issn 1616-6345

Vol. 1 • Issue 1/2006

roots

international magazine of endodontology

1 2006

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dti Dental Tribune International

Dear Colleagues,


Dr. Karl Behr
Editor-in-Chief

_It has finally arrived! In your hands you hold the first edition of *roots, the international magazine of endodontology.* In the future we hope to offer scientists, endodontic specialists, and those generally interested in the subject a forum within its pages four times a year.

In spite of the increasing number of publications for our profession, there is not one trade publication that concerns itself with the exchange of information between science and the practice of different specialized disciplines. This is not at all unfortunate as on the one hand, the variety of systems existing today is often confusing, and on the hand research frequently does not take into consideration the problems actually found in the practice.

Direct lines of communication between scientist and practitioners can result from the establishment of our journal and create a new impetus for innovation and for the practice. Given the upswing of endodontology in the last years, we would like *roots* to close the gap in the spectrum of available publications and create a place for shared debates. It allows for a greater exchange between its readership, and particularly the Internet community created by Dr. Ken Serota at www.roots.com, to which we want to grant a worthy new home within these pages.

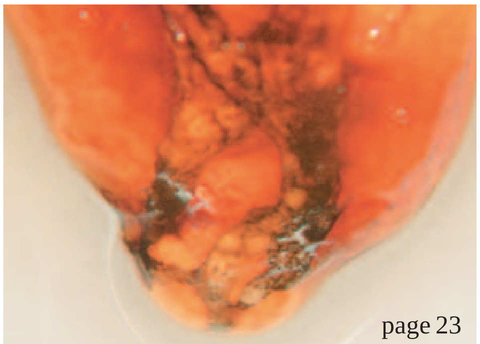
roots will begin with this international English edition, soon to be followed by a country-specific edition for the USA. Editions for North America, South America, Europe and Asia will also follow.

Our goals include counting those in general practice as well as scientists among our list of published authors. The scientific side will be handled by Mr. Professor Benjamin Brisenio, whom I would first cordially like to thank for his commitment.

I am eager to see your contributions and look forward to many years of lively debates and interesting contributions from endodontic's research side as well as its practical side.

Respectfully Yours,

Dr. Karl Behr
Editor-in-Chief
Germany



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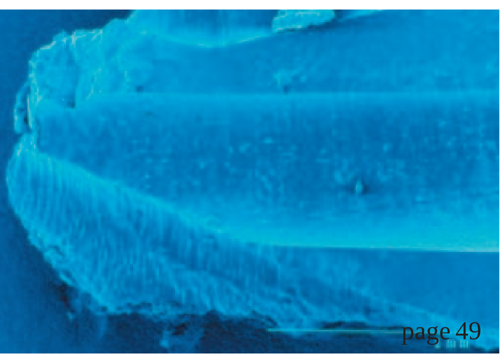
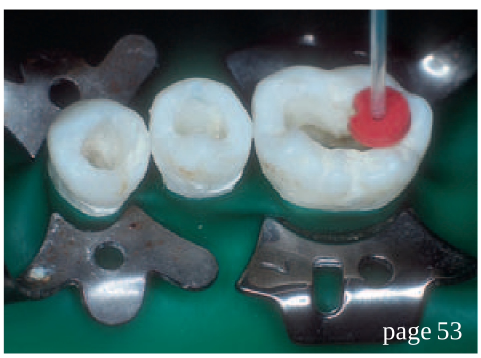
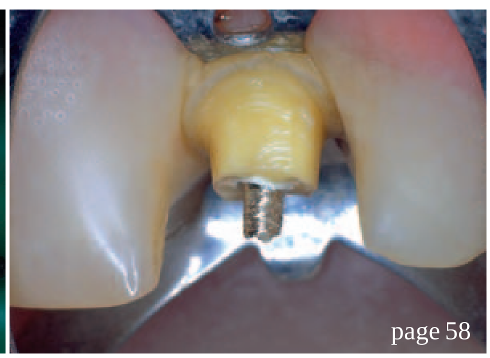




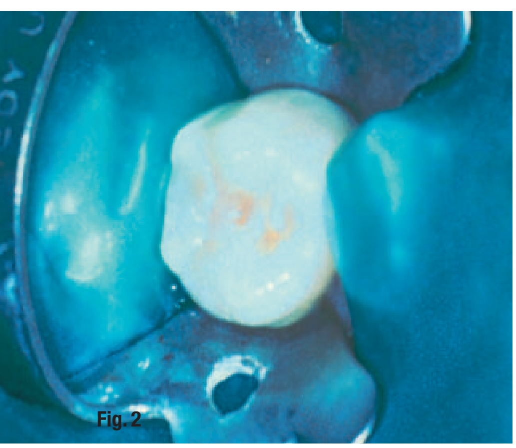


Multiple vs. One-Step Apexification

Author_Mohamed Fayad & Marilia J. Montero, U.S.A.

An immature tooth that develops pulpal or periapical disease presents special problems. Because the apex has not yet completely formed, conventional root canal treatment procedures would be unpredictable. This article will review the endodontic management of necrotic teeth with an open apex. Problems associated with treatment and outcomes of treatment will be discussed. Two cases presenting a new approach, single-step apexification, will be presented.

Fig. 1_Case 1—Preoperative picture showing a sinus tract in the left premolar area.
Fig. 2_Occlusal view of tooth #20. Notice the invagination on the occlusal surface. Tooth #20 responded negative to cold and EPT testing.



_Root development commences after the completion of the enamel formation. Pulp vitality is required for root development to take place. Any factor that will sacrifice pulp vitality, such as trauma, caries, and dental anomalies (dens evaginatus and ivaginatus), may lead to the arrest of the physiological process of root formation.

Immature pulpless teeth present special problems in meeting the objectives of nonsurgical endodontic therapy. Immature pulpless teeth have thin, short divergent walls in the apical third, which makes normal development of an apical stop and obtaining an optimal apical seal impossible. This leads to an inability to confine the filling material to the canal space. The most commonly used technique is inducing apical closure by formation of an apical stop using calcium hydroxide as an intracanal medicament. This process is known as apexification.

A new approach is placing a biologically acceptable material in the apical portion of the root canal, thus forming an apical barrier; followed by filling the root canal with gutta-percha and sealer. This procedure has been called one-step apexification.

_Multiple-visit apexification

Induction of apical closure has been the most widely used approach to treating open apex. Kaiser[1] first introduced the use of calcium hydroxide mixed with camphorated monoparachlorophenol (CMCP) to induce apical closure. The technique was popularized later in 1966 by Frank[2], who described a step-by-step technique and four types of apical closure. Calcium hydroxide can be mixed with a number of different substances (CMCP, distilled water, sterile saline, anesthetic solutions and recently chlorohexidine) to induce apical closure. The relatively good success rate of this procedure has been attributed to one or more of the following properties: (a) the high pH, (b) the calcium ion, (c) the hydroxyl ion, and (d) the antibacterial effect.

However, the property that actually promotes the mechanism for the calcific bridge formation is not known. From the previous literature, the most important factors in achieving apexification seem to be thorough debridment of the root canal (to remove all necrotic pulp tissue) and sealing the tooth (to prevent the ingress of bacteria and substrate).

The usual time required to achieve apexification with conventional calcium hydroxide treatment is 6 to 24 months (the average is 1 year $\pm$ 7 months). Factors that lead to increased treatment time are the presence of a radiolucent lesion, inter-appointment symptoms, and loss of the external seal with reinfection of the canal.

During this time, the patient is recalled at 3-month intervals. If any signs or symptoms of reinfection or pathology occur during this phase of the treatment, the canal is recleaned and refilled with the calcium hydroxide paste. The patient is recalled until radiographic evidence of apexification has become apparent.

Determination of the extent of the apical closure is often difficult to ascertain. Radiographic interpretation of apical closure may be misleading. It must be remembered that the dental radiograph is a two-dimensional picture of a three-dimensional object. The faciolingual aspect of the root canal is usually the last to become convergent apically as the root develops. Therefore, it is possible to have a dental radiograph showing an apically convergent root canal while in the faciolingual plane the root canal is divergent.

Fig. 3

Fig. 4

Fig. 3_Preoperative radiograph of tooth #20 showing a large periapical radiolucency and a wide open apex.
Fig. 4_Wire measurement radiograph with a size 100 file. No apical stop could be detected.
Fig. 5_Collacote packed periapically (radiolucent) as a matrix for apically 4–5 mm condensed MTA (radiopaque).
Fig. 6_Postoperative radiograph with the access cavity restored with resin bonded restoration.

_One-Step Apexification

A one-step alternative to conventional apexification procedures has been proposed by Koeings et al.[3] Successful performance of a one-step procedure may benefit both the patient and the practitioner because of the reduced amount of office time required. The potential problem of patient compliance is also reduced, and it appears that reopening the root canal and recleaning during multiple visits may disturb the process of apexification.

The objective of one-step apexification is to condense a biocompatible material into the apical end of the root to establish an apical stop. However, this procedure only fulfills one aspect of apexification, the creation of an apical stop. It does not allow for continued root development. Several materials—such as resorbable ceramics, calcium phosphate, freeze-dried demineralized bone, and recently, mineral trioxide aggregates (MTA)—have been utilized in one-visit apexification

Mineral trioxide aggregate has been proposed as a potential material to create an apical plug. MTA is a powder that consists of fine hydrophilic particles that set in the presence of moisture. The major compounds of MTA are tricalcium silicate, tricalcium aluminate, tricalcium oxide and silicate oxide.[4]

Cases 1 and 2 are examples of one-step apexification for a dens evaginatus (dental anomaly) and trauma, respectively. Both resulted in pulpal necrosis before complete root development. In both cases a collagen barrier (CollaCote, Calcitek, Carlsbad, CA) was packed as a matrix, and MTA (Proroot, Tulsa Dental, Tulsa, OK) was condensed to form a barrier. The collacote is absorbed in 10–12 days. The remainders of the root canals were filled utilizing warm gutta percha technique and a resin bonded final restoration.

