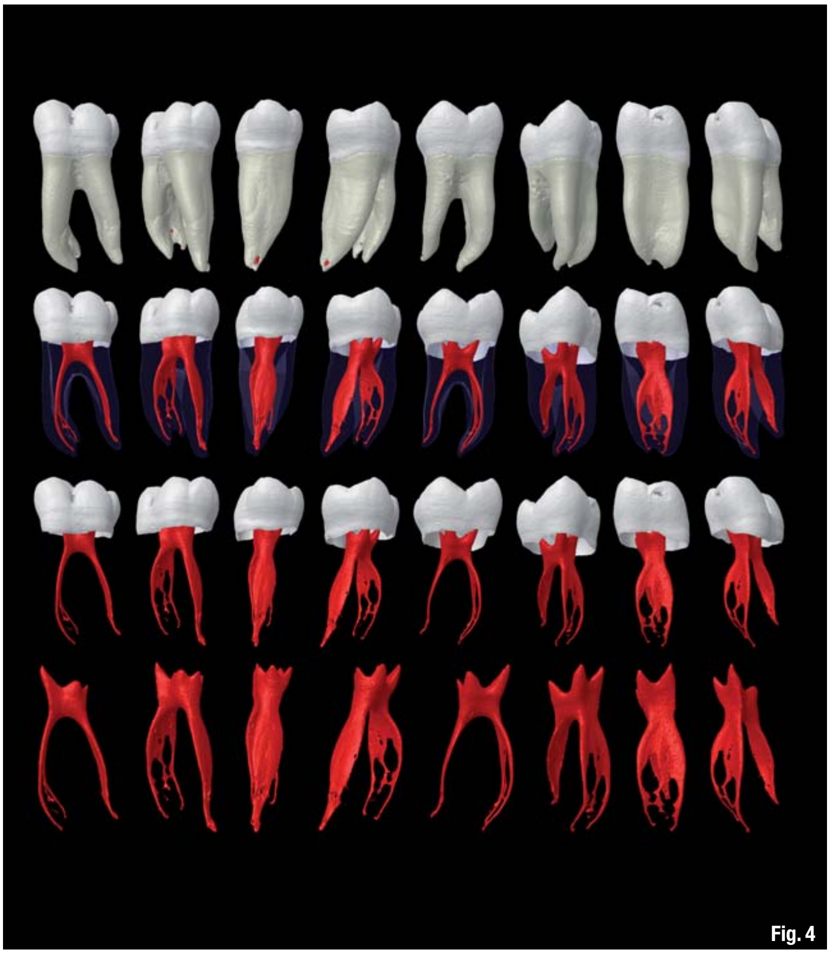


Fig. 4_Micro-computed tomography of an MFM with 3-D reconstructions on different projections showing the very complex anatomy of the root-canal system (Image courtesy of Prof Marco Versiani and Prof Manoel D. Sousa Neto, Ribeirão Preto Dental School, University of São Paulo).

_Conclusion

The following is a summary of the findings of our review:

1. The number of roots in the MFM is directly related to the ethnicity of the population studied.
2. The instrumentation of the third root requires a different access and the use of small and flexible instruments, considering the curvature at the apical third.
3. Mesial roots present two canals on a regular basis, with 2-2 and 2-1 the most frequent configurations. A third canal might be present in 2.6 % of the population.
4. The most common configuration in the distal root is 1-1 (62.7 %), followed by 2-1 (14.5 %) and 2-2 (12.4 %).
5. Access modifications are required in order to find extra roots and/or canals.
6. The presence of isthmuses is 55 % in the mesial root and 20 % in the distal root. This anatomical configuration should be taken into consideration during endodontic treatment and peri-apical surgery._

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

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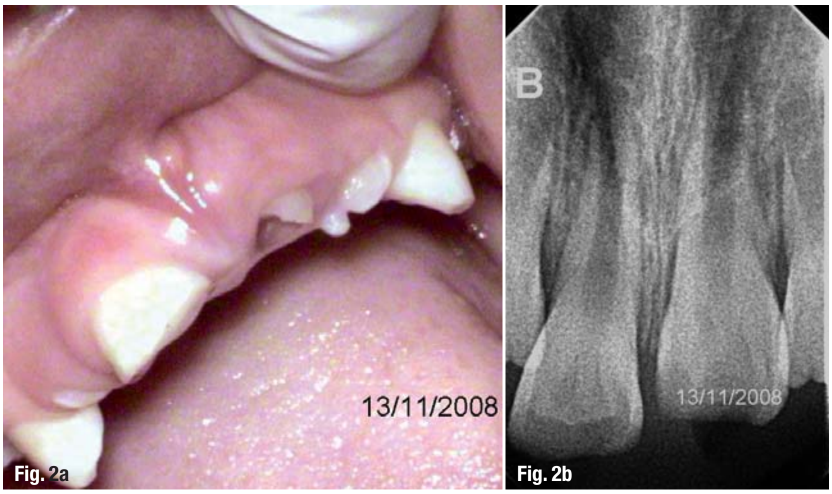
Revascularisation of the necrotic open apex

Author_ Dr Antonis Chaniotis, Greece

Fig. 1a_Pre-op radiograph of tooth #11 with $Ca(OH)_2$ dressing from the referring doctor.
Fig. 1b_Radiographic appearance of properly placed apical MTA plug.
Fig. 1c_Post-treatment radiograph with gutta-percha backfilling.

_**Two years ago,** I was struggling to learn how to perform a good apical MTA plug. I used all the existing MTA carriers and absorbable barriers that I could find on the Greek dental market. It took me a while, but I finally ended up performing some proper apical MTA plugs and with practice, I am now able to perform apical MTA plugs even without using absorbable barriers (Figs. 1a–c).

Figs. 2a & b_Initial situation.



It was back then, that I started gathering information on revascularisation procedures of the necrotic open apex. A case report by Iwaya *et al.* published in a 2001 issue of *Dental Traumatology* was reproduced by Banchs and Trope in 2004, giving the work of Nygaard-Ostby *et al.* and Skoglund *et al.* from the seventies a whole new meaning. According to Dr Martin Trope, "If the canal is effectively disinfected, a scaffold into which new tissue can grow is provided, and the coronal access is effectively sealed, revascularisation should occur as in an avulsed immature tooth." I believe this is an excellent description of the philosophy behind the revascularisation procedure. Dr Trope's words gave me all the information that I needed for making the attempt myself.

_Case report

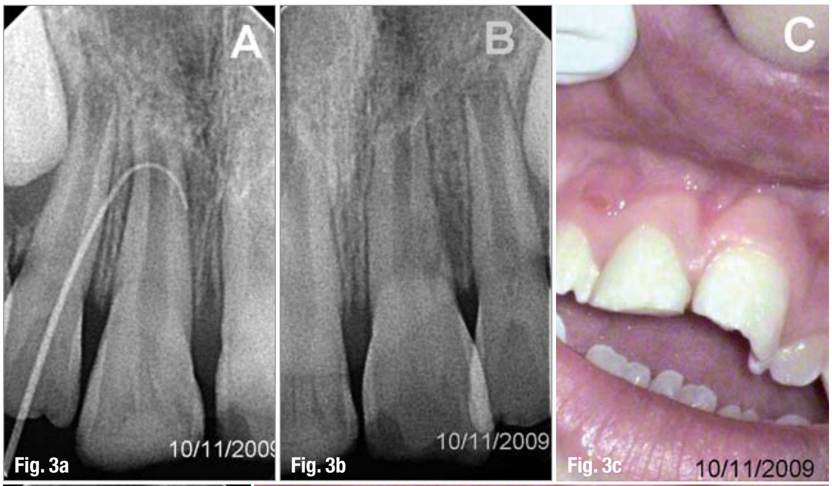
On a rainy morning, the phone in my private practice rang. The referring doctor was very anxious to obtain an early appointment, as it concerned a trauma case of an eight-year-old child. I saw the little girl the same afternoon. Two days earlier, little Marlene had been hit by a car. Her right maxillary central incisor had suffered an enamel-dentine fracture while her left maxillary central incisor had been displaced into the alveolar bone (intrusion; Figs. 2a & b). Thermal and electrical pulp testing was positive for the right maxillary central incisor. However, it was impossible to perform vitality tests on the intruded incisor.

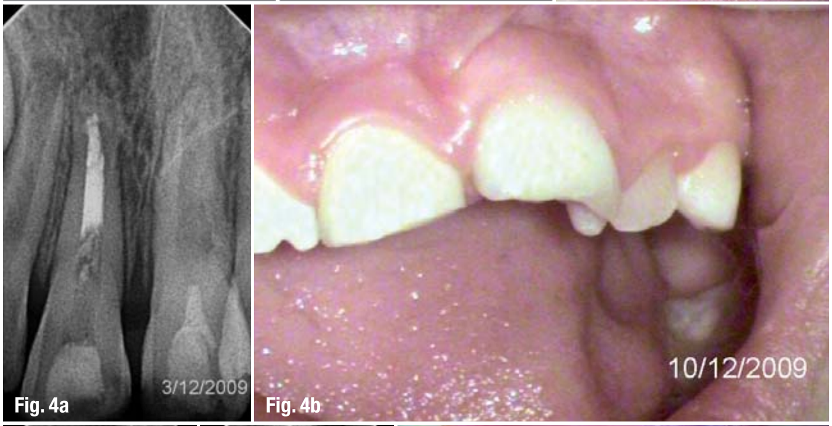
The treatment plan aimed mainly at protecting the vital pulp tissue of the immature fractured tooth with bonded resin, while the intruded tooth was left for spontaneous repositioning. Instructions for a week long, soft food diet was given and an appointment was scheduled for the following month. Unfortunately, the little girl did not return to my practice until one year later. At that time, there were two sinus tracts associated with the traumatised central incisors, and both thermal and electrical vitality tests were negative for both incisors. Probing depths were within normal limits (Figs. 3a–c). The spontaneous repositioning of the left central maxillary incisor had succeeded, but the pulp tissue had become necrotic.

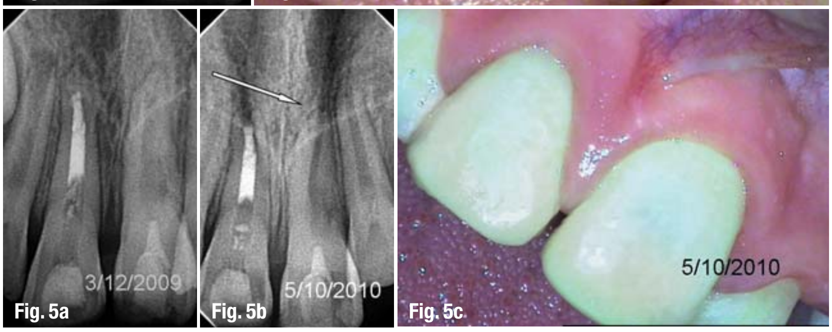
I then decided to attempt revascularisation of the necrotic immature apices. The treatment plan aimed mainly at the effective disinfection of the wide canals, followed by blood clot induction and MTA placement. Effective disinfection is one of the main issues in endodontics. Articles by Sato *et al.* and Hoshino *et al.* describe an effective disinfection procedure using a triple antibiotic paste. The effectiveness of a metronidazole, ciprofloxacin and minocycline mixture for the disinfection of the immature necrotic open apex was demonstrated by Windley *et al.* However, the minocycline component of the mixture stained the dentine excessively. Therefore, many researchers suggest either a bi-antibiotic paste regimen (without minocycline) or with cefaclor as a substitute.

Back then, I thought it was not safe to place antibiotics inside the wide-open canal of an nine-year-old child. Therefore, I sought to achieve effective disinfection by using only syringe irrigation of a 2 % chlorhexidine digluconate solution. After administrating infiltration anaesthesia, the incisors were isolated with Hygenic Wedjets (Coltène/Whaledent) and access was achieved. The wide canal was completely necrotic in the right central incisor. In the left central incisor, however, there appeared to be vital pulp tissue in the middle part of the wide-open canal. Both canals were irrigated with a 2 % chlorhexidine digluconate solution. The thin dentinal walls were lightly brushed using a #110 Hedstrom file. The final rinse was accomplished using sterile water, and the canals were dried using sterile paper points.

A sterile #60 K-file was used for bleeding induction. Only in the left central maxillary incisor was a







Figs. 3a–c_One year after the initial visit.
Figs. 4a & b_Post-treatment.
Fig. 5a_Post-treatment radiograph of tooth #21 after the revascularisation attempt.
Fig. 5b_One-year follow-up radiograph indicating successful revascularisation and dentin wall thickening.
Fig. 5c_Clinical image after the successful revascularisation procedure.

blood clot successfully produced to the level of the cemento-enamel junction, followed by an MTA seal in the cervical area and a bonded resin coronal restoration above it. In the other incisor, bleeding induction was unsuccessful and an apical MTA plug was placed. One week later, the sinus tracts had disappeared and the little girl was referred back to her dentist for appropriate restoration (Figs. 4a & b).

One year later, the patient returned for her scheduled follow-up examination. The radiographic image showed healing, root wall thickening and root lengthening of the left central maxillary incisor, indicating that the root canal had been revascularised with vital tissue (Figs. 5a–c). Unfortunately, the post space of the right central maxillary incisor had been left empty. The patient was referred back to her dentist for retreatment of the restoration.

_Conclusion

Revascularisation research has introduced me to a whole new area of great interest. I have learnt that it is important to distinguish between revascularisation and pulp regeneration.

"When looking for the 'bag of gold coins from the Emperor' we must separate the treatment of immature teeth from stem cell research. Both topics are valid topics for research but with very different objectives and pathways." These are the exact words of Prof Larz Spångberg in his editorial titled *The emperor's new cloth*, which was published in *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology* 5/2009. Prof Spångberg goes on to say that "there is much indirect evidence that revascularization of necrotic pulp space content will result in fibrous connective tissue with cellular/acellular apposition on the root canal walls."

A couple of months later, a study on dogs by Wang *et al.* provided direct evidence on the importance of the blood clot as a scaffold for the stimulation of the revascularisation process. Their histological findings found bone ingrowth in the lumen of infected immature dog teeth and cementum on the inner root wall, which was the reason for the thickening of the root.

Further studies are probably underway to find new and more predictable scaffolds for tissue ingrowth. Until a definite predictable revascularisation protocol is proposed, the procedure described in this paper could be safely attempted in most cases. An apical MTA plug can always be performed, if no signs of regeneration are present after three months._

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

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When nature laughs at endodontists: Two case reports

Author_ Dr Bojidar Kafelov, Bulgaria


Fig. 1a


Fig. 1b


Fig. 1c


Fig. 2

_**Every endodontist knows** that each tooth is different and has to be treated with care, paying attention to detail. There are various studies on root-canal anatomy, the configuration of canal orifices and the canals themselves.[1] Several scientific articles discuss the presence of additional canals in maxillary first premolars and mandibular first molars.

The percentage of additional root canals varies between 0 and 6 % for the maxillary first molar and between 6 and 23 % for the mandibular first molar.[1–6] The root-canal treatment (RCT) of these teeth is challenging for every clinician and requires knowledge, patience and a variety of instruments and devices.

_Case I: Three-rooted maxillary first premolar

A 34-year-old male patient was referred to our clinic with mild symptoms of pain and soreness owing to chronic apical periodontitis on tooth #5. The general practitioner referred the patient because she was unable to perform the RCT. The preoperative radiographs revealed three separate roots in the first upper right premolar (Figs. 1a–c). The access cavity was modified with a safe-end bur and a Start-X ultrasonic tip #1 (DENTSPLY Maillefer) in order to locate the third root canal. The negotiation of the distobuccal canal began with a 10.04 Micro-Opener and a ProTaper SX file (DENTSPLY Maillefer). Negotiation of the canal was facilitated by coronal pre-enlargement using ProTaper S1, S2 and SX files. After patency had been confirmed with a 08.02 K-file, the working length was determined with the electronic apex locator (iPex, NSK) and a glide path was established using PathFiles (DENTSPLY Maillefer) at 250 rpm and maximum torque.

All three canals were shaped with ProTaper NiTi instruments. The last instrument used to length was a ProTaper F1 file and then apical gauging was performed. The final instruments were a ProTaper F2 file for the mesiobuccal and distobuccal canals and a ProTaper F3 file for the palatal canal. Copious irrigation with 5 % sodium hypochlorite was performed throughout the RCT. Final irrigation entailed passive ultrasonic irrigation with 5 % sodium hypochlorite, followed by ultrasonically activated 40 % citric acid. A final rinse was done with 95 % ethyl alcohol.

Obturation of the root-canal system was done according to the Continuous Wave of Condensation technique with Alpha II and Beta devices (B&L Biotech;

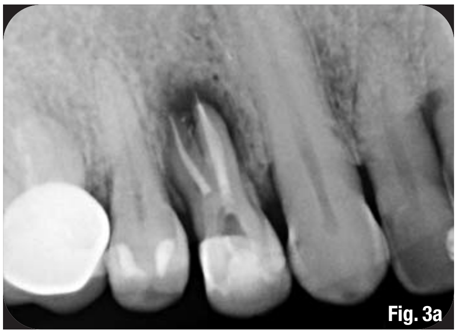

Fig. 3a

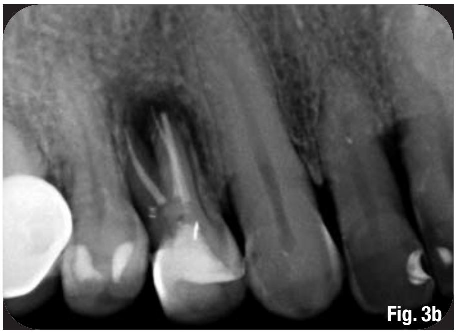

Fig. 3b

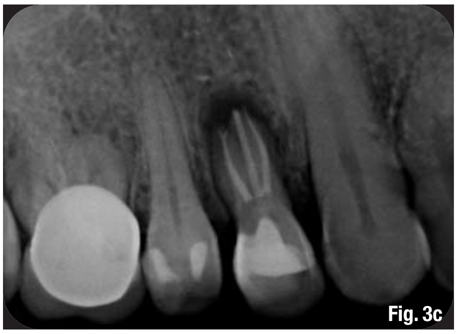

Fig. 3c

Fig. 2), and an orifice barrier was made using Gradia Flow (GC). After root-canal obturation, three radiographs were taken, one with normal angulation and two angled (Figs. 3a–c). The radiographs clearly reveal the complexity of the root-canal system and the 3-D obturation. Post-endodontic composite obturation was done with Miris 2 (Coltène/Whaledent).

_Case II: Three-rooted mandibular first molar

A 22-year-old male patient was referred to the clinic with pain in teeth #29 and 30. He was in good health, with mild to acute pain to percussion. The referring dentist was concerned about the complex anatomy, which was the reason for the referral. After taking a preoperative radiograph (Fig. 4), an access cavity through the crown was made using a Crown Cutter bur and a safe-end diamond bur (KOMET/Gebr. Brasseler). Cavity refinement was done with the Start-X ultrasonic tip #1 and a #3 Mueller bur (Mani, Inc.; Fig. 5).

Coronal pre-enlargement was necessary because of the calcified orifices of the root canals. This was done with a ProTaper SX file with brushing movements. Negotiation of the canals was done with a 10.02 K-Flexofile (DENTSPLY Maillefer) with the aid of Glyde Gel (DENTSPLY Maillefer). A glide path was established with PathFiles and shaping was done using the ProTaper System (DENTSPLY Maillefer). After apical gauging, the four canals were shaped to a ProTaper F3 file with 5 % sodium hypochlorite irrigation. Final irrigation was done using ultrasonically activated 5 % sodium hypochlorite and 40 % citric acid. A final rinse was done with 95 % ethanol. Obturation of the root-canal system was performed with the Alpha II and Beta devices using the Continuous Wave of Condensation technique, and flowable composite was used to create the orifice barriers (Gradia Flow; Fig. 6).

The post-endodontic build-up was made using a fibre post and composite (Core-X Flow and Ceram-X Duo, DENTSPLY DeTrey), and a final radiograph was taken (Fig. 7).

_Conclusion

When dealing with such challenging cases, one needs to have an immense amount of patience and a great deal of curiosity to discover the hidden secrets of the root-canal system. After unveiling all of the pulp chamber anatomy, one can continue moving towards the apical foramen to reach the endodontic goal: to clean, shape and fill the 3-D root-canal space the best way one can._

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

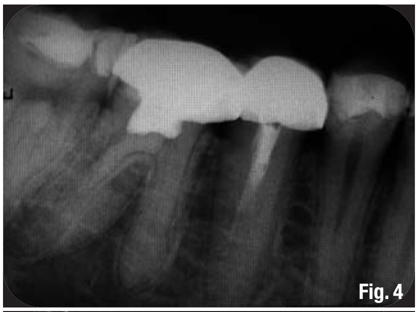

Fig. 4

Fig. 5

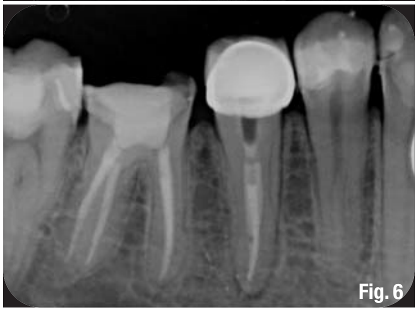

Fig. 6

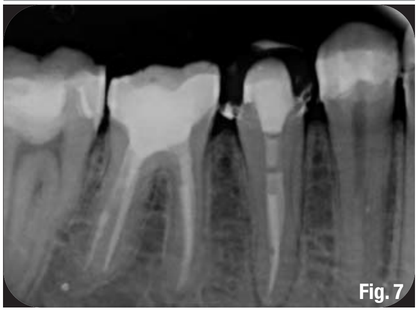

Fig. 7

_about the author

roots

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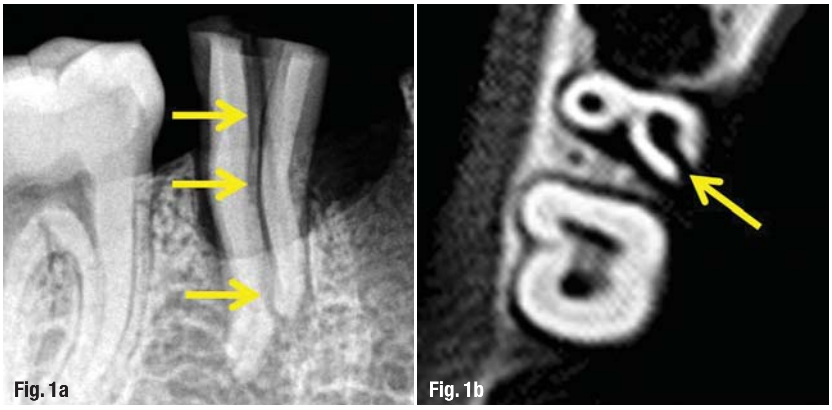
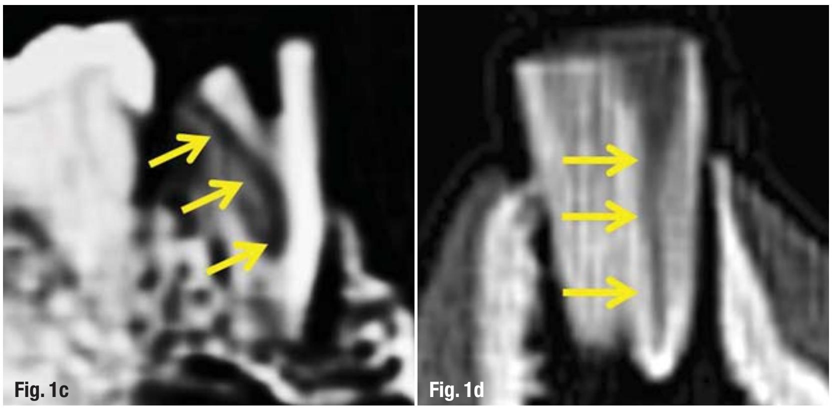
Diagnosis of vertical root fractures using CBCT and an alternative treatment modality

Author_ Dr Senem Yiğit Özer, Turkey



Figs. 1a–d_An intra-oral radiography image of an experimentally induced VRF of 0.4 mm thickness (a). Arrows indicate the VRF and it is difficult to determine whether the fracture is on the buccal or on the palatinal root. CBCT images of an experimentally induced VRF, axial view (b). Note that the VRF obviously includes the palatinal root and this finding may change the treatment modality. Sagittal view showing the extent of the VRF (c). Coronal view (d). Arrows show the fracture lines through the entire root surface.



_Longitudinal root fractures are confusing to both the clinician and the patient, and it is often more a case of prediction rather than diagnosis. In order to provide a global terminology and to prevent bias, five types of root fractures with different treatment modalities have been classified, from least to most severe: craze lines, cuspal fractures, cracked teeth, split teeth and vertical root fractures (VRFs).[1]

Craze lines, which are asymptomatic, affect only the enamel and often do not need to be treated. *Cuspal fractures* on the cusps and the cervical margins of the root are usually reinforced by a crown or an onlay restoration to keep the separated segments in their original positions. A *cracked tooth* occurs on the crown with variable symptoms. Cuspal reinforced restorations represent an appropriate treatment modality. If the fracture continues to develop, a *split tooth* is formed and wedging of the separated fragments can be identified visually and clinically with pain in mastication. If the fracture lies through the middle to the cervical third of the root without extending apically, the mobile segment can be removed and the tooth can be preserved. Crown lengthening and orthodontic extrusion of the remaining root are further treatment alternatives.[1]

A *VRF* is the most severe type of longitudinal defect, originating from the apical end of the root and continuing coronally. A VRF extends to the periodontal ligament and soft tissue grows into the fractured fragments over time. As the separations between fractured fragments increase over time, resorption areas become enlarged, which has a negative effect on the prognosis of the affected area for further treatment.[2] Thus, a rapid decision is required to prevent additional bone loss, which might cause difficulty in reconstructing the area for further treatment, such as implant placement. Clinical signs, radiographic features and symptoms observed in VRFs are very similar to those in a failed root-canal treatment and manifestations of periodontal disease, making an accurate diagnosis difficult.[3] Referring these patients for periodontal therapy or endodontic retreatment results in a loss of time and patience, as well as greater bone resorption.

Today, the three major indications for the extraction of endodontically treated teeth are unrestorable teeth (43.5 %), endodontic failures (21.1 %) and VRFs (10.9 %).[4–6] Recently, high prevalence rates of VRFs have been reported.[2,4–6] A VRF can be treated by many treatment modalities, such as tooth extraction, removal of the fractured root and replantation of the tooth after bonding the fractured fragments extra-orally.[4,7–9]

Saving a tooth via intentional extraction causes minimal damage to periodontal tissues. 4-META/MMA-TBB resin is generally used to bond the separated fragments and afterwards, replantation is performed.[8,9] The distance between separated fractures is an important factor to determine whether surgery will be planned with simultaneous flap operation or with normal extraction without flap reflection.[4] In addition, determining the position and extent of the fracture might be helpful for deciding when to recommend extraction.

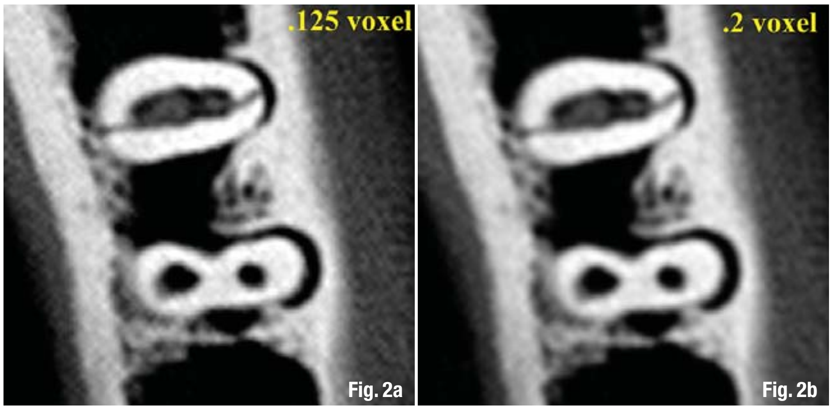
A root fracture can be overlooked if the X-ray beam does not pass along the fracture line.[10] Furthermore, the interpretation of root fracture on radiographs is problematic, especially if there is no oedema and granulation tissue between the separated fragments.[11] Another major problem for conventional intra-oral radiography is the superimposition of other structures, which limits the sensitivity of diagnosis.[12]

Cone-Beam Computed Tomography (CBCT) units have become commercially available recently, in which all data is acquired at one time, providing a 3-D scan of the patient's head.[13–15] Previous studies have indicated the superiority of CBCT to intra-oral conventional film and digital radiography for detecting VRFs.[12,14–17] A recent study reported that CBCT scans had provided more accurate results than intra-oral radiography during the diagnosis of VRFs with 0.2 to 0.4 mm thicknesses, which may indicate the early stages of the problem (Figs. 1a–d).[16]

Choosing the appropriate radiation dose using CBCT in detecting VRFs is a major and critical concern. ALARA is the acronym for *as low as reasonably achievable*, which constitutes the basic principle for diagnostic radiology in all fields. One must consider keeping the dose as low as possible while still obtaining the information needed.[18] It is reported that with smaller voxel sizes, radiation exposure would be higher.[19–21] Without sacrificing image quality and adopting the ALARA principle, changing the voxel settings would be helpful in reducing the radiation dose.