_Technique

1) Chemico-mechanical debridement with 5.25% NaOCl solution followed by 17% EDTA. Apply 2% chlorohexidine to the root canal for 2 minutes, then rinse with NaOCl 5.25%.
2) Use gentle pressure to dry the canal with pre-measured sterile paper points to working length.
3) Select the appropriate size plugger to working length (not too large to bind with canal walls and not too small to pierce the MTA).
4) Choose the depth of the MTA plug using a Messing Gun that deposits a 3 mm MTA plug to working length.
5) Pack the CollaCote using the pre-measured plugger to working length.

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Fig. 7_Two-year recall showing evidence of healing. Patient is asymptomatic.
Fig. 8_Intraoral picture showing soft tissue healing at the one-year recall period.


Fig. 9

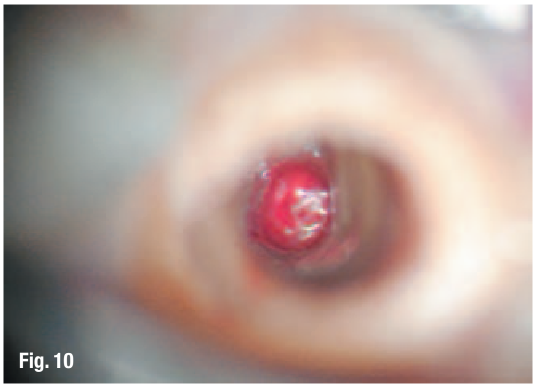


Fig. 10

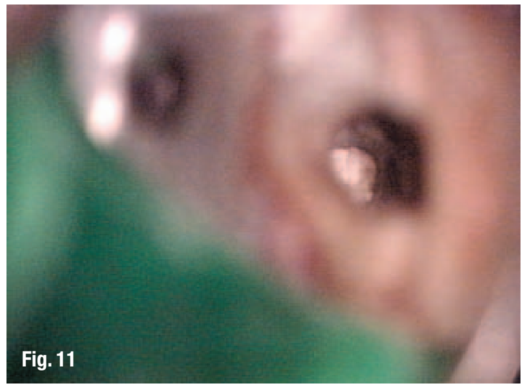


Fig. 11

Fig. 9_Case 2—Tooth #9 with a history of trauma and necrotic pulp.
Fig. 10_Picture through the operating microscope showing periapical tissue.
Fig. 11_Picture through the operating microscope showing Collacote packed periapically as a matrix. Periapical radiograph verifying MTA placement in the apical 3–4 mm.
Fig. 12_Postoperative radiograph showing a dense fill with control in apical plug placement.
Fig.13_Six month postoperative radiograph showing a dense fill with apical control and reduction in the size of the periapical lesion.


Fig. 12


Fig. 13

6) Mix the MTA according to the manufacturer's instructions and load the pre-set Messing Gun.
7) Apply the 3 mm MTA plug to the orifice of the canal and gently tease the material apically until the stopper on the plugger is at the reference point.
8) Verify the 3 mm apical plug radiographically.
9) Fill the remainder of the canal with gutta percha and resin bonded restoration.

These cases are an example of immature roots. MTA was utilized in both cases. The success of the previous cases could be attributed to several factors, such as magnification (being able to visualize and control the placement of CollaCote and MTA in the apical, most critical part of the canal).

Other contributing factors are cleansing and shaping of the canals; superior biocompatibility, antimicrobial and sealing ability of MTA as documented in several studies.[5, 6, 7, 8] Obtaining an early final coronal seal compared to temporized teeth in the multiple visit (6–12 months) procedures is another important factor. Combination of the previous factors may play a major role in increasing the success rate of necrotic teeth with immature apices.

Following obturation with gutta-percha, restoration of the immature teeth must be designed to attempt to strengthen the immature teeth. Clear plastic posts such as the Luminex System® have been developed to allow light transmission throughout the canal, curing the entire mass of composite resin and possibly strengthening the root.

Although highly successful, apexification should be the treatment of last resort in a tooth with an incompletely formed root. Attention should be focused on the maintenance of pulp vitality in these teeth so that as much root length and dentin formation as possible can occur. To evaluate one-step apexification further, a standardized method or model must be developed to compare the various materials being advocated. _

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Case Presentations from the Endodontic Practice

Author_Dr. Clemens Bargholz, Germany

Over the last few years, tremendous strides have been made in endodontics. On the one hand, findings in basic research have extended our understanding of the pathological correlations of the origin and control of endodontic disease. On the other hand, the operating microscope facilitates treatment under powerful magnification and in full visibility. With these developments an elementary change has taken place in endodontics, bringing with it a marked improvement in the prognosis for every individual tooth in root canal system therapy.

_Case I

The patient was referred to my practice with latent pain in the left mandible. Clinically, the extensive filling in tooth 36 was striking. Tooth 36 was sensitive to percussion and there was definite pressure pain in the apical region. The diagnostic X-ray showed an incomplete root filling at tooth 36 with suspected ledging in the mesial canal systems and clear apical brightening at both roots (Fig. 1). In subsequent discussion with the patient, a revision of the root filling was recommended.

After complete cleaning out of the old amalgam filling, the vestibular and oral wall was shortened to


Fig. 1

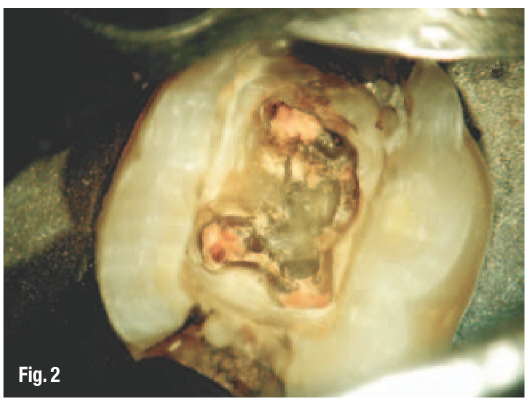
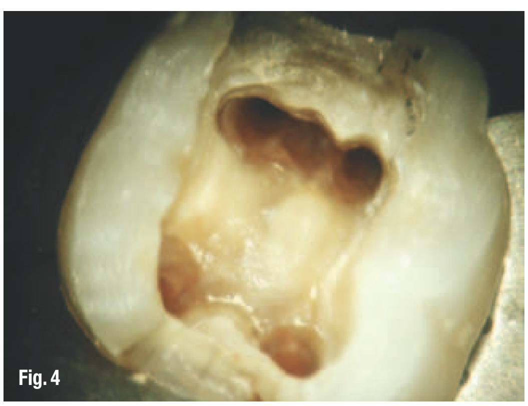


Fig. 2


Fig. 3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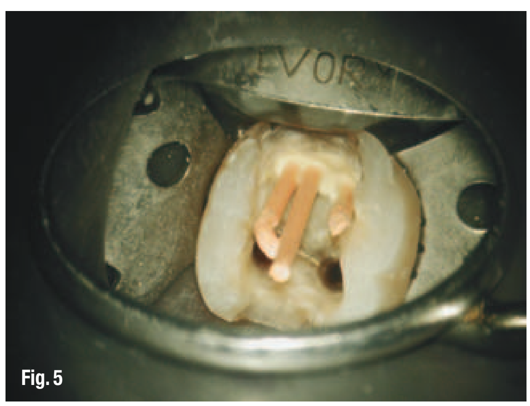


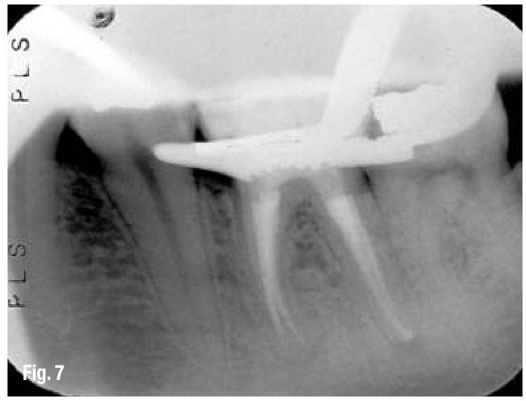
Fig. 5

Fig. 1_Incomplete root filling at tooth 36 with apical periodontitis.
Fig. 2_Situation after removal of the filling materials.
Fig. 3_Excentric instrumentation image.
Fig. 4_Five canal systems exposed.
Fig. 5_Application of the gutta percha points into the canal systems of the distal root.

create clear reference points and relieve pressure on the tooth (Fig. 2). After removal of the infected root filling, all the canal systems were exposed to their full length. The excentric instrumentation contrast image shows, particularly from the mesial aspect, the two separately located root contours (Fig. 3). In the mesial root two completely separate canal systems were revealed; by contrast, distal three had a partial conflux of the canal systems (Fig. 4). Upon completion of the combined manual rotating preparation, the gutta percha points were inserted.

Figs. 6 & 7_Upon completion of the root filling in vertical condensation.
Figs. 8–14_ Individual steps in the fabrication of the dentin adhesive build-up (starting to etch, etched surface, primer, bonding, filling of the cavity.).


Fig. 6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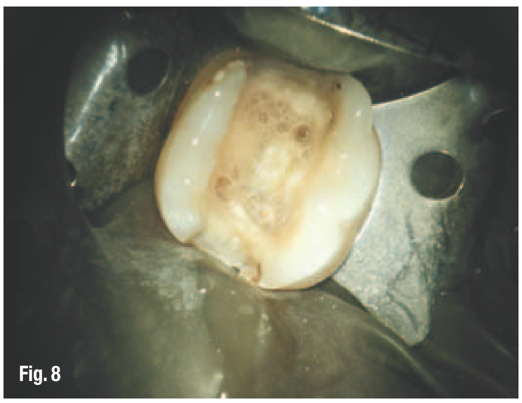
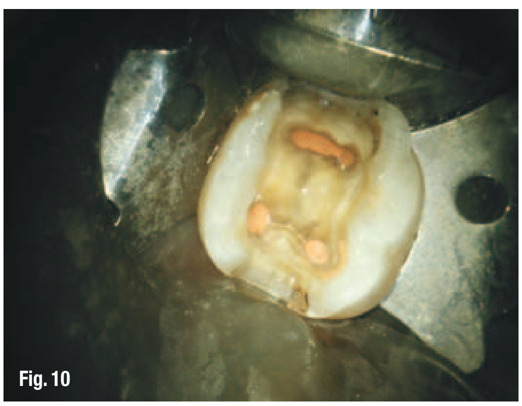


Fig. 8


Fig. 9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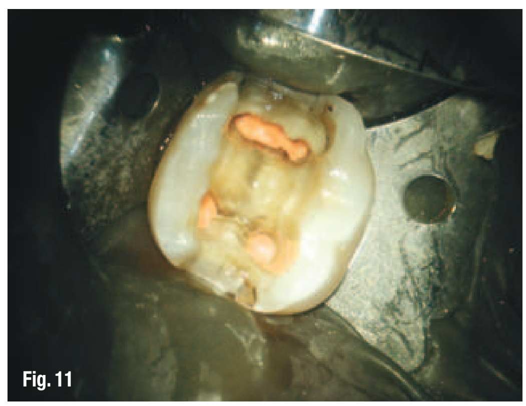


Fig. 11


Fig. 12

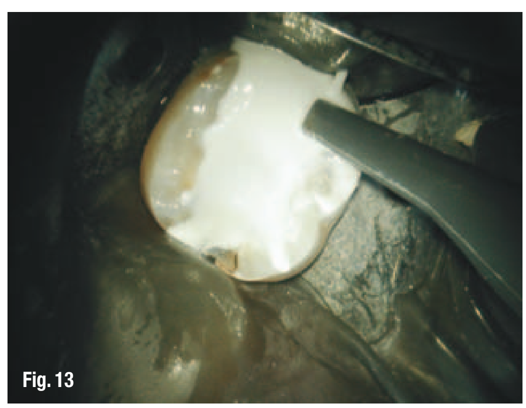


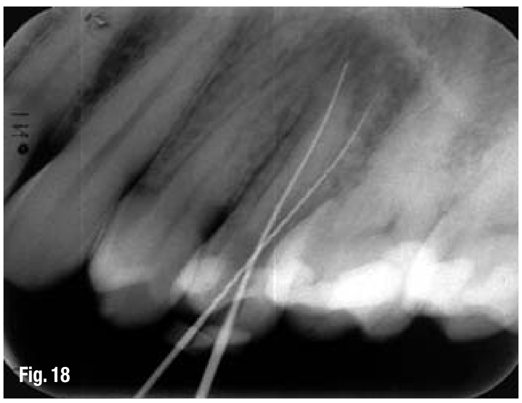
Fig. 13


Fig. 14


Fig. 15


Fig. 16


Fig. 17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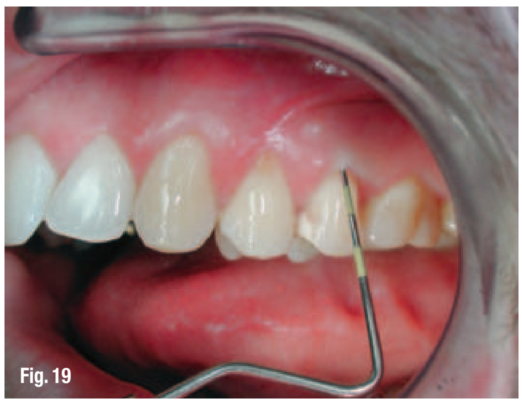
Fig. 19

Fig. 15_Check after six months.
Fig. 16_Check after 18 months.
Fig. 17_Tooth 25 showing marked periradicular brightening.
Fig. 18_First instrumentation image forwarded by referring dental practitioner.
Fig. 19_Clinically palpable retraction of the buccal furcation at tooth 25.

As shown in Fig. 5, the medial distal canal converged with the lingual canal system in the apical third. (The medial gutta percha tip could not be inserted to its full working length.) The ensuing root filling was carried out with Schilder's vertically condensation technique to about 3 mm beneath the floor of the pulp chamber (Fig. 6). The separated canal routes can be seen clearly in the excentric control image (Fig. 7).

Immediately upon completion of the root filling, a composite build-up of Core Paste (Den-Mat Corp., USA) was anchored on all surfaces with Scotch Bond MP (3M Medical, Borken) in a procedure using the total etch technique. The individual stages with the dentin etching, the application of primer and bond, the application of the composite material with the centrix system (Hawe-Neos, Bioggio, Switzerland), as well as the completed interim treatment are shown in Figs. 8 to 14. The X-ray checks at the end of 6 and 18 months show the steadily continuing healing of the apical process (Figs. 15 & 16).

_Discussion

The prognosis for the conservative revision of incomplete root fillings can be described as very good. The success quota for presentation of apical periodontitis is given in the literature as approximately 78% (Bergenholtz et al. 1979). In contrast to microsurgical intervention, this is to be seen as causal therapy as the cause is primarily an infection of the canal systems and therefore, in most cases, a complete cure can be brought about by removal of the noxious substances.

The canal anatomy in the case example is described in less than 50% of mandibular first molars;

Fig. 20_Access cavity at commencement of treatment.
Fig. 21_Access cavity after widening of the vestibular portion.
Fig. 22_Separation of the two vestibular canal systems is seen clearly at a depth.

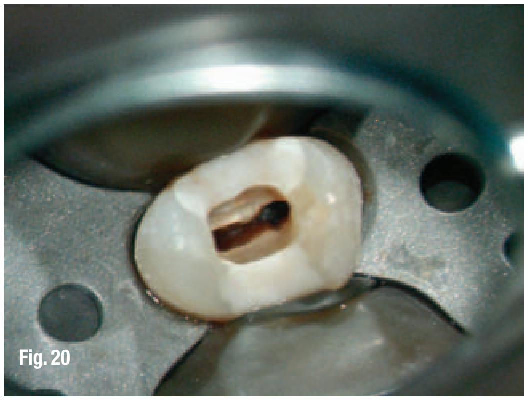

Fig. 20

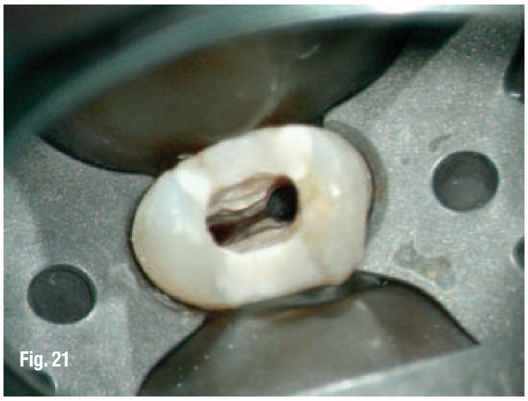

Fig. 21

Fig. 22

it is more often found that the two distal main canals flow into a common foramen in the apical region. The third distal canal shown may also be the slit-shaped off-shoot of a "main canal". However, the mechanical widening of such structures is necessary for the disinfection of the complete canal system with rinsing solutions. The subsequently implemented dentin adhesive build-up is increasingly discussed as post-endodontic therapy.

To prevent any reinfection of the canal systems, bacteria-proof protection from the oral cavity is required (Ray & Trope 1955). This can be achieved with a dentin bonding placed under a rubber dam. Teeth that have been endodontically treated are more prone to factures, not because of their altered physical dentin properties, but rather because of the significant loss of substance (Howe & Kendry 1990, Sedgley & Messer 1992, Bargholz 1996). The aim of post-endodontic therapy must therefore be to ensure optimal stabilization and, under no circumstances, to cause further weakening of the hard tooth substance by pin drilling.

_Case II

The patient was referred because in spite of repeated preparation of both canal systems at tooth 25 and frequent changing of the medicated insert, the primary endodontic treatment had not resulted in freedom from pain. The massive periradicular brightening is already clearly visible in the initial X-ray and the instrumentation images brought along by the patient (Figs. 17 & 18).

However, the root contour of tooth 25 is not distinct. During the first clinical check of the cervical root surface a retraction was palpable (Fig. 19). This is a clear indication of the existence of three roots with separate canal systems. The initially slit-shaped access cavity was first widened to facilitate unhindered access to both vestibular canal systems (Figs. 20 and 21).

After location of the radicular access cavities, all three canal systems could be safely instrumented and thoroughly prepared and disinfected (Figs. 22 & 23). The root filling with vertically condensed gutta percha completed during this treatment undergoes a final check (Figs. 24 & 25). The X-ray check at the end of 4 months reveals an almost complete healing of the periradicular osteolysis (Fig. 26)

_Discussion

The second upper premolar has three root canal systems in only 1% of cases (Vertucci et al. 1974). On the other hand, in first upper premolars there is a 6% incidence of three canal systems. When assessing the X-rays this possibility must be considered, in particular when there is such an indistinct root configuration in comparison to the adjoining teeth. The success of endodontic therapy depends on the complete elimination of the pathogenic microbial flora within the root canal system. While a one-phase procedure does not contravene this requirement, it is however important to ensure that the disinfecting rinsing solutions have adequate time to act after preparation

Fig. 23_Instrumentation contrast image of the vestibular canal systems.
Figs. 24 & 25_Completed root filling.
Fig. 26_X-ray check of tooth 25 after four months.

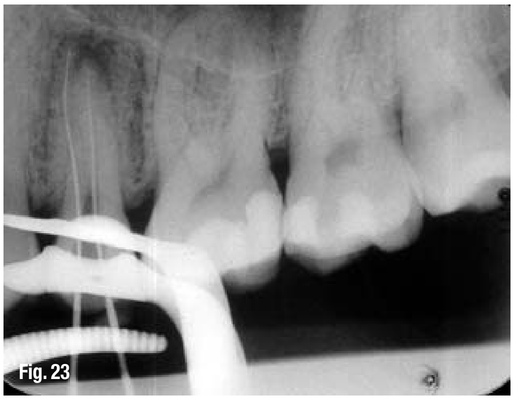
Fig. 23


Fig. 24


Fig. 25


Fig. 26

of all the canal systems. Only a prolonged period of disinfection with constantly renewed solutions will ensure complete germ elimination in endodontic therapy (Sen et al. 1999)._

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Control and Elimination of Endodontic Infection

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The main goal in endodontics is the prevention and treatment of diseases of the dental pulp and periapical tissues. These objectives can be best achieved if preventive measures and treatment procedures are based on a thorough and detailed understanding of the etiology and pathogenesis of endodontic diseases.