Recent studies comparing the diagnostic accuracy of different voxel sizes for the detection of VRFs report that voxel sizes equal to or smaller than 0.2 mm are the best choice, with a shorter scanning time and reduced radiation exposure of the patient (Figs. 2a–d).[22,23]

After diagnosing the VRF, a rapid decision has to be made whether to extract or retain the tooth. Extra-oral VRF treatment that includes resin cement bonding and intentional replantation is an alternative treatment modality. This alternative treatment method in particular is reported to be appropriate for anterior teeth.[4,8,24,25] A clinical report by Hayashi *et al.* demonstrated no failure in vertically fractured incisors treated with this method, although failures occurred in premolars and molars in that the posterior teeth were negatively affected by strong occlusal forces.[25]



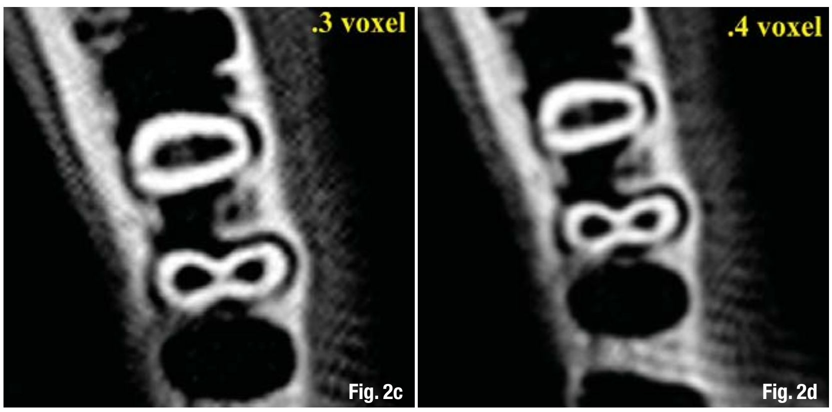
Figs. 2a–d_CBCT images of a fractured root with four different voxels in the axial plane. 0.125 mm voxel (a); 0.2 mm voxel (b); 0.3 mm voxel (c); 0.4 mm voxel (d). Fracture lines are difficult to detect when compared with the 0.125 mm and 0.2 mm voxels.

For a vertically fractured incisor, Öztürk and Ünal reported a successful four-year outcome clinically.[4] Similarly, Arıkan *et al.* reported a successful 18-month outcome for VRF treatment and recommended the procedure described in this article.[24] They also demonstrated that the use of a dual-curing material instead of 4-META/MMA-TBB resin shortened extra-oral working time and preserved the vitality of the periodontal ligament, thereby increasing the probability of long-term replantation success. In addition, Özer *et al.* reported success after two years in treatment outcomes of VRFs treated in the same manner as above.[26]

_Alternative treatment of VRFs

The alternative treatment plan for VRFs consists of the following steps:

1. Extraction of affected teeth;
2. Bonding of the separated segments with a self-etching, dual-cure adhesive resin cement extra-orally; and
3. Intentional replantation of the reconstructed teeth.



The following surgical protocol is helpful during the process:

1. Local anaesthesia using a solution of 2 % articaine with 0.1 % epinephrine and a full-thickness mucoperiosteal flap for better visualisation;
2. Circumferential dissection of the supra-alveolar fibres;
3. Gentle extraction of the tooth with minimum damage to the periodontium and immersion in saline solution; and
4. Curettage of the socket walls adjacent to the fracture region and irrigation with saline solution for the removal of inflamed tissue.

For the treatment of VRFs, the following steps are recommended:

1. The root-filling material and granulation tissue are removed with a sharp scalpel through the entire root. During this process, in order to prevent dehydration, tooth fragments should be kept in gauze moistened with saline.
2. The sealant should be applied in small amounts to avoid covering the periodontal ligament on the root-canal dentine, which is dried prior to sealing.
3. The self-etching, dual-cured adhesive resin cement should be cured for 20 seconds for proper setting of the material. In addition, this will help to reduce the working time extra-orally.
4. After fragment attachment, the root surfaces may be treated with tetracycline for 30 seconds to enhance periodontal ligament cell attachment.[27]
5. In the final step, the reconstructed tooth is replanted in its original position.[4,8,24]

After the surgical procedure, patients are prescribed a chlorhexidine-digluconate mouth rinse and 500 mg amoxicillin (3 tablets) plus 550 mg naproxen (2 tablets) daily for one week. Following intentional replantation, clinical examinations should be performed in intervals to evaluate tooth mobility and sensitivity to percussion. The percussion tone can be compared with healthy adjacent teeth.

Clinical success is defined by a lack of sensitivity to percussion, percussion tone that does not differ from the healthy adjacent teeth, and mobility within normal limits at six months. Failure is defined as clinical conditions that do not meet the requirements for success and/or increased discomfort of the patient.

In cases in which the tooth has been treated extra-orally, healthy cementum on the root surface and periodontal membrane vitality are important factors in preventing ankylosis.[4,28] Solutions such as citric acid, tetracycline and EDTA have been advocated for root-surface modification to produce a surface that is conducive to cellular adhesion and growth.[29] A 30-second application of tetracycline has been reported to remove the smear layer, leaving clean and open tubules.[27]

During evaluation of the CBCT images for VRFs, as previously reported by Hassan *et al.*, axial slices have proven to be more accurate than coronal and sagittal slices (Fig. 1b).[30] Thus, it is important to pay attention to axial plane images in particular. Sagittal plane images are useful for determining the extent and direction of each fracture line (Fig. 1c).

_Conclusion

1. Early and accurate diagnosis of a VRF is important in preventing bone destruction. CBCT imaging allows the clinician to accurately detect these problems and inform the patient about alternative treatment modalities.
2. Bonding the separated fragments of VRFs extra-orally followed by intentional replantation of the reconstructed tooth is an innovative method that provides an alternative to tooth extraction, especially for anterior teeth.
3. Scanner units with higher resolutions are advisable for use in detecting VRFs and in the follow-up period for better evaluation during the recovery phase._

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

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Dr Senem Yiğit Özer graduated from Selçuk University's Dental Faculty in Konya, Turkey, in 1997. She completed her PhD in 2004 at the Department of Endodontics at Ege University in İzmir, Turkey, and worked at the Dental Hospital of the Ministry of Health in Diyarbakır, Turkey, between 2005 and 2008. Thereafter, she began working at the Department of Operative Dentistry and Endodontics at Dicle University in Diyarbakır, and still serves there as Assistant Professor. Her research interests are root-canal instruments, root-canal obturation materials, survival analysis of endodontic treatment outcomes, diagnosis and treatment of VRFs, and use of CBCT in endodontics. Dr Özer can be reached at senemygt@hotmail.com.

Bypassing a fractured instrument

Author_ Dr Rafaël Michiels, Belgium

Fig. 1_Diagnostic radiograph showing a separated instrument in the canal at the curvature.

_In a previous case report published in roots 3/10, I demonstrated the possibility of removing a fractured instrument from the root canal.[1] In some cases, however, removal of a fractured instrument is impossible or undesirable. Favourable factors for the removal of a fractured instrument are straight canals, incisors and canines; localisation before the curvature; length of fragment of more than 5 mm; localisation in the coronal or mesial third of the root canal; reamer or lentulo spirals; and hand NiTi K-files.[2,3] If the case does not fulfil one or more of these criteria, removal of the fractured instrument might be impossible. Teeth with small roots may also be excluded for instrument removal, since excess removal of dentine will compromise the long-term prognosis of the tooth. In these cases, alternatives to instrument removal will have to be sought. Alternatives are leaving the instrument in place, surgical removal, extraction or bypassing the instrument. In the following case report, I will demonstrate the manner in which a fractured instrument can be bypassed.

_Case report

A 60-year-old patient was referred to our practice. He had type II diabetes, but no other health problems and hence was assigned an American Society of Anesthesiologists score of two. The patient had acute pulpitis on tooth #20. The referring dentist had performed a preliminary root-canal treatment but had been unable to pass the curvature.

Before starting the treatment, a new diagnostic radiograph was taken (Fig. 1). It showed a fractured instrument in the curvature of the root. The tooth was isolated with a rubber dam and the coronal filling was removed. Straight-line access was established, as this is imperative to be able to reach and see the fractured instrument. In this case, the fractured instrument could not be visualised (Fig. 2). The decision was made to try to bypass the instrument rather than try to retrieve it. The key factors for this decision were the impossibility of visualising the instrument, the location of the instrument, the

First appointment
D-Finder 08
D-Finder 10
K-file 08
K-file 10
PathFile 13
PathFile 16
PathFile 19
Flexile file 20
ProTaper S1 hand file
ProTaper S2 hand file

Table I

Table I_Shaping sequence of the first appointment.

limited thickness of the root and the canal's oval shape. Bypassing was started by introducing a size 08 D-Finder (Mani Inc.) to the instrument. The D-Finder was used for probing and searching for a way to bypass the instrument. After a few tries, I was able to get the D-Finder past the instrument (Fig. 3). Working length was established using the Root ZX mini (J. Morita) and confirmed radiographically (Fig. 4). The complete shaping sequence of the first appointment is shown in Table I.

During the shaping of the canal, copious irrigation with 5 % sodium hypochlorite was performed. Patency was kept with a size 08 K-file (Mani Inc.) between every instrument. After the canal had been shaped using a size 20 Flexile file (Mani Inc.) and a ProTaper S2 hand file (DENTSPLY Maillefer), calcium hydroxide (Ultracal XS, Ultradent Products Inc.) was placed in the canal and the cavity was sealed with a cotton pellet and a temporary restoration in Fuji IX Fast A1 (GC).

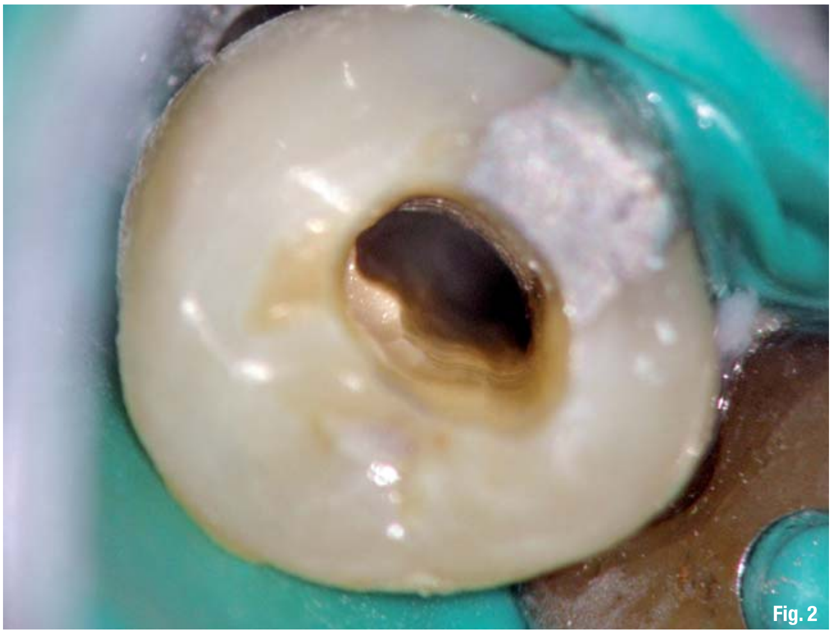

Fig. 2

Fig. 2_The instrument was not visible through the microscope.

Second appointment
Flexile file 20
ProTaper F1 hand file
Flexile file 25
ProFile 25.04
ProFile 30.04
ProTaper F1 hand file
Flexile file 30

Table II

Table II_Shaping sequence of the second appointment.

Two weeks later, the patient returned for his second appointment. The tooth was again isolated and this time, the old amalgam filling was removed. The carious dentine was then removed with LN burs (DENTSPLY Maillefer) and an Automatrix (DENTSPLY Caulk) was placed around the tooth. This should have been carried out at the first appointment; however, it was too tempting to try to bypass the fractured instrument first. Next, the calcium-hydroxide paste was removed using 10 % citric acid and passive ultrasonic irrigation with an Irrisafe tip (Satelec). Further shaping of the canal was performed and copious cleaning was carried out using 5 % sodium hypochlorite. The complete shaping sequence of the second appointment is shown in Table II.

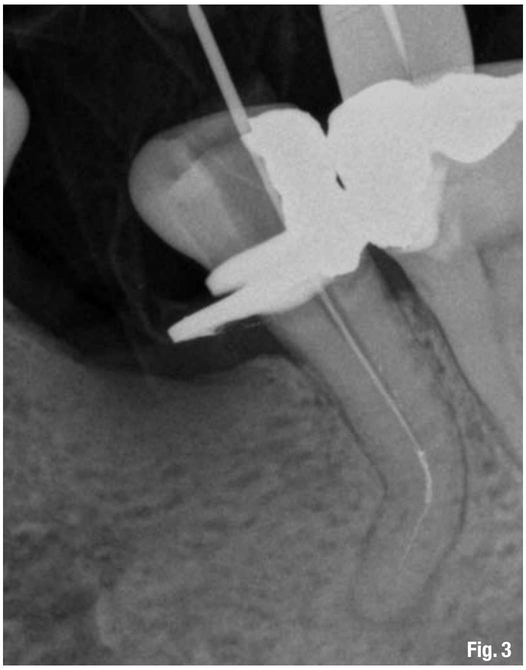

Fig. 3

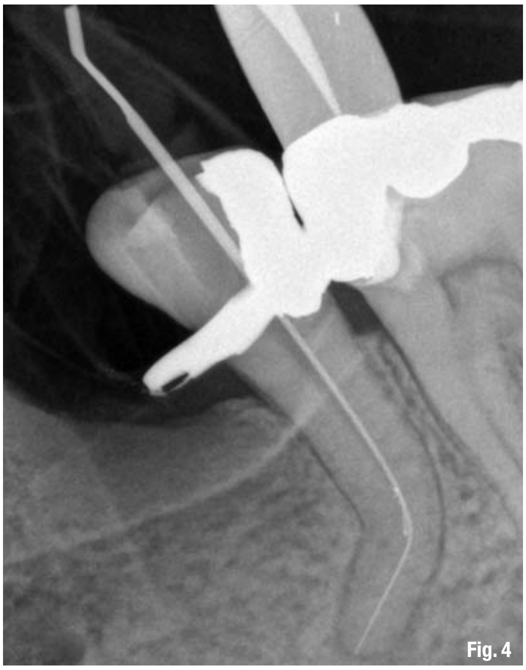

Fig. 4

Fig. 3_Bypassing of the instrument with a size 08 D-Finder.
Fig. 4_Working length determination.