_In pulpitis, caused by a deep caries lesion, the inflammatory reactions in the pulp start a long time before bacteria are found in the pulp tissue. The initial inflammatory reactions are initiated by bacterial antigens interacting with the local immune system (Bergenholtz 1990, Pashley 1996, Jontell et al. 1998). As long as the body of the carious lesion has not entered the pulp, the inflammatory process in the pulp is supposed to be reversible and no endodontic therapy is usually required. With progressing caries, bacterial cells enter the superficial layers of the pulp. As long as there is vital pulp tissue, the pulp, even though heavily inflamed, is considered to be relatively bacteria-free.

Apical periodontitis is an inflammatory process in the periradicular tissue caused by microorganisms in the necrotic root canal (Kakehashi et al. 1965). Some studies have indicated that the prognosis of the treatment of apical periodontitis is lower if there are living bacteria in the root canal at the time of filling (Engström et al. 1964, Sjögren et al. 1997, Katebzadeh et al. 2000). It is generally accepted that successful treatment of primary apical periodontitis rests on effective elimination of the causative agents in the root canal system (Chugal et al. 2001). However, other studies have not been able to show a difference in healing between teeth filled after positive or negative cultures from the root canal or between one and two-appointment treatments (Weiger et al. 2000, Peters & Wesselink 2002).

Elimination of endodontic infection is different from elimination and control of most other infections in the human body. Because of the special anatomic environment in the root canal and tooth, host measures that in other sites are sufficient to eliminate the infectious organisms are alone not enough for complete recovery in endodontic infections. Therefore, control of an endodontic infection is a concerted effort by several host and treatment factors. Success in all aspects of this cooperation will eventually result in elimination of the infective microorganisms and healing of the periapical lesion.

The necessary components in the elimination of endodontic infection are: i) host defense system, ii) in some cases systemic antibiotic therapy, iii) chemomechanical preparation and irrigation, iv) local root canal disinfecting medicaments, v) permanent root filling, vi) permanent coronal restoration. While the main focus of this article will be on chemomechanical preparation and local disinfecting agents (factors iii and iv), the role of other contributory factors will also be briefly summarized. Periapical actinomycosis and other extraradicular infections are left outside this review.

_Host defense

The host's defense system is a key factor in preventing the spreading of the infection from the root canal to the periapical tissues and bone. However, lack of circu-

_abstract | roots

Control of an endodontic infection is a concerted effort by several host and treatment factors. Success in all aspects of this cooperation will eventually result in elimination of the infective microorganisms and healing of the periapical lesion. The necessary components in the elimination of endodontic infection are host defense system, chemomechanical preparation, canal disinfection, permanent root filling and coronal restoration. The main focus in this article will be on chemomechanical preparation and local disinfecting agents, but the role of other contributory factors will also be briefly summarized. At present it seems correct to conclude that no locally used root canal disinfectant can predictably produce sterile canals in the treatment of apical periodontitis. However, their use further reduces the number of infecting microorganisms after chemomechanical preparation to the level of total elimination. Future studies will probably verify the new observation that root filling with gutta-percha and sealer can have an actively dualistic role as a canal disinfectant and as a permanent root filling.

Fig. 1

lation in the necrotic root canal makes it impossible for the phagocytes and the rest of the immune system to penetrate into the root canal space for more than a few hundred micrometers. Therefore, although of crucial importance in maintaining general health, the defense system is limited to achieving a balance between the microbial intruders and the body, but it cannot eliminate the source of the infection in the root canal.

In chronic apical periodontitis the main mechanism responsible for destruction of normal bone structure is activation of bone osteoclasts and inhibition of osteoblast activity (Stashenko et al. 1992, 1998). The sequence of events resulting in osteoclast stimulation is a network of immunological chain reactions where inflammatory cytokines play a major role. Although alternative theories about the major route in osteoclast activation have been presented, the key fact remains that it is the host's own cells, osteoclasts, that remove the bone around the root tip. Nowadays, removal of bone is understood as an important and necessary defense strategy: bone has a poor capability to defend itself against bacterial intruders, and osteomyelitis might be a result of the spreading of the intracanal infection. That is why bone is removed by the defense system before the infection reaches the periapical tissues. In apical periodontitis the lesion is filled with phagocytes and other defense cells which effectively prevent further spreading of the microbial infection.

_Systemic antibiotics

Use of systemic antibiotics is not a routine part of endodontic treatment of apical periodontitis. On the contrary, antibiotics are only rarely used in endodontics. Minimizing the risk of post-treatment symptoms has been one argument often used when prescribing antibiotics to endodontic patients. However, according to several studies, use of systemic antibiotics has not been helpful in reducing the number of patients with flare-ups or other acute problems after the start of the treatment (for review see: Fouad 2002). Neither is there scientific evidence that systemic antibiotic therapy has a beneficial effect on the long-term prognosis of the treatment of apical periodontitis. There is presently a consensus in endodontics that systemic antibiotics should be used only when general indications for their use are present (Fouad 2002).

Administration of systemic antibiotics should be considered with a spreading infection indicating failure of local host responses, or in cases of known reduced host defense mechanisms that might expose the patient to increased systemic risks (Fouad 2002, Siqueira JF Jr. 2002).

Also, when the patient has a fever, antibiotics should be given. The effectiveness of antibiotic therapy is never fully predictable because of a variety of parameters affecting the outcome. Therefore, the focus must always be on local antimicrobial measures (chemomechanical preparation and disinfection). Whenever there are general symptoms or spreading infection, the patient must be carefully monitored, and referral to hospital must be considered.

_Chemomechanical preparation & irrigation

Manual instrumentation

There is no disagreement on the fact that mechanical cleaning and high quality shaping of the root canal is the most important single factor for successful endodontic treatment. Together with the use of local irrigating solutions with antibacterial activity, the majority of, if not all bacteria in the root canal system will be eliminated. Mechanical instrumentation is a primary means of bacterial reduction in endodontic treatment. Byström & Sundqvist (1981) measured the reduction in bacterial counts cultured from the infected root canal when instrumented with manual steel instruments and saline irrigation. Fifteen root canals with necrotic pulps and periapical lesions were instrumented at five sequential appointments.

Mechanical instrumentation greatly reduced the number of cfu (colony forming units), usually 100–1,000-fold, but the number of bacteria-free root canals increased slowly. Even after five appointments with mechanical preparation and saline irrigation, several canals still showed growth. Corresponding observations were reported also by Ørstavik et al. (1991). Since it has become obvious that mechanical preparation with manual instruments and irrigation with saline (which has practically no antibacterial activity) is unable to predictably produce sterile root canals, focus has been put on the combined effect of instrumentation and strong antibacterial irrigating solutions.

Canal irrigation

Use of irrigating solutions is an important part of effective chemomechanical preparation. It facilitates removal of necrotic tissue and dentine chips from the root canal and thus prevents packing of infected tissue apically in the root canal and into the periapical area. In addition, many irrigating solutions have other beneficial effects. EDTA (ethylene-diamine-tetra-acetic acid, 17% disodium salt, pH 7) is a chelating agent widely used in endodontic preparation. It has low or no antibacterial activity, but it effectively removes the smear layer by affecting the inorganic component of the dentine. Therefore, by facilitating cleaning and removal of infected tissue, EDTA contributes to the elimination of bacteria in the root canal. It has also been shown that removal of the smear layer by EDTA (or citric acid) improves the antibacterial effect of locally used disinfecting agents in deeper layers of dentine (Haapasalo & Ørstavik 1987, Ørstavik & Haapasalo 1990).

Sodium hypochlorite (NaOCl), used in concentrations varying from 0.5% to 5.25%, is a strong antimicrobial agent that is supposed to play an important role in dissolving the organic part of pulpal remnants and dentine. Most importantly, it kills bacteria very rapidly even at relatively low concentrations. Pashley et al. (1984) demonstrated greater cytotoxicity and caustic effects on healthy tissue with 5.25% NaOCl than with 0.5% and 1% solutions. No studies have clearly shown that the stronger solutions have a better antibacterial effect in vivo in the root canal. However, careless use of both NaOCl (in high and low concentrations) as well as EDTA will result in severe pain if they are introduced to the periapical area. Niu et al. (2002) observed the ultrastructure on canal walls after EDTA and EDTA + NaOCl irrigation by scanning electron microscopy. They reported that more debris was removed by irrigation with EDTA followed by NaOCl than with EDTA alone. Byström & Sundqvist (1983, 1985) showed that although 0.5% NaOCl, with or without EDTA, improved the efficiency of preparation, all canals could not be made bacteria-free even after repeated appointments.

Sodium hypochlorite effectively kills bacteria, but is caustic if pressed to the periapical area. In addition, active chlorine may cause damage to the patient's clothes through its strong bleaching effect. Therefore, there has been interest for alternative irrigating solutions that could replace NaOCl. Chlorhexidine gluconate (CHX) has long been used in dentistry because of its antimicrobial properties and its relatively low toxicity. It is also increasingly used in endodontics. Although studies comparing the antibacterial effect of NaOCl and CHX have given somewhat conflicting results, it seems that when used in identical concentrations, their antibacterial effect in the root canal and in infected dentine is relatively similar (Buck et al. 2001, Heling & Chandler 1998, Vahdaty et al. 1993, Ørstavik & Haapasalo 1990). However, CHX lacks the tissue dissolving ability, which is one of the obvious benefits of NaOCl. Waltimo et al. (1999) studied the antifungal effect of combinations of endodontic irrigants and found that the combinations of disinfectants were equally or less effective than the more effective component.

However, it has been shown that in certain concentrations chlorhexidine and hydrogen peroxide have a strong synergistic effect against *Enterococcus faecalis, Streptococcus sobrinus* and *Staphylococcus aureus* (Heling & Chandler 1998, Steinberg et al. 1999).

MTAD is a new irrigating solution with promising antibacterial activity. However, more data will be needed before final evaluation of its antimicrobi-al effect can be done (Shabahang & Torabinejad, 2003; Portenier et al. 2006).

Rotary instrumentation

Use of rotary preparation with nickel-titanium instruments undoubtedly offers several potential advantages. The most obvious of these are probably quality of the apical preparation and efficiency (Fig. 1). However, comparative studies have not always been in favor of rotary instruments when the various aspects of preparation have been analyzed (Deplazes et al. 2001). Ahlqvist et al. (2001) showed that manual instrumentation produced cleaner canals than preparation with rotary instruments. Similar results have been reported by Schäfer et al. (2002). However, rotary nickel-titanium instruments seem to maintain the original canal curvature better, particularly in the apical part of the root canal (Schäfer et al. 2002).

Dalton et al. (1998) compared steel K files and NiTi rotary instruments in removing bacteria from infected root canals with saline as an irrigant. Only about a third of the teeth were made bacteria-free while no significant difference could be detected between the two groups. However, larger preparation diameter of the apical canal produced significant reduction in bacterial counts. Coldero et al. (2002) studied the effect of apical preparation on the number of residual bacteria in the root canal. They concluded that additional apical enlargement to #35 did not further reduce the number of surviving bacteria. However, the size of the original preparation in this study is not given, and it is possible that even #35 is too small of a preparation size to show differences in bacterial elimination. In fact, Rollison et al. (2002) showed that apical enlargement to #50 instead of #35 resulted in a more effective elimination of bacteria in the root canal, although absolute sterility was not obtained.

In a recent study Card et al. (2002) reported sterility in a majority of root canals instrumented by rotary instruments using large apical sizes and irrigation with 1% NaOCl. The instrumentation and bacterial sampling was done in two phases: The first instrumentation utilized 1% NaOCl and 0.04 taper ProFile rotary files. The cuspid and bicuspid canals were instrumented to a #8 size and the molar canals to a #7 size. The second instrumentation utilized LightSpeed files and 1% NaOCl irrigation for further enlargement of the apical third. Typically, molars were instrumented to size #60 and cuspid/bicuspid canals to size #80. All of the cuspid/bicuspid canals and 81.5% of the molar canals were bacteria-free after the first instrumentation as shown by negative cultures from samples obtained from the root canals. The molar results improved to 89% after the second instrumentation. When the molar canals were divided into two groups, one with no visible anastomoses between root canals and one with a complex root canal anatomy, the proportion of sterile canals in the first group was 93% already after the first instrumentation. The results of Card et al. (2002) are indirectly supported by earlier observations by Peters et al. (2001), who studied rotary preparation of root canals of maxillary first molars. They compared the effects of four preparation techniques on canal volume and surface area using three-dimensionally reconstructed root canals in extracted teeth. Micro CT data was used to describe morphometric parameters related to the four preparation techniques. Specimens were scanned before and after canals were prepared using Ni-Ti-K-

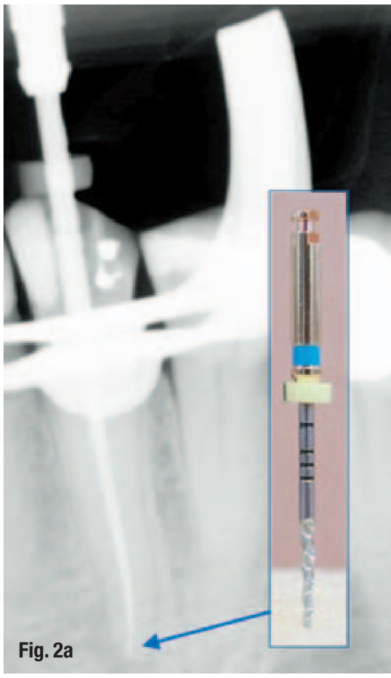

Fig. 2a

Files, Lightspeed instruments, ProFile. 04 and GT rotary instruments. Differences in dentine volume removed, canal straightening, the proportion of unchanged area and canal transportation were calculated in this study (Peters et al. 2001).

The results showed that instrumentation of canals increased volume and surface area. Prepared canals were significantly more rounded, had greater diameters and were straighter than unprepared canals. However, all instrumentation techniques left 35% or more of the canals' surface area unchanged. Whilst there were significant differences between the three canal types investigated, very few differences were found with respect to instrument types. The relatively large proportion of untouched canal walls in molar root canals offers a possible explanation why in the study of Card et al. (2002) it was difficult to totally eliminate bacteria from such canals as compared to canines and premolars.

Apical preparation size

The main goals of mechanical preparation are the following: i) to remove infected tissue from the root canal, ii) to facilitate the use and effectiveness of irrigating solutions, iii) to create sufficient space for effective delivery of intracanal medicaments between appointments, iv) to create sufficient space in the root canal to allow placement of permanent root filling of high quality. Despite these clearly defined and widely accepted general goals for preparation, there is no consensus about the recommended size for the apical preparation in various teeth. Theoretically, optimal apical preparation would require an instrument size equal to or bigger than the largest diameter of the apical canal. This would guarantee that all walls in this critically important part of the canal would be engaged by the instruments. Studies by Kerekes and Tronstad (1977a, 1977b, 1977c) suggested that the final preparation size should be quite high as compared to the sizes often used in practice: #50 to #90 in incisors, canines and premolars, and even in molar curved canals sizes #50 to #60.

These studies also demonstrated that in some roots, such as in maxillary first premolars, it was often impossible to obtain a round apical preparation without perforation of the root as the smaller external diameter of the root was in several cases smaller than the larger internal diameter of the root canal. The same was concluded in another study of maxillary first molars by Gani and Visvisian (1999).

In clinical practice, there are no methods available that would reliably measure the size of the apical root canal. Morfis et al. (1994) studied the size of apical foramen in various tooth groups and found that the largest foramen was in the distal root of lower molars, the average diameter being almost 0.4 mm (#40). Wu et al. (2002) studied if the first file to bind apically would correspond to the diameter of the canal in the apical region. The canals were prepared three sizes larger than the first binding file, and the quality of the final preparation was then analyzed. The result of this study showed that there was no correlation between the first binding file and larger diameter of the apical canal. At present, the typical size of the apical preparation in curved molar canals varies from #20 to #60 in different parts of the world. It is possible that in the treatment of vital pulp (pulpectomy) the size of the apical preparation is not of crucial importance because of lack of microorganisms in the apical canal. However, in the treatment of apical periodontitis apical enlargement may be more important in favor of larger preparation size (Rollison et al. 2002, Card et al. 2002).

However, final evidence of the importance of this to long-term prognosis is still lacking. It is obvious, however, that with size #25 as the final preparation instrument in the apical canal, it leaves the walls in many canals relatively untouched.

The quality of apical shaping and cleaning is affected, not only by the diameter of the last instrument, but also by the taper. For example, in manual preparation, the typical 2% taper in the preparation of #30 gives canal diameters of #32, #34 and #36, 1, 2, and 3 mm from the working length. However, with a size #30 instrument with 9% taper, the corresponding diameters are #39, #48 and #57 (Fig. 2). It has been speculated that the greater taper may facilitate the effect of antibacterial irrigants in the apical canal (Coldero et al. 2002). However, at present there are no studies to show the possible importance of the differences of apical taper.

Working length vs. apical foramen

Anatomic studies about the location of the foramen have demonstrated that it may often exist at a distance of 0–3 mm from the anatomic apex (Burch & Hulen 1972). Using the radiographic apex of the tooth as the only guideline for working length determination would therefore result in over instrumentation in a large number of cases. It is recommended that the working length is determined by use of radiographs and electronic apex locators (Consensus report of the ESE on quality guidelines for endodontic treatment, 1994). In pulpitis treatment, the recommended working length is 1–2 mm short of the radiographic apex. In apical periodontitis, elimination of root canal infection, not the least in the apical canal, is the key to successful treatment. Therefore, in an optimal situation the root canal should be instrumented, disinfected and filled to the level of the coronal side of the apical foramen (Fig. 3) to avoid the possibility of residual microbes surviving in the uninstrumented apical canal (Trope and Bergenholtz 2002).

Over instrumentation, with the possible exception of the smallest hand files of size #06 to #10 for certain situations, should be avoided at all costs because of the following reasons: i) direct physical trauma to periapical tissue, ii) introduction of necrotic canal contents and dead and living microorganisms into the periapical area → persisting infection, periapical actinomycosis,

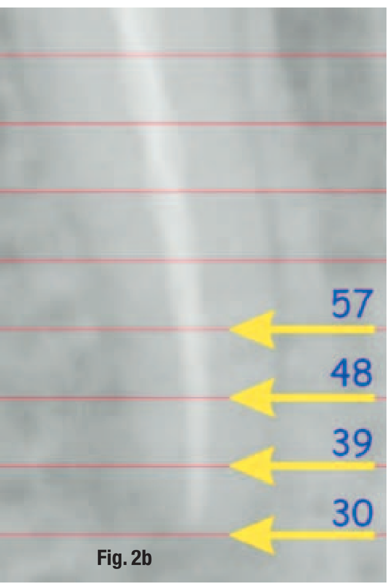

Fig. 2b

iii) bleeding into the root canal → nutrients to intracanal bacteria, iv) growth of the foramen size → better possibilities for bacteria to get nutrients from the periapical area (inflammatory exudate), v) increased risk for extrusion of irrigating solutions as well as overfilling with sealer/gutta-percha, vi) in curved canals (most canals) creation of an oval foramen instead of a round one → poorer apical seal with a round gutta-percha master point (complete compensation with a sealer is theoretical) → hide-out for residual microbes (Fig. 4).

_Disinfection of the root canal by intracanal medication

In pulpectomy, intracanal medication is not an integral part of the treatment because the pulp is bacteria free or only superficially infected. Only when a time limitation has not allowed complete treatment in one appointment, the canal space has been filled, e.g., with calcium hydroxide, to prevent contamination of the canal during appointments. In anatomically demanding teeth, inter-appointment calcium hydroxide may have been selected to facilitate removal of residual pulp tissue or to help to control bleeding.