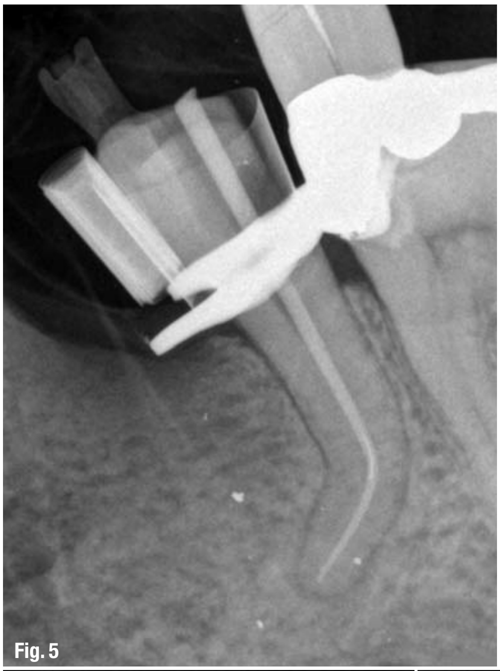
Fig. 5


Fig. 6


Fig. 7


Fig. 8

Fig. 5_Gutta-percha cone-fitting.
Fig. 6_The pulp chamber after obturation with gutta-percha.
Fig. 7_Final radiograph (parallel).
Fig. 8_Final radiograph (angled).

The canal was shaped to an apical size of 30. Smear layer removal was performed with a rinse of 10 % citric acid. A final wash of the canal was carried out with sterile saline. The canal was then dried with paper points (Roeko). A 04 tapered gutta-percha cone was fitted into the canal.

Topseal (DENTSPLY Maillefer) was used as a root-canal sealer. After radiographical confirmation (Fig. 5), additional gutta-percha cones, ISO size 20, were placed into the canal, according to the cold lateral condensation technique. Next, the gutta-percha was removed to about 5 mm from the apex with the System B Elements Obturation Unit (SybronEndo). Owing to the curvature, it was not possible to go any deeper. Hence, I decided to create a hybrid technique with cold lateral condensation. Finally, the backfill was done with the Elements Obturation Unit. After obturation (Fig. 6), a temporary restoration in glass-ionomer cement (Fuji IX FAST A1, GC) was placed. Final radiographs were taken, both parallel and angled (Figs. 7 & 8). The prognosis of this case was excellent and the patient was referred to his general dentist for a definitive coronal restoration.

_Conclusion

Sometimes removal of a fractured instrument is impossible or undesirable. In these cases, bypassing the instrument is a valid alternative, which can lead to a favourable outcome as presented in this case._

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

_about the author roots

Dr Rafaël Michiels graduated from the Department of Dentistry at Ghent University, Belgium, in 2006. In 2009, he completed the three-year postgraduate programme in Endodontics at the University of Ghent. He works in two private practices limited to Endodontics in Belgium. He can be contacted at rafael.michiels@gmail.com and via his website www.ontzenuwen.be.

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The WaveOne single-file reciprocating system

Authors_ Dr Julian Webber, UK; Drs Pierre Machtou & Wilhelm Pertot, France; Drs Sergio Kuttler, Clifford Ruddle & John West, USA

Fig. 1_WaveOne Small (yellow), Primary (red) and Large (black) files.

_The new WaveOne NiTi file system from DENTSPLY Maillefer is a SINGLE-use, SINGLE-file system to shape the root canal completely from start to finish. Shaping the root canal to a continuously tapering funnel shape not only fulfils the biological requirements for adequate irrigation to rid the root-canal system of all bacteria, bacterial by-products and pulp tissue,[1] but also provides the perfect shape for 3-D obturation with gutta-percha.[2,3]

In most cases, the technique only requires one hand file followed by one single WaveOne file to shape the canal completely. The specially designed NiTi files work in a similar but reverse "balanced force" action[4] using a pre-programmed motor to move the files in a back and forth "reciprocal motion". The files are manufactured using M-Wire technology, improving strength and resistance to cyclic fatigue by up to nearly four times in comparison with other brands of rotary NiTi files.[5]

There are many dentists who, for whatever reason, are reluctant to use NiTi rotary instruments to prepare canals, despite the recognised advantages of flexibility, less debris extrusion and maintaining canal shape, amongst other advantages.[6–8] For them, the use of a single reciprocating file will be very attractive both in terms of time and cost saving.

At present, there are three files in the WaveOne single-file reciprocating system available in lengths of 21, 25 and 31 mm (Fig. 1):

1. The WaveOne Small file is used in fine canals. The tip size is ISO 21 with a continuous taper of 6 %.
2. The WaveOne Primary file is used in the majority of canals. The tip size is ISO 25 with an apical taper of 8 % that reduces towards the coronal end.
3. The WaveOne Large file is used in large canals. The tip size is ISO 40 with an apical taper of 8 % that reduces towards the coronal end.

The instruments are designed to work with a reverse cutting action. All instruments have a modified convex triangular cross-section at the tip end

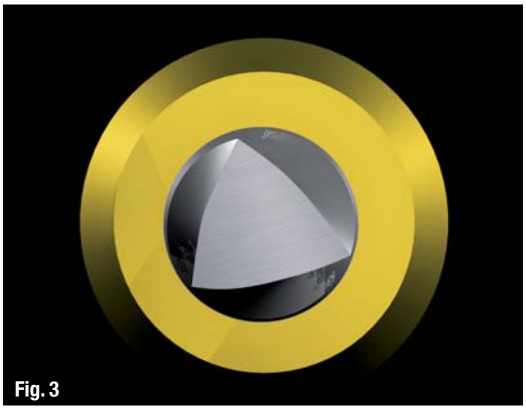


Fig. 2_WaveOne apical cross-section, modified convex triangular.
Fig. 3_WaveOne coronal cross-section, convex triangular.

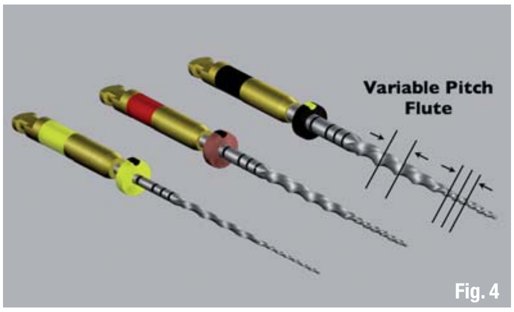


Fig. 4

(Fig. 2) and a convex triangular cross-section at the coronal end (Fig. 3). This design improves instrument flexibility overall. The tips are modified to follow canal curvature accurately. The variable pitch flutes along the length of the instrument considerably improve safety (Fig. 4).

Because there is a possibility of cross-contamination associated with the inability to completely clean and sterilise endodontic instruments[9] and the possible presence of prion in human dental pulp tissue,[10] all instruments used inside root canals should be single use.[11] WaveOne instruments are a new concept in this important standard of care, as they are truly single use. The plastic colour coding in the handle becomes deformed once sterilised, preventing the file from being placed back into the handpiece.

The recommendation for single use has the added advantage of reducing instrument fatigue, which is an even more important consideration with WaveOne files, as one file does the work traditionally performed by three or more rotary NiTi files.

The WaveOne motor (Fig. 5) is rechargeable battery operated with a 6:1 reducing handpiece. The pre-programmed motor is set for the angles of reciprocation and speed for WaveOne instruments. The counter-clockwise (CCW) movement is greater than the clockwise (CW) movement. CCW movement advances the instrument, engaging and cutting the dentine. CW movement disengages the instrument from the dentine before it can (taper) lock into the canal. Three reciprocating cycles complete one complete reverse rotation and the instrument gradually advances into the canal with little apical pressure required.

All brands of NiTi files can be used with the WaveOne motor, as it has additional functions for continuous rotation. However, as WaveOne files have their own unique reverse design, they can ONLY be used with the WaveOne motor with its reverse reciprocating function.

The WaveOne technique involves the following stages:

1. straightline access, accepted protocol;
2. WaveOne file selection;
3. single-file shaping;
4. copious irrigation with 5% NaOCl and EDTA before, during and after single-file shaping.

Fig. 5

_WaveOne file selection and clinical procedure (Figs. 6–8)

Whilst a good preoperative periapical radiograph will give an indication of what to expect before the canal is prepared (size and length of the canal, number of canals, degree and severity of curvature),

Fig. 4_WaveOne variable pitch flute increases safety.

Fig. 5_WaveOne motor and 6:1 reducing handpiece.

Figs. 6–8_WaveOne Small, Primary and Large files with their respective file selection and clinical procedural flow chart.

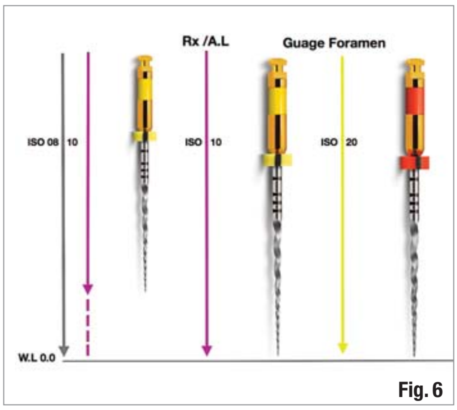


Fig. 6

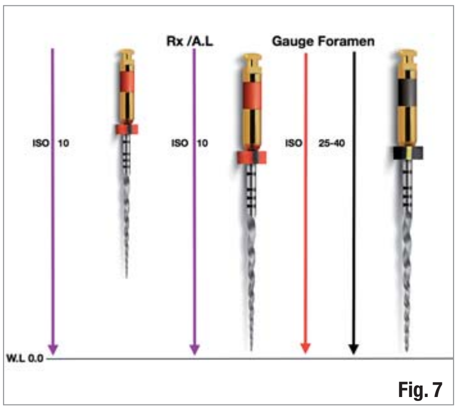


Fig. 7

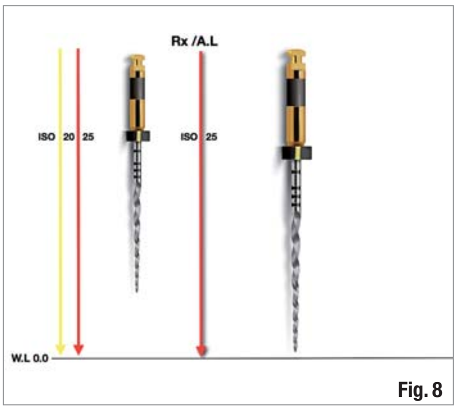


Fig. 8

Fig. 9

Fig. 13

Fig. 9_EndoActivator irrigation device.

Fig. 13_Calamus Dual 3-D Obturation System.

only the first hand file into the canal will aid in the selection of the WaveOne file as follows:

1. If a 10 K-file is very resistant to movement, use WaveOne Small file.
2. If a 10 K-file moves to length easily, is loose or very loose, use WaveOne Primary file.
3. If a 20 hand file or larger goes to length, use WaveOne Large file.

Single-file shaping

1. take hand file into canal and watch-wind to length or resistance (approximately two-thirds of canal length);
2. use appropriate WaveOne file to approximately two-thirds of canal length;
3. irrigate copiously;
4. take hand file to length and confirm with an apex locator and radiograph;
5. take WaveOne file to length;
6. confirm foramen diameter with hand file the same size as WaveOne file; if snug, preparation is complete;
7. if foramen diameter is larger than WaveOne file, consider the next larger WaveOne file;
8. majority of cases will be completed with WaveOne Primary file.

Fig. 10_WaveOne matching paper points.
Fig. 11_WaveOne matching gutta-percha points.
Fig. 12_WaveOne matching Thermafil obturators.

Fig. 10

Fig. 11

Fig. 12

Guidelines for use

1. use WaveOne files with a progressive up and down movement no more than three to four times, only little force is required;
2. remove file regularly, wipe clean, irrigate and continue;
3. if file does not progress, confirm patent canal and consider using a smaller WaveOne file;
4. whilst glide path management is minimal with WaveOne shaping files, some practitioners will be more comfortable if the glide path is first secured with PathFiles (DENTSPLY Maillefer);
5. in severely curved canals, complete apical preparation by hand if reproducible glide path is not possible;
6. WaveOne files can be used to relocate the canal orifice and expand coronal shape; even in a reciprocating motion use them with a "brushing" action short of length to achieve this;
7. never work in a dry canal and constantly irrigate with NaOCl and later EDTA;
8. as preparation time is short, activate the irrigating solutions to enhance their effect; the EndoActivator (DENTSPLY Maillefer) is ideal for this (Fig. 9).[12]

WaveOne obturating solutions

Obturation of the root-canal system is the final step of the endodontic procedure. The WaveOne system includes matching paper points, gutta-percha points and Thermafil WaveOne obturators (Figs. 10–12). The matching gutta-percha points can be used in conjunction with the Calamus Dual 3-D Obturation System (DENTSPLY Maillefer; Fig. 13) as demonstrated in the following cases.

Figs. 14a–c_Pre-op radiograph of #36 showing narrow and curved canals (a). Post-op radiographs: Canals were shaped with a WaveOne Primary file and filled with gutta-percha with WVC (b & c).

Figs. 15a–c_Pre-op radiograph of #16 showing severely curved MB and DB canals (a). Post-op radiographs: Canals were shaped with a WaveOne Primary file and filled with gutta-percha with WVC (b & c).

_Case studies

Case I (Figs. 14a–c)

Tooth #36 presented with symptoms of irreversible pulpitis and early apical periodontitis. Initial radiographic assessment showed four narrow and curved canals. Access was made and all canals were worked to length with a 10 K-file. A WaveOne Primary file (25.08) was selected and length was reconfirmed with a 10 K-file. The WaveOne Primary file was worked to length in all four canals. Obturation was done with warm vertical condensation (WVC) using Calamus Dual.

Case II (Figs. 15a–c)

Tooth #16 had symptoms of acute pulpitis with a temporary filling, covering exposure distally, as well as severe curvature of the mesiobuccal (MB) canals and apically in the distal canal. K-files 8 and 10 were taken to length in all the canals. A WaveOne Primary file (25.08) was selected. Length was confirmed with a 10 K-file. The WaveOne Primary file was taken to length in all the canals. Obturation was done with WVC using Calamus Dual.

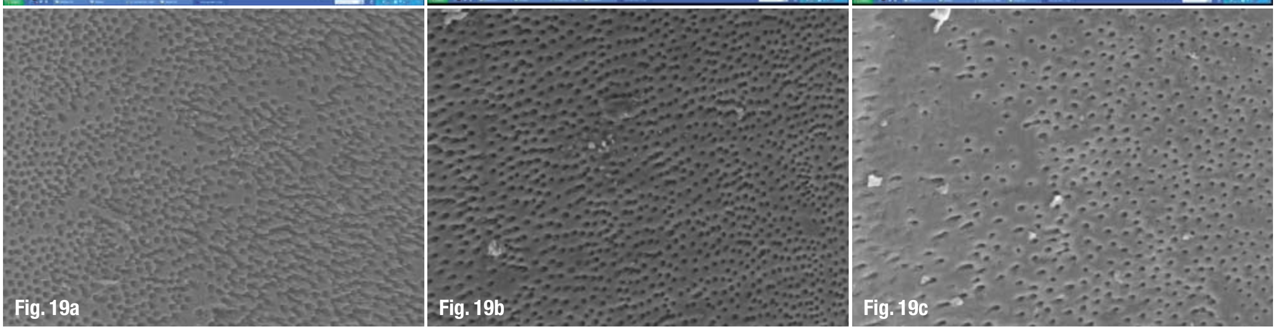
Case III (Figs. 16a–c)

Tooth #17 presented with radiographic evidence of apical periodontitis and was non-vital. The canals were hardly visible on the preoperative X-ray. Primary consideration would have been a WaveOne Small file (21.06). In all canals, the 8 K-file moved to length easily. The 10 K-file also moved to length but was tight.