In the treatment of apical periodontitis, intracanal medication has been recommended to eradicate the microbes that survive instrumentation and irrigation. A variety of different medications have been used for this purpose. These include calcium hydroxide, phenol compounds eugenol and camphorated parachlorophenol (CMCP), iodine potassium iodide (IPI), glutaraldehyde, formocreosol, and pastes containing a mixture of antibiotics with or without corticoids. Byström et al. (1985) showed that calcium hydroxide was more effective as an intracanal medication than CMCP or camphorated phenol and made 34 out of 35 canals bacteria free after four weeks. The effectiveness of inter-appointment calcium hydroxide was also demonstrated by Sjögren et al. (1991) who showed that the 7-day dressing with calcium hydroxide eliminated bacteria that survived instrumentation and irrigation of the canal, while the 10-minute application was ineffective.

However, the outstanding results in canal disinfection by calcium hydroxide have been to some extent challenged by other studies that reported a residual flora in 7–35% of cases after the use of calcium hydroxide (Ørstavik et al. 1991, Reit et al. 1999, Schuping et al. 2000). Peters et al. (2002) reported that the number of positive canals had increased in the period between visits when calcium hydroxide was used as an intracanal dressing. However, the number of microorganisms had only increased to about one percent of the original number. The different results may be partly explained by differences in the clinical cases studied (e.g., intact teeth vs. carious teeth), and in techniques employed in sampling and culturing the microbes.

Retreatment of root filled teeth with apical periodontitis has a lower prognosis than treatment of primary apical periodontitis (for review see Friedman 1998). This may be due to several reasons such as technical complications, difficult anatomy, unlocated root canals, etc. One possible explanation for poorer prognosis is the presence of microflora that is more resistant to normal treatment procedures than the flora in primary apical periodontitis. It is well documented that *Enterococcus faecalis* is the dominant microbe in persistent apical periodontitis (retreatment) (Siren et al. 1997, Molander et al. 1998, Sundqvist et al. 1998, Hancock et al. 2001, Peciuliene et al. 2000, 2001). It is ecologically very tolerant and can survive in water without nutrients for several months (Figdor et al. 2003). It is also more resistant to most locally used disinfecting agents than other endodontic microbes (Haapasalo & Ørstavik 1987). In vitro and in vivo studies have clearly demonstrated that intracanal calcium hydroxide fails to eliminate *E. faecalis* from the infected dentine (Haapasalo & Ørstavik 1987, Molander et al. 1999). On the other hand, no other medication has shown better in vivo effectiveness against *E. faecalis* either (Molander et al. 1999). However, although there is no disagreement about the dominance of *E. faecalis* in retreatment cases of apical periodontitis, the importance of this bacterium for the long-term prognosis of the treatment has not been demonstrated in clinical studies. Other microbes more frequently found in retreatment cases include gram-positive facultative organisms such as *Streptococcus spp., Lactobacillus spp., Actinomyces spp., Propionibacterium spp.,* gram-negative coliform rods and the yeast *Candida albicans* (Peciuliene et al. 2001, Chavez et al. 2003, Waltimo et al. 2003).

Root canal disinfecting agents are extremely effective against even the resistant microbes when tested in a test tube environment. The clearly poorer results in vivo in the root canal indicate the presence of interfering factors that negatively affect the outcome of the disinfection. Haapasalo et al. (2000) and Portenier et al. (2001, 2002) studied the effect of dentine and other substances present in the root canal milieu on the antibacterial effect of calcium hydroxide, chlorhexidine and IPI on *Enterococcus faecalis.* These studies showed that all three disinfectants were negatively affected by the various substances tested, calcium hydroxide being particularly sensitive to the inhibitory effect of a variety of substances present in the root canal. Earlier, Messer and Chen (1984) had reported short duration of the vapors from cotton pellets soaked in phenol compounds. The inactivation of locally used disinfecting agents in the root canal may explain the relative resistance of the root canal microflora. Gram-positive facultative bacteria, which best tolerate the harsh ecological conditions created by the chemomechanical preparation, have been shown to increase their relative proportion of the flora after preparation and use of disinfection even though the total numbers are strongly reduced by the treatment procedures.

At present, it seems correct to conclude that no locally used (inter-appointment) root canal disinfectant can predictably produce sterile canals in the treatment

Fig. 3a

Fig. 3b


Fig. 4a

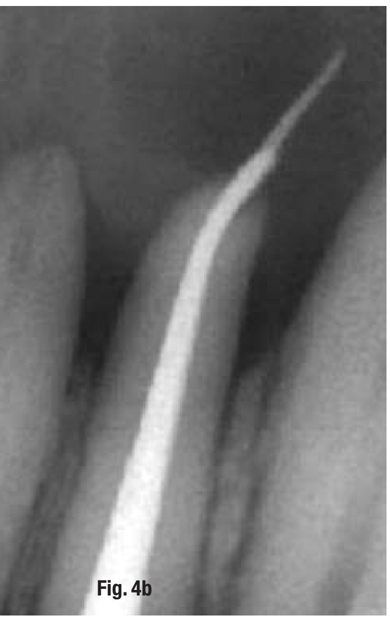
Fig. 4b

of apical periodontitis. However, it is clear from most studies that their use further reduces the number of infecting microorganisms after chemomechanical preparation. Furthermore, calcium hydroxide may help to better remove the residual necrotic pulp tissue at the second appointment as well as neutralize bacterial antigens remaining in the root canal system (Safavi & Nichols 1993, 1994).

Root filling & permanent restoration

Eventually, all locally used disinfectants lose their antibacterial effect over time and/or are washed away from the canal through the apical foramen, e.g., permanent root filling is necessary to secure that bacteria cannot reenter the root canal space after chemomechanical preparation and disinfection. It has also been suggested that the root filling entombs the residual bacteria in the root canal system so that they don't have a possibility of coming in contact with living tissue in the periapical area, which could compromise healing. However, there is very little data available about the effectiveness of entombment of root canal bacteria by the root filling. Katebzadeh et al. (1999, 2000) studied the effect of entombment on healing in dog teeth that were experimentally infected, followed by the development of apical lesions. Some of the canals were obturated at the first appointment after instrumentation and irrigation with saline, while the rest were disinfected before root canal filling with inter-appointment calcium hydroxide dressing. The results showed better healing in cases where calcium hydroxide had been used. However, apical anatomy of dog teeth is quite different from human teeth, which may have affected the results. Hernandez et al. (2001) evaluated the root canal morphology in 72 maxillary fourth premolar and 59 mandibular first molar teeth in dogs. An apical delta was present in all roots (n = 334), and the apical delta represented approximately 12 to 18% of the total root length for all roots. The results of the study by Sjögren et al. (1997) indicate the importance of negative bacterial growth for the prognosis of the treatment of apical periodontitis. However, Peters and Wesselink (2002) found no difference in healing of teeth with apical periodontitis filled after negative or positive culture at the time of filling.

In a new study, Saleh et al. (2004) using infected dentine blocks in vitro showed that root filling with gutta-percha and sealer AH plus or Grossman's sealer was clearly more effective in eliminating *E. faecalis* from the dentine surrounding the root canal than calcium hydroxide one week after filling. Root fillings made of gutta-percha and several other sealers proved to be less effective than calcium hydroxide against *E. faecalis* dentine infection (Saleh et al. 2004). The result is supported by an earlier observation by Ørstavik (1988) that AH 26 was clearly more effective in killing bacteria in dentine around the root canal than other sealers tested. It may be of interest that in the study of Peters and Wesselink (2002), AH 26 was used as a sealer. In future studies comparing the outcome of single-appointment and two-appointment endodontic treatment of apical periodontitis, the type of the sealer has to be taken into consideration.

Finally, all root fillings must be protected by a coronal restoration of high quality. Lack of coronal restoration or a leaking restoration may result in bacterial contamination of the whole root filling in only a couple of weeks. Although the clinical relevance of coronal leakage is not yet fully understood, it is obvious that a considerable part of the need for retreatment is caused by coronal leakage.

_Conclusions

Success in the treatment of apical periodontitis is a result of a combined effort by several different factors contributing to the inhibition of spreading of the infection, elimination of the infection, and prevention of reinfection. A high level of asepsis and chemomechanical preparation with irrigating solutions are the cornerstones of successful therapy. In light of present knowledge, interappointment use of calcium hydroxide dressing in the root canal is a secure way to guarantee effective antimicrobial strategy. However, one-appointment treatment of apical periodontitis may be a reachable goal in the future with more complete understanding of the various key factors affecting the control of the root canal infection._

Editorial Note: Parts of this article were published in Endodontic Topics, 2003,6:29-56 (Blackwell Publishing).

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The New Era of Foramenal Location

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Predictable endodontic success demands accurate determination of and strict adherence to the preparation length of the root canal space in order to create a small wound site and good healing conditions.[1] Each portal of exit (POE) on the root face has biologic significance; this includes the furcal canals of bifurcations and trifurcations, lateral and accessory arborizations and the myriad of apical termini (Figs. 1a–d).

_The ability to distinguish between the innermost (physiologic/histologic foramen) and outermost (anatomic foramen) diameters of the apical terminus is essential to the creation of the *apical control zone*.[2] The *apical control zone* is a mechanical alteration of the apical terminus of the root canal space that addresses the rheology of thermolabile filling materials, offering resistance and matrix style retention form against the condensation pressures of obturation (Figs. 2a–c).

The determination of the instrumentation finishing level is one of the primary factors associated with the resolution of an endodontic infection both clinically and histologically.[3,4] The majority of studies postulate that optimal success rates occur when instrumentation, debridement, disinfection and obturation are contained within the region of apical narrowing (bracketed by the minor apical diameter and apical foramen).[5,6,7] In teeth/roots with apical periodontitis (AP) for example, a millimeter loss in working length can increase the chance of treatment failure by 14%.[8]

Fig. 1a

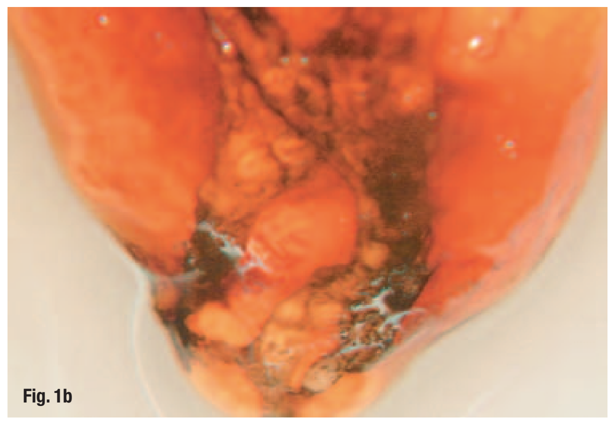

Fig. 1b

The Toronto Study noted that the highest healing rate differential (15%) was observed in teeth with AP that were most likely over instrumented, resulting in transportation of contaminated debris periapically.[9] The evidence is indisputable that electronic root canal length measuring devices provide significantly more accurate results than radiographs[10,11] and therefore offer greater control of the creation of the *apical control zone*.

Fig. 1c

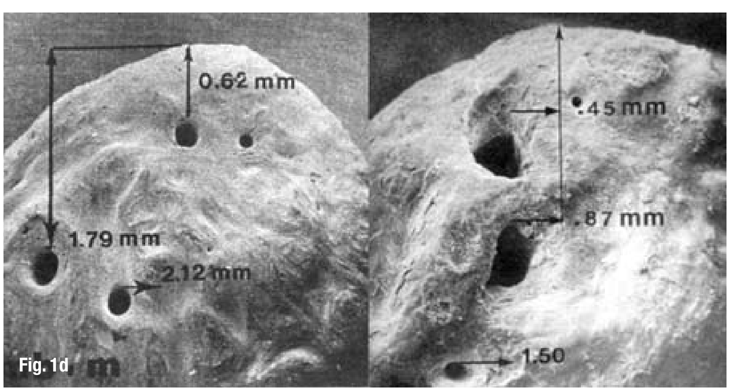

Fig. 1d

Fig. 1a_Arrows indicate multiple POEs associated with the mesial-buccal and distal-buccal apices of a maxillary first molar.

Figs. 1b & c_The complexity of the root canal system has been graphically evidenced since the work of Hess in the 1920s. Radical improvement in materials and techniques are now enabling clinicians to replicate that complexity as evidenced in the cleared specimen (Fig. 1b and the radiograph, Fig. 1c, courtesy of Dr. William Watson).

Fig. 1d_The number, shape and diameter of the physiologic foramen at the root apex mandate the continuing pursuit of excellence in endodontics through increased sophistication in materials and methods and the alliance of scientific innovation and clinical acumen (from Gutierrez and Aguayo, OS, OM, OP June 1995).

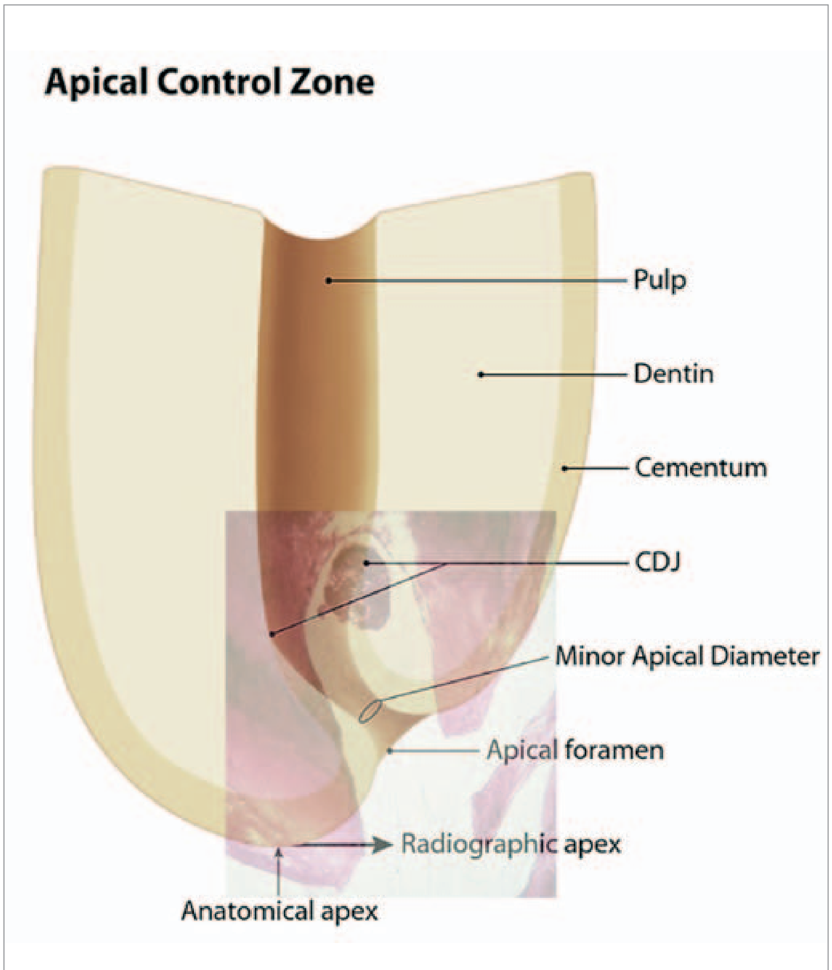

Fig. 2a

Fig. 2a_The definitions of the morphologic entities comprising the regional terminus of the apex are shown diagrammatically with superimposition of the histologic anatomy.

Fig. 2b_Retreatment of tooth #4.6 with K3 nickel-titanium (NiTi) files (G Pack system). The goal is identification of the histologic terminus of the root canal space and the use of variable tapered rotary NiTi instrumentation to create an apical control zone and optimize the seal produced by the new generation of resin thermoplastic root canal filling materials and sealers (courtesy of Dr. Gary Glassman).

In 1942, Suzuki discovered that the electrical resistance (single current source) between an instrument inserted into a root canal and an electrode attached to the oral mucosa registered a consistent value. In 1962 Sunada, using a direct current device with a simple circuit, demonstrated that the consistent electrical resistance between the periodontium and the mucous membrane was 6.5 kΩ (DC Resistance). Through the 1970s, frequency measurements were measured through the feedback of an oscillator loop by calibration at the periodontal pocket of each tooth. This culminated with the efforts of Hasedgawa in 1979 with the use of high frequency waves and a specially coated file that could record in conductive fluids.

In 1983, Ushiyama introduced the voltage gradient method where a concentric bipolar electrode measured the current density evoked in a limited area of the canal. Maximum potential was reached when the electrode was at the apical constriction. The mid '80s saw the development of a relative value of frequency response method where the apical constriction was picked by filtering the difference between two direct potentials after a 1 kHz rectilinear wave was applied to the canal space.

A third generation electronic foramenal locator (EFL) developed in the late '80s by Kobayashi used multi-channel impedance/ratio based technology to simultaneously measure the impedance of two different frequencies, calculate the quotient of the impedance and express it in terms of the position of the electrode (file) in the canal. This formed the basis of the technology used in the Root ZX® (J. Morita USA Inc., Irvine, CA) where no calibration was required and a microprocessor calculated the impedance quotient.

Fourth generation EFLs (Elements Diagnostic, SybronEndo, Orange, CA) measure resistance and capacitance separately rather than the resultant impedance value—impedance being a function of resistance and capacitance (Fig. 4a).

There can be different combinations of values of capacitance and resistance that provide the same impedance, and thus the same foramenal

Fig. 2b

reading. This can then be broken down into the primary components and measured separately, ensuring better accuracy and less chance for error. In addition, the Elements Diagnostic unit uses a lookup matrix (Fig. 4b) rather than making any internal calculations. While calculations take place very quickly, they are still relatively much slower than simply looking up comparative values in a pre-calculated matrix (in the range of 10–20 times slower).

This allows the unit to "crunch" through much more data in a given amount of time, and a larger sample size tends to make the results more accurate. Figure 5 demonstrates the technologic protocol difference between third and fourth generation foramenal locators.

In the course of preparation of this paper, the importance of regulation of battery power was assessed. The Elements Diagnostic circuitry runs at 3.3 volts (common for electronics), which is internally regulated to remain extremely consistent. The battery pack is rated at a nominal 6 volts, and at 7.5 volts with a full charge and no load. As the battery pack is depleted, the voltage decreases to a point where the electronics cannot continue to regulate the operating voltage to such a precise value and therefore the signals sent through the electrodes will not be as reliable either. The device is set to automatically shut off when battery voltage is a little above this threshold. The Root ZX runs on AA alkaline or lithium batteries (mixing battery types should be avoided) and will shut itself off after twenty minutes. There is a bar graph on the face of the unit that indicates residual battery power. The question of the accuracy of signals sent through the electrode is in doubt if the battery power level drops below the first three or four bars (author's observation) (Fig. 7).

Paper point measurement, a foramenal detection technique, has been advocated by Rosenberg.[12] It is designed to determine the point positional location of the apical foramen as well as divulge three-dimensional information regarding the slope of the foramen. A trial paper point is placed 1 mm short of the EFL determined length. If the point is retrieved dry, it is advanced further until fluid is noted. The length of the dry segment of the point is noted. This sequence is repeated as evidenced in Figures 6a–c, and the maximum length of the point that can be placed into the canal and remain dry reflects the orientation of the cavosurface of the apical foramen (Fig. 6d).

There are several basic conditions that ensure accuracy of usage for all generations of foramenal locators:

1) preliminary debridement should remove most tissue or debris obstructions,
2) cervical leakage must be eliminated and excess fluid removed from the chamber as this may cause inaccurate readings,
3) extremely dry canals may result in low readings (long working length),
4) long canals can produce high readings (short working lengths),
5) lateral canals may give a false foramenal reading, and
6) the use with open apices is contraindicated.