A WaveOne Primary file (25.08) was selected and taken to approximately three-quarters of the length. Recapitulation was achieved with a 10 K-file to length. The WaveOne Primary was taken to length in all the canals and the canals were then obturated with WVC.

Figs. 16a–c_Pre-op radiograph of #17 with canals hardly visible (a). Post-op radiographs: Canals were shaped with a WaveOne Primary file and filled with gutta-percha with WVC (b & c).

Figs. 17a–c_Pre-op radiograph of #17 with canals barely visible and #15 with a quite large canal (a). Post-op radiographs: #17 canals were shaped with a WaveOne Primary file. #15 canal was shaped with a WaveOne Large file. All canals were filled with gutta-percha with WVC (b & c).



Figs. 18a–c_Micro-focus CT scan at coronal level (a), mid-root level (b) and apical level (c) of the mesial canals of the lower first molar demonstrates the excellent centring and shaping ability of the WaveOne Primary file.

Figs. 19a–c_A SEM representative sample at coronal level (a), mid-root level (b) and apical level (c) of the canal wall, showing excellent cleanliness and open dentinal tubules after shaping with a WaveOne Primary file and assisted irrigation with the EndoActivator.

Case IV (Figs. 17a–c)

Tooth #16 presented with radiographic evidence of asymptomatic apical periodontitis. The canals were hardly visible on the preoperative X-ray. The MB canal was severely curved, and the distobuccal (DB) and palatal canals were not visible. A 10 K-file moved to length easily in the MB and DB canals. In the palatal canal, 10 and 15 K-files moved to length easily. A WaveOne Primary file (25.08) was selected for all canals. Lengths were confirmed and the canals were shaped to length with WaveOne files.

In tooth #15, a large, single canal was clearly visible. 20 and 25 K-files went to length and a WaveOne Large file (40.08) was selected. Canal length was confirmed and the WaveOne Large file was used to shape the canal.

_Advantages of the WaveOne file reciprocating system

1. only one NiTi instrument per root canal and in most cases per tooth;
2. lower cost;
3. less instrument separation owing to the unique reciprocating movement that will prevent and/or delay the instrument advancing from plastic deformation to its plastic limit;
4. decreases global shaping time, allowing the clinician to spend more time cleaning the root-canal system with enhanced irrigation techniques;
5. eliminates procedural errors by using a single instrument rather than using multiple files;
6. a new standard of care, eliminating the possibility of prion contamination owing to single use;
7. easy to learn;
8. easy to teach.

_WaveOne research

The Nova Southeastern University College of Dental Medicine in the USA is conducting research into WaveOne. The following areas of research, amongst others, are being investigated using micro-focus CT scanning technology, which provides remarkable insight into:

1. canal-centring ability of WaveOne[13] (Figs. 18a–c);
2. remaining canal wall thickness after instrumentation with WaveOne;[14]
3. final shape versus initial shape of the canal with WaveOne;[15]
4. canal wall cleanliness with WaveOne[16] (Figs. 19a–c).

Other areas of research are flexibility,[17] fatigue[18] and debris extrusion.[19] To date, the results of these studies suggest that WaveOne single reciprocating files are comparable in performance to all the major leading brands of NiTi files that operate in continuous rotation.

_Conclusion

The WaveOne system is an exciting new concept in the preparation of the root canal. Whilst current teaching advocates the use of multiple NiTi files of different diameter and taper to gradually enlarge the root canal, only one WaveOne single shaping file is required to prepare the canal to an adequate size and taper, even in narrow and curved canals.

However, along with this, there must be a caveat. WaveOne files only shape the canal, extremely quickly in many instances, but they do not clean the root canal. It is the duty of teachers, clinicians and manufacturers to emphasise the role and importance of irrigation as a major determinant of endodontic success. Once it is fully appreciated that shaping and cleaning the root-canal system are irrevocably intertwined, then endodontics will be easier for all and available to all, and WaveOne will truly become the root-canal preparation instrument of the future.

Drs Julian Webber, Pierre Machtou, Wilhem Pertot, Sergio Kuttler, Clifford Ruddle and John West where involved in the development, field testing and research associated with WaveOne._

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_about the lead author

roots

Dr Julian Webber has been a practising endodontist in London, England, for over 30 years. He was the first UK dentist to receive a Master's degree in Endodontics from a university in the USA (Northwestern University Dental School, Chicago) in 1978. He has lectured extensively and given many hands-on courses on endodontics worldwide. He has written in numerous peer-reviewed journals and contributed numerous chapters in endodontic texts. Dr Webber is a former President of the British Endodontic Society, a faculty member of the Pacific Endodontic Research Foundation in San Diego, Honorary Professor at the University of Belgrade, Serbia, and an Honorary Member of the Ukrainian Medical and Stomatological Academy. He is a fellow of the International College of Dentists and an active member of the American Association of Endodontists. He is the editor of *Endodontic Practice* (UK) and a board member of many prestigious dental journals.

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R-phase advantages in shaping curves

Author_ Dr Philippe Sleiman, Lebanon

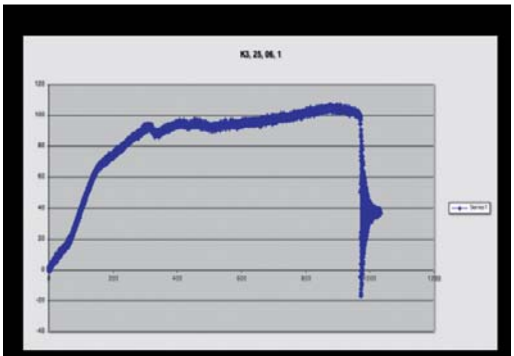


Fig. 1

Fig. 1_Graph showing the stress test result of a K3 file conducted with a torque metre. It shows the austenite phase, yield point and the martensite plateau before file separation.

_Every dentist and endodontist dreams that all root canals could be straight and large. Unfortunately, in reality they are often everything but. On a daily basis, we are faced with new challenges in curved and narrow root canals. While NiTi rotary files have changed our world significantly, our first experiences were not so encouraging.

We were faced with file separation owing to anatomical considerations of the root-canal system and our poor knowledge of the files, the alloy and the way to use the files properly.

Much research has been conducted in order to better understand the properties of the alloy and the files. Researchers have used a torque metre to study the files (Fig. 1). However, we realised that different data was required with regard to stressed or used files. Further research demonstrated that the yield, which is the point beyond the austenite phase, is stable regardless of the dimension and the size of the file (Figs. 2 & 3). The major difference is in the torque value and the behaviour of the martensite phase. Deformation in the martensite phase is irreversible and leads to file separation. Some file deformation can be seen clinically and it is a safety property of files that they have a longer deformation period under stress in the martensite phase.

There are two types of clinical stresses on a file in curved canals: bending and torsional stress (Figs. 4 & 5). Bending stress occurs when the file passes inside a curve and is subjected to stresses at an equal level: stretching on the outer part of the curve and compression of the alloy structure from the internal part of the curve. This kind of stress cannot break a file, but it can lower its torsional stress by at least 30% from the first few seconds that the file is active inside the curve.

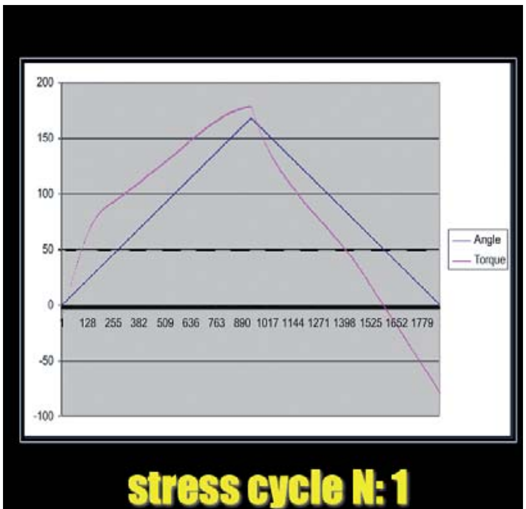


Fig. 2

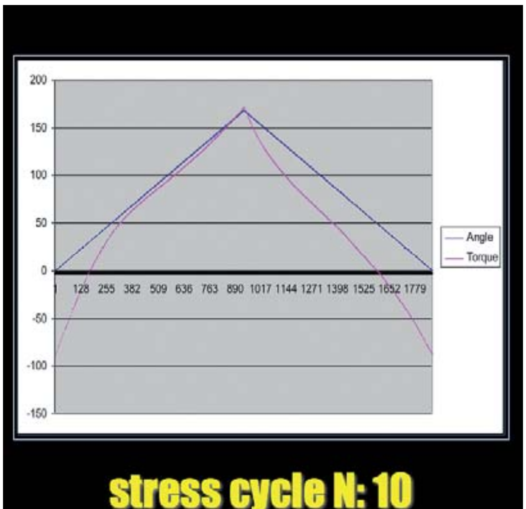
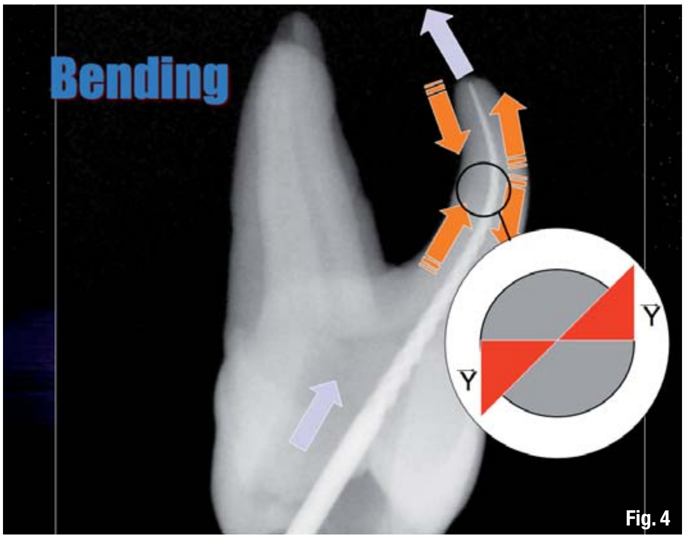
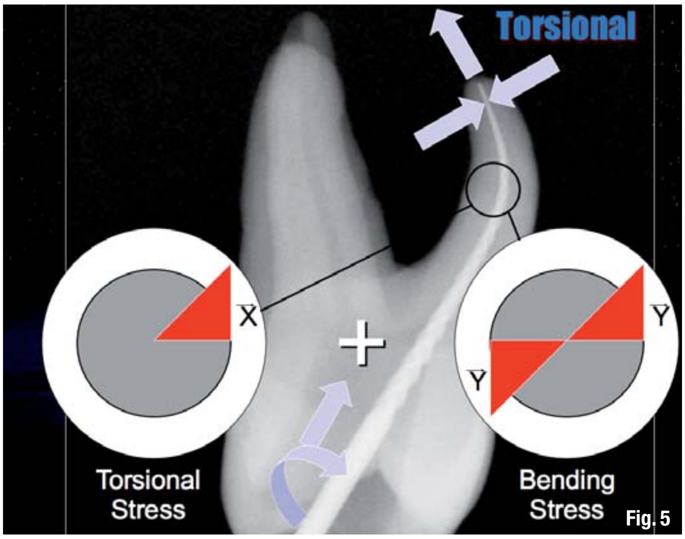


Fig. 3

Figs. 2 & 3_Graphs showing the difference between stress cycle #1 (Fig. 2) and 10 (Fig. 3). The yield is fairly stable and the austenite phase decreased in torque value.





Torsional stress is more dangerous. It occurs when the tip or any other section of the file is locked inside the canal while the rest of the file is still rotating. This can lead to instant file separation. Torsional stress can occur anywhere inside the canal and can be even more dangerous when it is combined with bending stresses inside the curvature of the canal (Fig. 5). This can be the perfect trap for rotary files.

Combining the two essential features of a file—security and flexibility—was not possible with the NiTi alloy available. Therefore, some manufacturers focused on the flexibility of the files while compromising security, and others focused on security while compromising flexibility. Intensive research was conducted into changing the crystalline structure and obtaining a dual-phase structure as its main characteristic. The dual phase is a mix of austenite and the R-Phase. The R-phase has the advantage of being able to cope with increased pressure while increasing the torque value (Fig. 6). It appears after the austenite phase and still increases in torque until the ultimate deformation point. There is then a short martensite phase prior to separation. During the R-phase, there are actually two kinds of R-phases: R1 and R2. According to thermal cycling tests under various constant stresses, the transformation strain of R2 is greater than that of R1. With constant stress increasingly applied, the latter strain increases and the former decreases. However, the total strain of both R1 and R2 is almost constant irrespective of the amount of stress. R1 will start immediately after austenite, and then R2 will take over in the middle of the transition area until the ultimate deformation point, where martensite will be formed. With the R-phase, shaping curves will be much easier and safer as the files produced with the modified NiTi alloy are much more flexible than any other file with the same dimensions. This allows the file to cope with the pressure of shaping the curves safely.

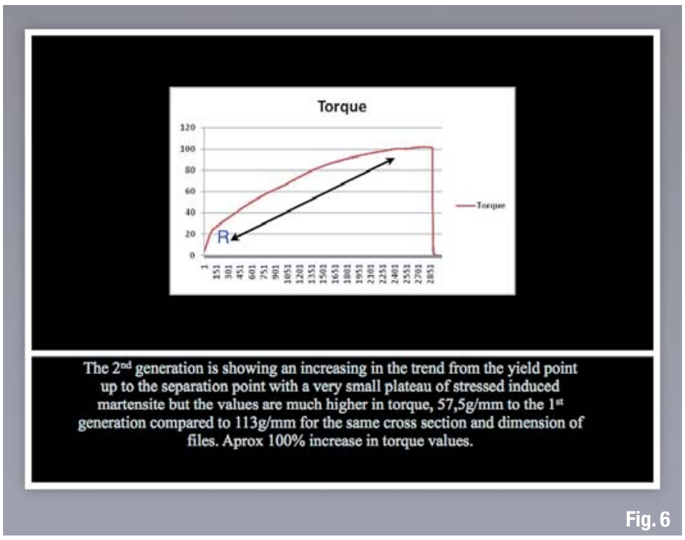
As for the clinical applications, we must ensure that we do not place a very large file in a curve, such as a 0.10 or 0.08 taper, but pay attention to the severity of the curves, for two reasons:

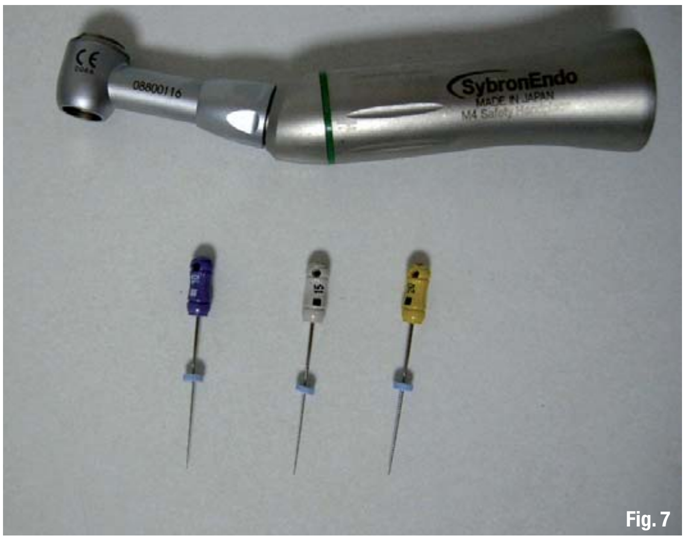
Fig. 4_Illustration of the bending stress to which a file is subjected inside the curve.

Fig. 5_Illustration of the torsional stress and the load of stress that a file will take at the tip of the root canal or inside the curve, which will lead to file separation.

Fig. 6_Graph showing the stress test result of a TF file using a torque metre.

Fig. 7_M4 handpiece.





Figs. 8–11_Clinical cases.

1. in order to avoid a taper lock, which can lead to file separation or damage in severely curved canals; and
2. in order to avoid a strip perforation caused by aggression of the files.

We must carefully analyse the preoperative X-ray to determine the location of the curve. This can be achieved by inserting a size 10 K-file, which will take the impression of the canal. It gives us a good idea of the curve or curves, as well as the shape of the canal, thereby helping us determine a strategy regarding the depth to which we can go with our large files and then switch to a lesser taper. This is a simple clinical tip that is helpful in avoiding serious complications in shaping curved canals.

The sequence I personally follow with Twisted Files (TF; SybronEndo) is as follows. After checking root-canal patency and taking the impression of the canal with a size 10 K-file, I use my M4 handpiece with a size 20 SS file for 15 seconds in each canal (Fig. 7). It does not have to go to length. I only take it as deep as it will go with a simple push and pull movement and use sizes 15 and 10 SS files, if required, after the size 20 in a crown-down method. After achieving patency, I use the rotary files in order to clean and shape the root-canal system. I start with a size 25 with taper 0.08, taking it to the beginning of the curve. I limit its insertion to this point. I then usually switch to a size 25 TF with taper 0.06, depending on the severity of the curve. If the curve is normal to medium, a size 25 TF with taper 0.06 should be able to enlarge it safely. If the curve is severe, which will show on the size 10 K-files and from the resistance of the previous file, I use a size 25 TF with taper 0.04 to full working length. The apical enlargement will follow the crown-down, which has opened a safe way to the apical area, or the last 3 mm for enlargement. I use a size 40 TF with taper 0.04 whenever I am able to for optimal cleaning of the apical area, as well as for reducing the colony formation unit and preparing the dentine for obturation using RealSeal (SybronEndo) according to proper irrigation protocol.

Achieving step-by-step root-canal preparation is the gold standard of care that we can offer to our patients without any negative surprises along the way. Respecting a few simple rules and not letting ourselves be carried away by our temptation to work more quickly can lead to excellent clinical results.

I would like to thank Yulia Vorobyeva, interpreter and translator, for her help with this article._

_contact roots

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"Our goal is to offer solutions and products with a definite benefit for the practitioner"

An interview with Dr Martin Rickert, Executive Chairman Sanavis Group

Dr Martin Rickert, Executive Chairman Sanavis Group

_The dental supplier SycoTec, headquartered in Leutkirch in Germany, acquired MICRO-MEGA, a French company with a long-standing tradition of excellence, in autumn of 2009. In February 2010, the Canadian company SciCan joined the duo. The merger of SycoTec, MICRO-MEGA and SciCan formed the Sanavis Group, which is now one of the ten largest suppliers of dental equipment worldwide. Executive Chairman Dr Martin Rickert spoke with roots about these new developments.

_roots: *Dr Martin Rickert, what does the name Sanavis mean and what new tasks has the merger brought to the group?*

Dr Martin Rickert: The word *sanavis* is borrowed from Latin and, simply translated, means "health and strength". The name is meant to illustrate that the group consists of companies whose main business segment is dental products designed to enable dentists and, consequently, patients to attain and maintain good oral health. Contemporary and innovative products are the foundation of our company strategy. Our main task is gradual orientation towards a joint fundamental strategy and the development of joint processes so that our customers can directly benefit from the advantages of this merger.

_Which advantages do you see resulting from this merger?

First of all, we are able to offer our customers an improved service. With a much greater regional presence, our customers now receive a far more regional and consequently more individualised service.

Furthermore, we are now able to coordinate sales of the individual companies much more effectively, thus making them more attractive to our customers. This will also affect the product development process and, in turn, lead to products that enable improved courses of treatment. Internally, we will be able to benefit from clear advantages in production, purchasing, logistics, administration and reporting.

_What are the individual companies going to focus on and which role will they play within the Sanavis Group?

Ergonomics and safety are the key features of all our future products. In this context, ergonomics means enabling the person providing the treatment to work as simply, efficiently and carefully as possible. Safety refers to minimising the potential for error during the course of the treatment and to the wide field of infection control.

MICRO-MEGA is our endodontic specialist, offering everything from root-canal instruments to filling materials. SciCan is our infection-control specialist, covering general practice hygiene, instrument sterilisation and infection control during treatment. Both companies have similar needs with regard to *dental drive technology*. Simply put, this term refers to technologies and products that make devices rotate or move, such as micro-motors, handpieces and turbines. SycoTec, an expert original equipment manufacturer, is our specialist in this.

_Let's look at the individual companies. MICRO-MEGA, the French manufacturer of high precision tools for root-canal treatments, has been setting world standards on the international dental market for over 100 years. Which product is considered to be state of the art at the moment?

With the Revo-S system for root-canal preparation, MICRO-MEGA undisputedly has the right to claim a pioneering role once again. Revo-S is a NiTi instrument system that offers unparalleled ease of handling for the practitioner with maximum protection against file breakage. The root canal can be prepared in a clever sequence with only three files. Easy-to-use upgrades are also available for complicated canal shapes. This system is a good example of the advantage of MICRO-MEGA's many years of experience in endodontics.

_... and SciCan complements the range of products with its full spectrum of infection-control solutions.

And the timing is excellent considering that the legal regulations with regard to infection control are increasingly becoming more stringent!

Infection control is becoming increasingly important, not only as a result of the regulatory requirements. SciCan offers complete solutions from A to Z. Dentists can rely on over 50 years of experience, which has led to products that offer maximum efficiency, consistency and safety. The rapid steriliser Statim is a great example. While it is easy to handle, economic and functional, its short cycle time is unrivalled. Furthermore, the new thermal disinfector Hydrim impresses with its simple installation and economic operation. Naturally, all products adhere to all regulatory requirements.

_Owing to the financial and economic crisis, many companies have struggled to maintain their position in the international markets. Do you feel well positioned as a result of the merger?

In the difficult macroeconomic environment we have been experiencing in recent years, it is an advantage to be part of a strong group. We therefore feel very well equipped for the future, not only in terms of purely economic aspects, but also generally with regard to our future business. Our goal is to offer solutions and products with a definite benefit for the practitioner. Being a strong group makes this easier and provides greater future security.

_MICRO-MEGA and SciCan are internationally recognised brands that are constantly investing in research and development. The Sanavis Group is now a global player. How do you intend to take advantage of this?

Even though we have reached the size of a global player, we will continue to structure our business locally. However, we will now make use of our expanded network in the respective local branches. This applies to our research partners, as well as to sales and service. Moreover, we can now also tackle new developments that would have been too large for the individual companies. The main advantage surely is that we are now able to access the expertise of the partner companies for new developments. In the future, products will become increasingly digitalised and integrated, making the integration of different product areas indispensable. A great deal can be expected of us in this respect.

_How will customer service be organised?

Customer service will be organised at local level, as has been the case up to now. Naturally, we will continue our existing, reliable partnerships. Furthermore, our customers can look forward to an extension of the services offered, as we are improving our presence for our entire product range, particularly in the German market.

“Moreover, we can now also tackle new developments that would have been too large for the individual companies.”

_Will the Sanavis Group appear under one umbrella at trade fairs and exhibitions in future?

Yes, this will be the case at the larger trade fairs, such as the IDS. However, a joint umbrella does not mean that the name *Sanavis* will be at the fore. MICRO-MEGA and SciCan will continue to form the backbone of the trade fair presence. However, the brands will exhibit at a joint booth.

_Which products will be in focus during the IDS and what new innovations can we expect?

We have already strengthened our development efforts and look forward to being able to present a large number of new products. These new developments include a new, rapid steriliser and advanced thermal disinfectors. We will also present new root-canal fillers. In the field of drive systems, visitors will be able to see a whole range of innovations, such as new micro-motors, handpieces and contra-angle handpieces, as well as motors with an innovative ergonomic design. I believe that never before have we been able to present such an explosion of innovations!_

Filling root-canal systems— The Calamus 3D Obturation Technique

Author_ Dr Clifford J. Ruddle, USA

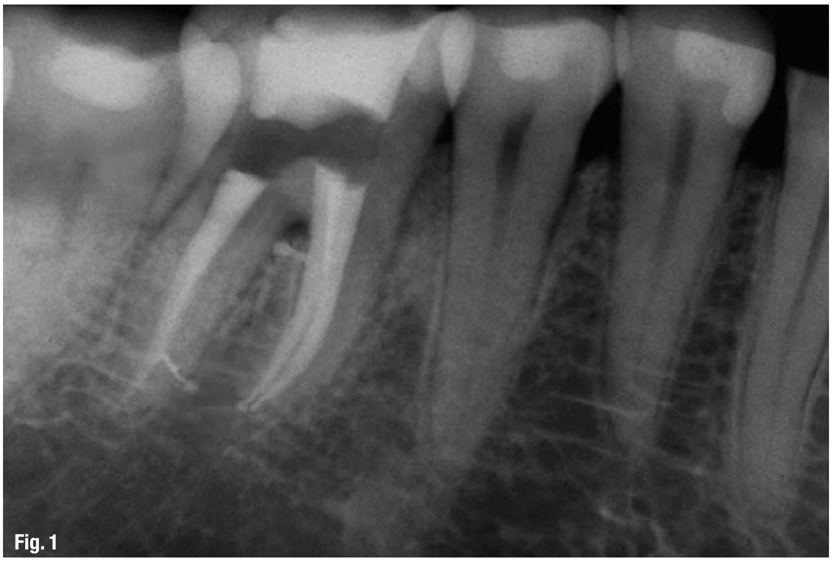


Fig. 1

Fig. 1_A post-op film of a mandibular first molar demonstrates the importance of shaping canals and cleaning and filling root-canal systems.

_**Virtually all dentists** are intrigued by endodontic post-treatment radiographs exhibiting filled accessory canals. Filling root-canal systems represents the culmination and successful fulfilment of a series of procedural steps that comprise start-to-finish endodontics (Fig. 1). Although the excitement associated with the so-called *thrill-of-the-fill* is understandable, scientific evidence should support this enthusiasm. Moving heat-softened obturation materials into all aspects of the anatomy is dependent on eliminating pulpal tissue, the smear layer and related debris, and bacteria and their by-products, when present. In order to maximise obturation potential, clinicians would be wise to direct treatment efforts toward *shaping* canals and *cleaning* root-canal systems.[1]

Shaping facilitates 3-D cleaning by removing restrictive dentine, allowing a more effective volume of irrigant to penetrate, circulate and potentially clean into all aspects of the root-canal system (Fig. 2). Well-shaped canals result in a tapered preparation that serves to control and limit the movement of warm gutta-percha during obturation procedures. Importantly, shaping also facilitates 3-D obturation by allowing pre-fit pluggers to work deeply and unrestricted by dentinal walls and move thermo-softened obturation materials into all aspects of the root-canal system. Improvement in obturation potential is largely attributable to the extraordinary technological advancements in shaping canals and cleaning and filling root-canal systems.[2,3]

This article features the new Calamus Dual 3D Obturation System (DENTSPLY Maillefer; Fig. 3) that may be used to fill root-canal systems. Schilder described the classic *vertical condensation technique* more than forty years ago.[4] Over time, a few different, yet similar, warm gutta-percha techniques have evolved. The purpose of this article is to describe the Calamus Dual 3D Obturation System and the

Fig. 2

Fig. 3

Fig. 2_This animation supports the scientific evidence that shaped canals enhance the active exchange of irrigant into all aspects of the root-canal system.

Fig. 3_The Calamus Dual 3D Obturation System combines a Pack handpiece for down-packing with the Flow handpiece for back-packing.

manner in which to use this technology to perform the vertical condensation technique. The clinician is encouraged to read, visualise and learn more about the manner in which to perform each procedural step that directly serves to influence filling root-canal systems; this includes performing the other hybrid warm gutta-percha techniques using Calamus technology.[1,5]

_Vertical condensation technique

The objective of the vertical condensation technique is to carry a wave of warm gutta-percha along the length of the master cone continuously and progressively, starting coronally and ending in apical corkage (Fig. 4). The physical and thermo-molecular properties of gutta-percha are well understood and have been clearly described in a series of groundbreaking articles published decades ago.[6–10] The content of these scientific articles provides insight, understanding and reference for the clinical and technical description that follows. While I have previously described the vertical condensation technique,[11,12] this article represents the most recent advances in the manner in which to perform the warm gutta-percha with vertical condensation technique.

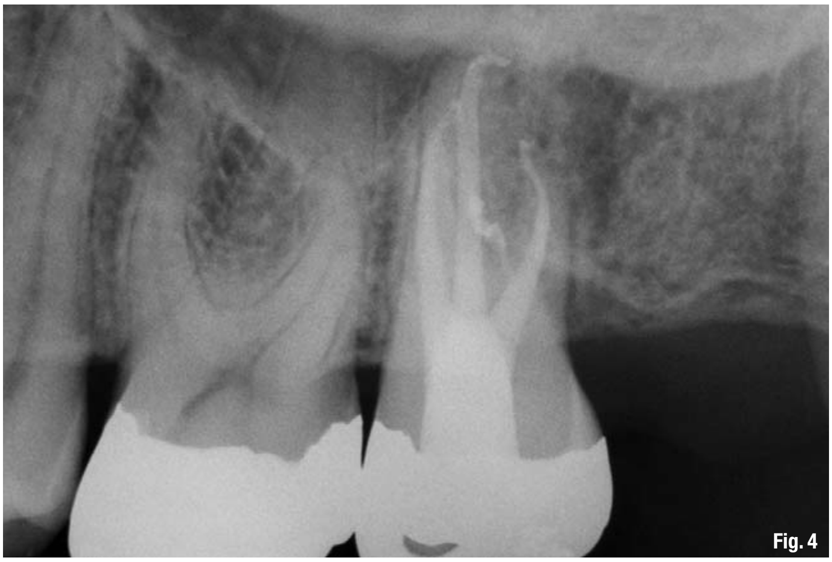


Fig. 4

Fig. 4_A post-op film of a maxillary second molar. Note the abrupt apical curvature of the palatal system, recurvature of the DB system and the filled furcal canal.

Cone fit and plugger selection

Traditionally, a medium-sized *non-standardised* gutta-percha master cone was selected and apically trimmed to fit snugly into the terminus of the prepared canal. The 6 % taper of these master cones, as compared to the 2 % taper of *standardised* gutta-percha, ensured more effective hydraulics during obturation. Today, the selection of the correct master cone has been simplified because of the rediscovery of system-based endodontics. System-based master cones streamline treatment in that they are intended to have an apical diameter the same as and a rate of taper slightly less than the largest manual or mechanically driven file that was carried to the full working length.

The master cone is fitted in a fluid-filled canal to simulate more closely the lubrication effect that sealer will provide when sliding the buttered master cone into the prepared canal. Further, the master cone should be able to be inserted to the full working length and exhibit *apical* tug-back upon removal. This master cone can be apically trimmed and further customised with glass slabs or a spatula, utilising either cold or heat rolling techniques. It is simple to fit a master cone into a patent, smoothly tapered and well-prepared canal.

A diagnostic working film should confirm the desired position of the master cone and verify all the previous operative steps. The master cone is typically cut back about 1.0 mm from the *radiographic terminus* so that its most apical end is just short of the *apical constriction* or the actual position of the *physiologic terminus* (PT; Figs. 5a & b). Specifically, the final length of any given prepared and finished canal is the reproducible distance from the reference point to the PT. Fortuitously, the position of the most apically instrumented foramen can be consistently located utilising the paper point drying technique.[12]

Four manual pluggers, utilised to compact heat-softened gutta-percha, provide working end diameters of 0.5 mm, 0.7 mm, 0.9 mm and 1.3 mm (DENTSPLY Maillefer). Generally, a *larger*-sized plugger

Fig. 5a

Fig. 5b

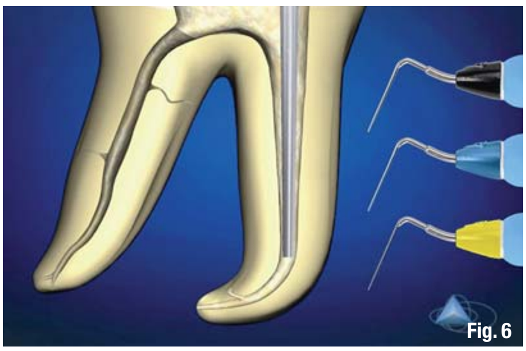
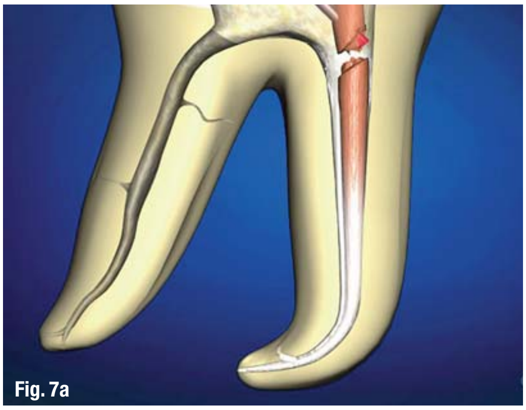


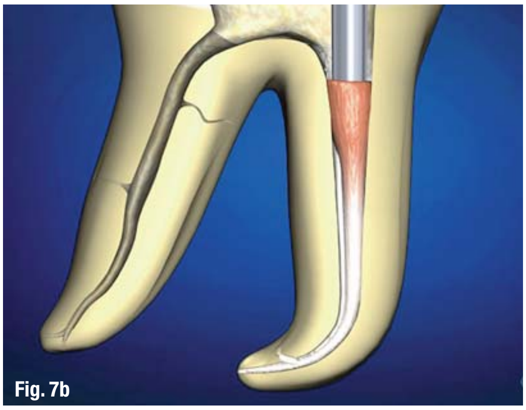
Fig. 6

Figs. 5a & b_These animations demonstrate the master cone fitted to length and the master cone apically cut-back based on the paper point drying technique.

Fig. 6_The EHP that will loosely fit through the straightaway portion of the canal and optimally to within 5 mm from the full working length is selected.

Fig. 7a_The Calamus Pack handpiece is activated, the non-useful portion of the master cone seared off and the transfer of heat through the gutta-percha noted.
Fig. 7b_A large-sized, pre-fit plugger generates the first WOC and automatically compacts warm gutta-percha vertically and laterally into the root-canal system.





is selected that will work loosely, yet efficiently, over a range of a few millimetres in the coronal one-third of the canal. A *medium*-sized plugger is selected that will work passively and effectively over a range of a few millimetres in the middle one-third of the canal. In longer roots, a *smaller*-sized plugger may be required to work more deeply and safely to within 5 mm of the canal terminus. Pre-fitting pluggers is essential and guarantees that when a plugger meets resistance, the plugger is on thermo-softened gutta-percha and not binding against unyielding dentinal walls.

Sealer and master cone placement

The radicular portion of the master cone is lightly buttered with sealer and gently swirled as it is slowly slid to length. Placing the master cone in this manner will serve to more evenly distribute sealer along the walls of the preparation, and importantly, allow surplus sealer to harmlessly vent coronally.

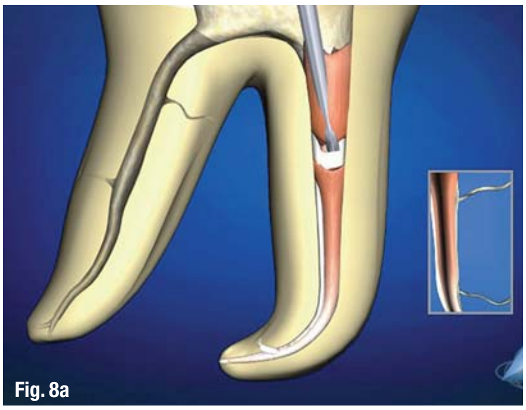
To be confident that there is sufficient sealer, the master cone is removed and its radicular surfaces inspected to ensure it is evenly coated with sealer. If the master cone is devoid of sealer, then this cone can simply be re-buttered and re-inserted to ensure there is sufficient sealer present. Once the master cone has been evenly coated with sealer and fully seated, obturation can commence.

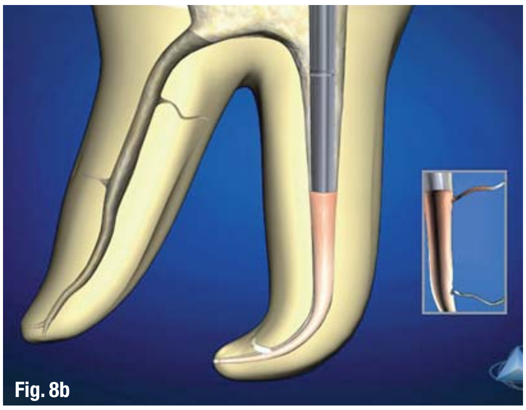
_Calamus Dual 3D Obturation System

The Calamus Dual 3D Obturation System is one unit that conveniently combines both Calamus Pack and Calamus Flow handpieces. The Calamus Pack handpiece is the heat source that, in conjunction with an appropriately sized electric heat plugger (EHP), is utilised to thermo-soften, remove and condense gutta-percha during the down-packing phase of obturation. There are three variably sized EHPs and the one selected is based on the apical size, taper and curvature of the finished preparation. The EHPs are available in ISO colours black, yellow and blue, corresponding to working end diameters and tapers of 40/03, 50/05 and 60/06, respectively (Fig. 6). The Calamus Pack handpiece also accepts a *thermal response tip* for conducting a diagnostic *hot test* on heat-sensitive pulps.

The Calamus Flow handpiece is utilised, in conjunction with a one-piece gutta-percha cartridge and integrated cannula, to dispense warm gutta-percha into the preparation during the back-packing phase of obturation. The cartridges are single patient use and are available in 20 and 23 gauge sizes. The Calamus Dual 3D Obturation System provides a *bending tool* that may be utilised to place a smooth curvature on the cannula. Ultimately, the gauge selected and the curvature placed should allow the cannula to pass through the coronal two-thirds of the preparation

Fig. 8a_Upon activation, the EHP is plunged 3 to 4 mm into the previously compacted material, deactivated, then removed, along with a *bite* of gutta-percha.
Fig. 8b_The medium-sized, pre-fit plugger carries a second WOC deeper into the progressively narrowing and tapering preparation.





and to contact the previously down-packed master cone.

Calamus down-pack

In preparation for initiating the down-pack, the clinician should select the Calamus EHP that fits passively through the straightaway portion of the preparation and optimally to within 5 mm from the terminus of the canal. When the EHP cannot reach this desired level, in a well-shaped canal, the Calamus bending tool may be utilised to place a suitable curvature on the more apical portion of the 40/03 EHP that matches the curvature of the prepared canal. A silicone stop may be placed on the EHP to monitor its maximum depth of insertion safely.

Because of the thermo-molecular properties of gutta-percha, the Calamus EHP will generate about a 5 mm heat-wave through gutta-percha, apical to its actual depth of placement. Following the placement of the sealer-buttered master cone in a canal with an irregular cross-section, it is beneficial to inject heat-softened gutta-percha lateral to the master cone. This method will serve to initially thermo-soften the master cone, maximise the volume of gutta-percha and effectively increase hydraulics when commencing with the down-packing phase of obturation.

The Calamus EHP is activated and utilised to sear off the master cone at the cemento-enamel junction in single rooted teeth or at the orifice level in multi-rooted teeth (Fig. 7a). In order to capture the maximum cushion of warm rubber, the working end of the *large*-sized, pre-fit plugger is methodically stepped around the circumference of the canal. This plugger is used with short, firm vertical strokes to scrape warm gutta-percha off the canal walls and flatten the material coronally.

The working end of the plugger is used to press vertically on this flattened platform of warm gutta-percha for five seconds (Fig. 7b). This action serves to automatically fill the root-canal system, laterally and vertically, over a range of a few millimetres and is termed a *wave of condensation* (WOC).[4] Specifically, a WOC moves thermo-softened gutta-percha into the narrowing cross-sectional diameters of the preparation, generates a piston effect on the entrapped sealer and produces significant hydraulics. During this heating and compaction cycle, the operator will tactilely feel the warm mass of gutta-percha begin to stiffen as it cools. Importantly, using a plugger to press on warm gutta-percha during the cooling cycle has been shown to offset shrinkage completely.

In order to generate a progressively deeper heat-wave along the length of the master cone, the Calamus EHP is activated and allowed to plunge 3 to 4 mm into the previously compacted material. Following the plunge, the EHP is deactivated and the operator should hesitate for a brief second before removing the cooling instrument along with a *bite* of gutta-percha (Fig. 8a). Removing a bite of gutta-percha results in the progressive apical transfer of heat another 4 to 5 mm along the length of the master cone and facilitates the placement of the *medium*-sized, pre-fit plugger deeper into the root-canal preparation. This plugger is used, as described above, to compact warm gutta-percha into this region of the canal, producing a second WOC (Fig. 8b).

Depending on the length of the canal, only two, three or four heating and removal cycles are required until the pre-selected EHP can be placed within 5 mm of the canal terminus (Fig. 9a). Owing to multiple heatings, thermal cycling progressively transfers heat into the apical one-third of the gutta-percha master cone. Advantageously, the temperature of gutta-percha only has to be elevated 3 °C above body temperature to become heat-softened and readily mouldable. Utilising this technique, obturation temperatures within the gutta-percha have been shown to be clinically safe and generate working temperatures that range from 40 to 45 °C. Fortuitously, the temperature produced on the external root surface is less than 2 °C. This minor transfer of temperature is

Fig. 9a_The EHP is activated and plunged deeper into the gutta-percha, deactivated, then the cooling EHP removed along with another bite of gutta-percha.
Fig. 9b_The working end of the small-sized, pre-fit plugger scrapes the walls of the canal clean, maximises the volume of gutta-percha and generates the final WOC.
Fig. 10_Following the down-pack, a working film demonstrates 3-D corkage and filled lateral canals coronal to the more apical mass of gutta-percha.

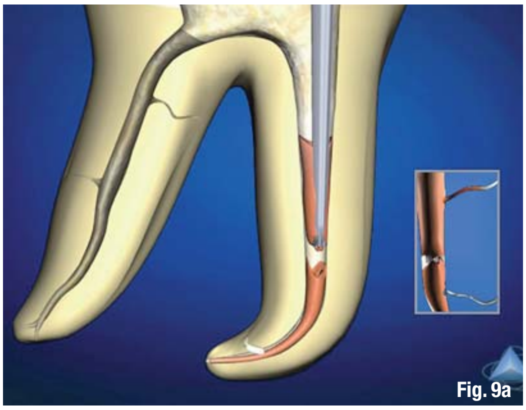


Fig. 9a

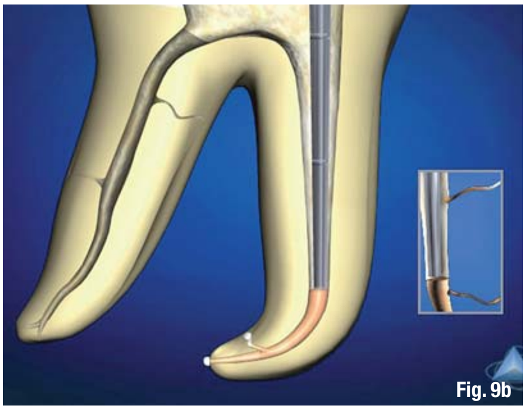


Fig. 9b

Fig. 10

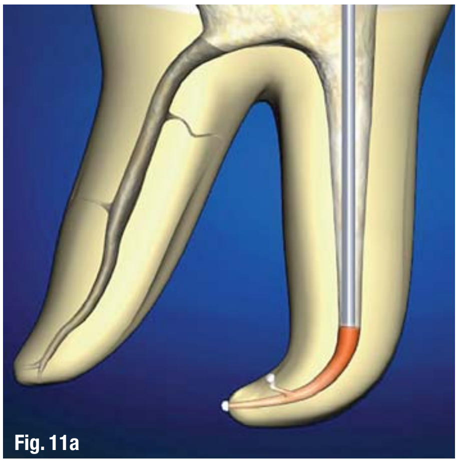


Fig. 11a

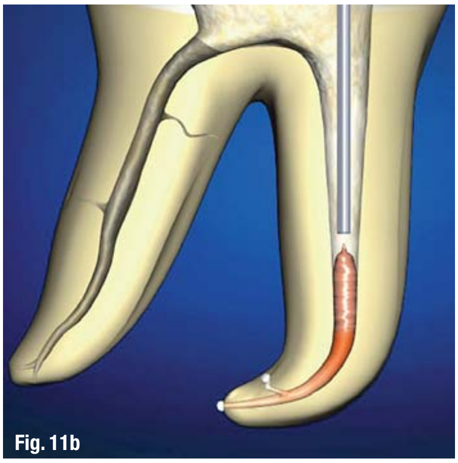


Fig. 11b

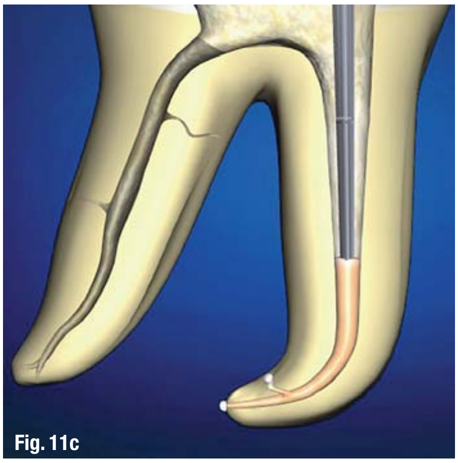


Fig. 11c

Fig. 11a_The tip of the warm Calamus Flow cannula serves to re-thermo-soften the coronal most aspect of the previously packed gutta-percha.
Fig. 11b_The activation cuff on the Calamus Flow handpiece is pressed and a small 2 to 3 mm segment of warm gutta-percha dispensed into this region of the canal.
Fig. 11c_The small-sized, pre-fit plugger is used to condense warm gutta-percha and generate a reverse WOC.
Fig. 12a_The Calamus Flow handpiece is activated and a little longer, 3 to 4 mm, segment of warm gutta-percha is dispensed into this region of the canal.
Fig. 12b_A medium-sized, pre-fit plugger densely compacts warm gutta-percha vertically and laterally into this region of the canal.
Fig. 13_This figure illustrates that the potential to fill root-canal systems is largely dependent on shaping canals and 3-D cleaning.

related to dentine being a poor conductor of heat; further, moisture within the periodontal ligament serves to wick off excessive heat.

Owing to the efficient transfer of heat into the apical extent of the gutta-percha master cone, the *small*-sized, pre-fit plugger need not be placed closer than 5 mm from the canal terminus. This plugger is stepped around the circumference of the canal to maximise the volume of gutta-percha available to achieve optimal hydraulics. A sustained five-second vertical press with this plugger will deliver a controlled thermo-softened wave of warm gutta-percha into the narrowing cross-sectional diameters of the prepared canal and result in apical corkage (Fig. 9b).

Again, a sustained five-second press with this *small*-sized, pre-fit plugger serves to offset shrinkage during the cooling cycle. Following the down-pack, a working film frequently reveals filled accessory canals coronal to the more apical mass of gutta-percha (Fig. 10). Once the root canal has been properly shaped and the root-canal system cleaned, then the material occupying the lateral anatomy may be all gutta-percha, all sealer, but is typically a mixture of both.

Calamus back-pack

When the down-pack has been completed and the apical one-third corked, reverse filling the canal is important to eliminate radicular dead space. The Calamus Flow reverse filling technique, or what is termed the *back-pack*, is easy, fast and 3-D.

Thermo-softened gutta-percha is readily dispensed into a shaped canal utilising the Calamus Flow handpiece in conjunction with a 20- or 23-gauge cartridge. A new cartridge is selected and inserted into the heating chamber and secured by tightening the cartridge nut. A protective heat shield may be used to prevent inadvertent thermal injury and is inserted over the cannula and the heating chamber portion of the handpiece prior to back-filling the canal. When the Calamus Flow handpiece is activated, an internal plunger travels toward the heating chamber and the cartridge, which is filled with gutta-percha. In this manner, the plunger serves to push thermo-softened material out of the heated cartridge, through the cannula and into the canal.

The tip of the warm cannula is positioned against the down-packed gutta-percha for five seconds to

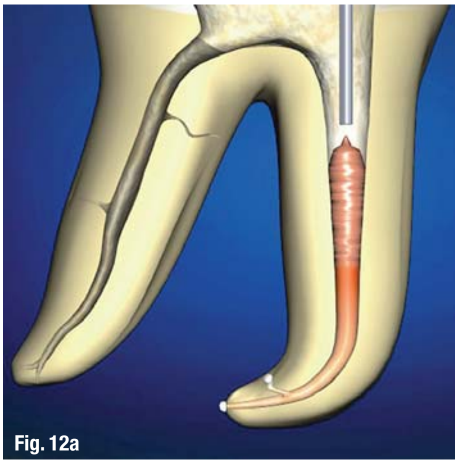


Fig. 12a

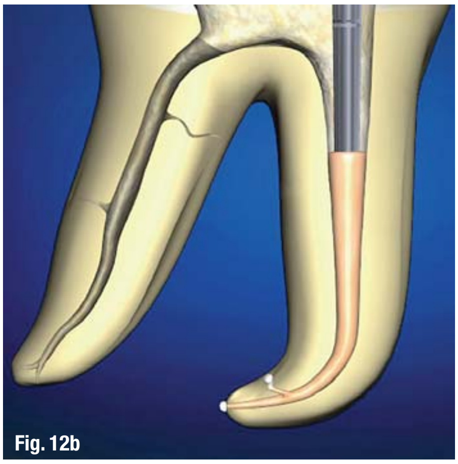


Fig. 12b

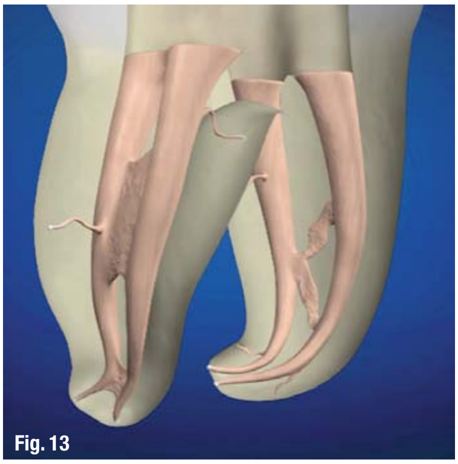


Fig. 13

re-thermo-soften its most coronal extent (Fig. 11a). This procedural nuance promotes cohesion between each injected segment of warm gutta-percha. The Calamus Flow handpiece is activated, and a *short* 2 to 3 mm segment of warm gutta-percha is dispensed into the most apical region of the empty canal (Fig. 11b). Injecting or dispensing too much gutta-percha invites shrinkage and/or voids, which result in poorly obturated canals judged radiographically.

The Calamus Flow handpiece should be held lightly so it will *back-out* of the canal when injecting thermo-softened gutta-percha into the canal. The *small*-sized, pre-fit plugger is used, as previously described, to densely compact warm gutta-percha into this region of the canal. Utilising the plugger in this manner will capture the maximum cushion of rubber, promote successful hydraulics and generate *reverse* waves of condensation (Fig. 11c).

To continue the back-filling technique, a *longer* 3 to 4 mm segment of warm gutta-percha should be dispensed into this more coronal region of the canal (Fig. 12a). The working end of the *medium*-sized, pre-fit plugger is stepped circumferentially around the preparation to clean the dentinal walls, flatten the dispensed material and deliver warm gutta-percha, laterally and vertically, into this region of the canal. This plugger is used to press against the cooling gutta-percha for five seconds to offset shrinkage during the cooling phase (Fig. 12b). The back-filling technique continues, in the manner described, until the canal has been reverse filled (Fig. 13). Alternatively, back-filling may be stopped at any level within the canal to accommodate a post to facilitate potential restorative needs.

In order to fill furcal canals, the pulp chamber floor of multi-rooted teeth is covered with a thin layer of sealer prior to dispensing gutta-percha. An appropriately sized amalgam plugger is used to compact thermo-softened gutta-percha on the pulpal floor effectively, which in turn, generates desirable hydraulics. Different horizontally angulated post-treatment radiographs may be taken to confirm that the root-canal system has been densely obturated, laterally and vertically, to the canal terminus (Fig. 14). Frequently, a puff of sealer will be noticed adjacent to a portal of exit and should be considered irrelevant to the prognosis of the case. When the prepared apical foramen is relatively round and if the master cone has been well fitted, sealer puffs will generally be larger laterally and smaller or non-existent apically. Following obturation procedures, gutta-percha and sealer are thoroughly excavated from the pulp chamber utilising a solvent such as xylol or chloroform. A solution of 70 % isopropyl alcohol is flushed into the pulp chamber to remove any obturation residues in preparation for the restorative effort. Scientific evidence has demonstrated that flushing out the chamber, as described, will eliminate free eugenol and allow for predictably successful bonding.[13]

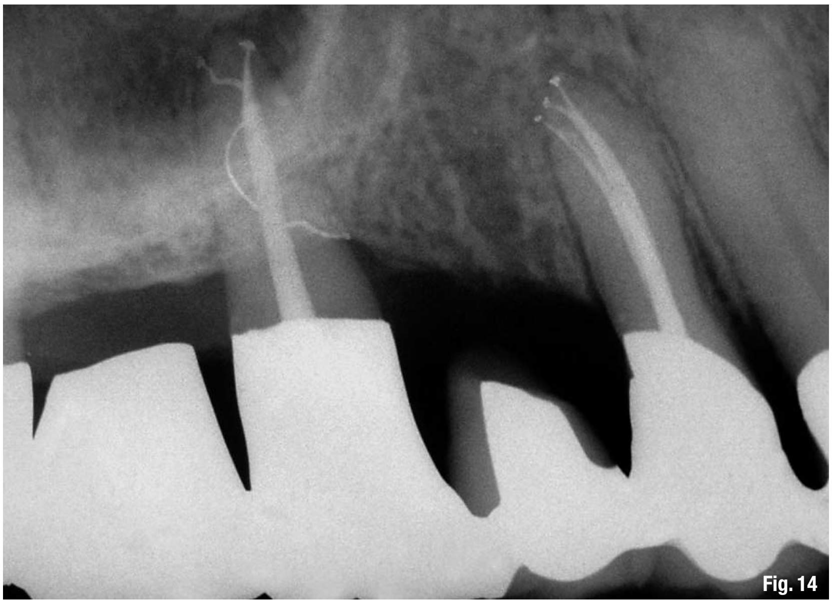


Fig. 14_Complete endodontic treatment provides a predictably successful foundation for perio-prosthetics.

_Conclusion

The Calamus Dual 3D Obturation System is innovative technology that may be utilised to fill root-canal systems. As the health of the attachment apparatus associated with endodontically treated teeth becomes fully understood and completely appreciated, the naturally retained root will be recognised as the *ultimate dental implant*. When properly performed, endodontic treatment is the cornerstone of restorative and reconstructive dentistry._

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

_about the author

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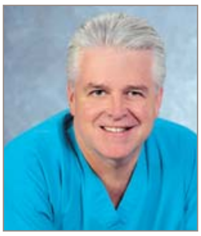

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The Morita Group is a manufacturer of medical-technical products. The Japanese traditional company with distribution companies in Europe, the USA, Brazil, Australia and Africa offers an extensive range of sophisticated products, such as high-performance imaging systems, treatment units, turbines, manual and contra-angle handpieces, instruments as well as endodontic measuring and preparation systems._

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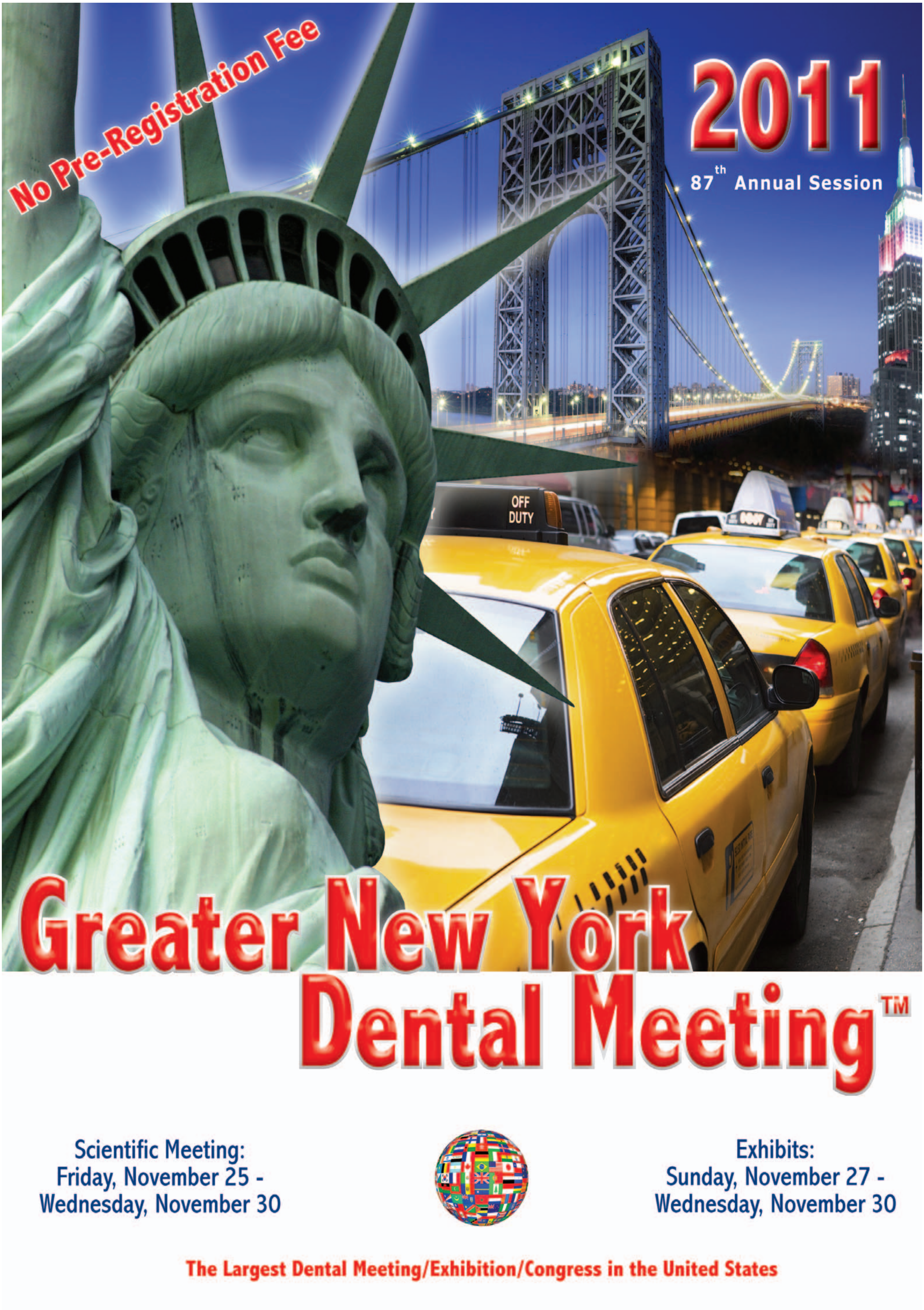
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