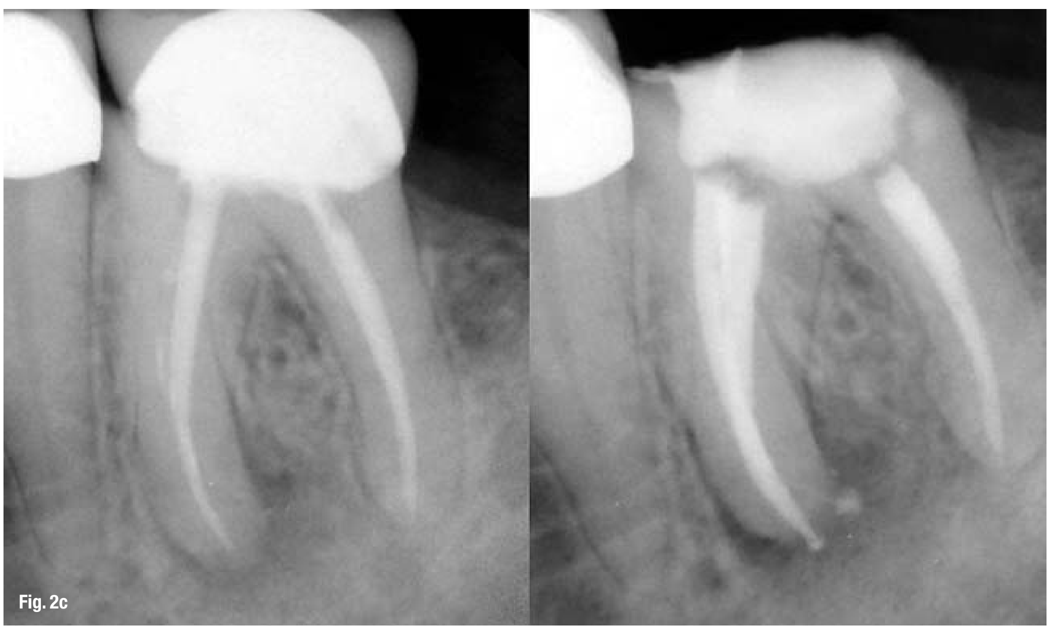

Fig. 2c

Fig. 2c_Retreatment of tooth #3.6 with K3 nickel-titanium (NiTi) files Varible Tip Varible Taper (VTVT) system. The K3 file sequence after the two Orifice Openers/Body Shapers is: #35/.06, #30/.04, #25/.06, #20/.04. In the majority of cases, the #25/.06 or the #20/.04 will reach the desired working length on the first pass. If not, the sequence is repeated from the beginning (courtesy of Dr. Fred Barnett).

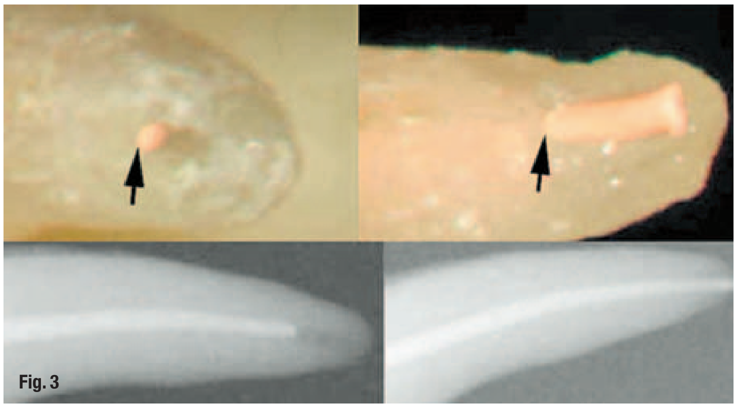
Fig. 3


Fig. 4a

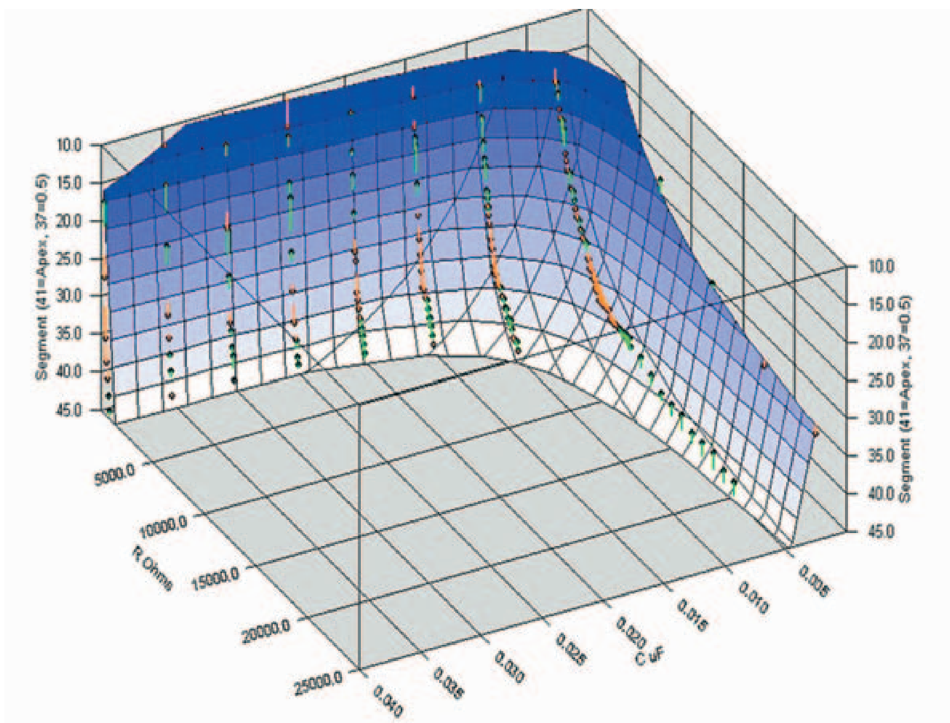

Fig. 4b

Fig. 3_The subtraction approximation technique: the average disparity of 0.5 to 1 mm between the radiographic apex or terminus (RT) and the cavosurface point of exit of the root canal space used as the standard for length determination is fraught with inaccuracy (courtesy of Dr. William Watson).

Fig. 4a_Fourth generation foramenal locator (Elements Diagnostic, SybronEndo, Orange, CA).

Fig. 4b_Lookup matrix generated from in-vivo studies (X-axis capacitance, Y-axis resistance, vertical Z-axis is resultant displayed location in the canal).

The residual fluid in the canal should possess a low conductivity value. In descending order of conductivity these are: sodium hypochlorite (NaOCl 5.25%), EDTA (17%), Smear Clear (SybronEndo, Orange, CA), saline, FileEze® (Ultradent Products, S. Jordan, UT), and isopropyl alcohol. It is advisable to use a crown-down canal preparation technique[13] and take the preliminary electronic measurement using a file that is approximately big enough to bind at the apical constriction.[14]

A second working length measurement is advisable after flaring the coronal and middle thirds as working length shortening occurs when instrumenting curved canals, and this shortening can vary from 0.22 to 0.5 mm. However, once coronal flaring has been done, little change in length occurs.[15,16]

From a medico-legal standpoint, a verification radiograph is recommended at this juncture. It is also advisable to do a final confirmation EFL reading after drying the canal and prior to obturation.

In the case of the third generation Root ZX (Fig. 7), the working length of the canal used to calculate the length of the filling material is actually somewhat shorter. The length of the canal up to the apical seat (i.e., the end point of the filling material) is found by subtracting 0.5 to 1.0 mm from the working length indicated by the 0.5 reading on the meter. The meter's 0.5 reading indicates that the tip of the file is in the vicinity of the apical foramen (i.e., an average of 0.2 to 0.3 mm past the entrance to the apical constriction towards the apex). The disparity between the EFL reading of such units as the Ultima EZ and the Root ZX is demonstrated to be the +0.5/−0.5 position indicated by the 0.5 reading on the meter. This finding has been consistently verified by numerous investigators.[17,18]

A recent investigation of the fourth generation EFL, the Elements Diagnostic (Sybron-Endo, Orange, CA) demonstrated an unprecedented level of accuracy in usage. Length calibrations were performed on teeth to be extracted, the files cemented to position and the teeth cleared for microscopic examination.[19]

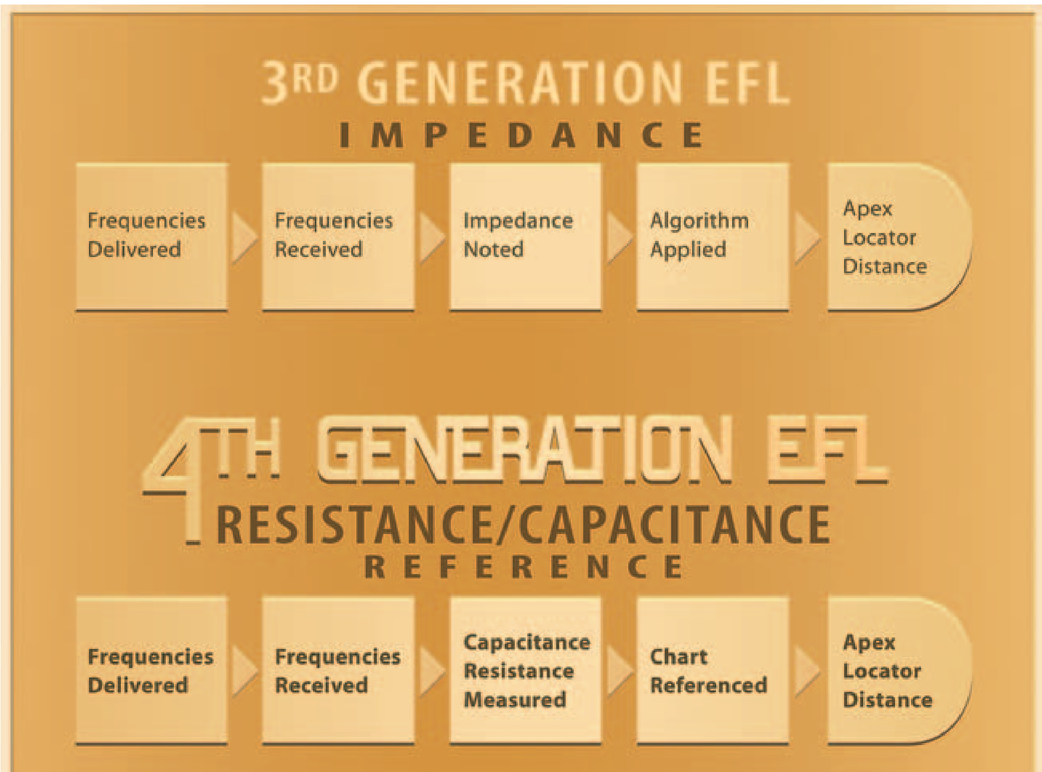

Fig. 5

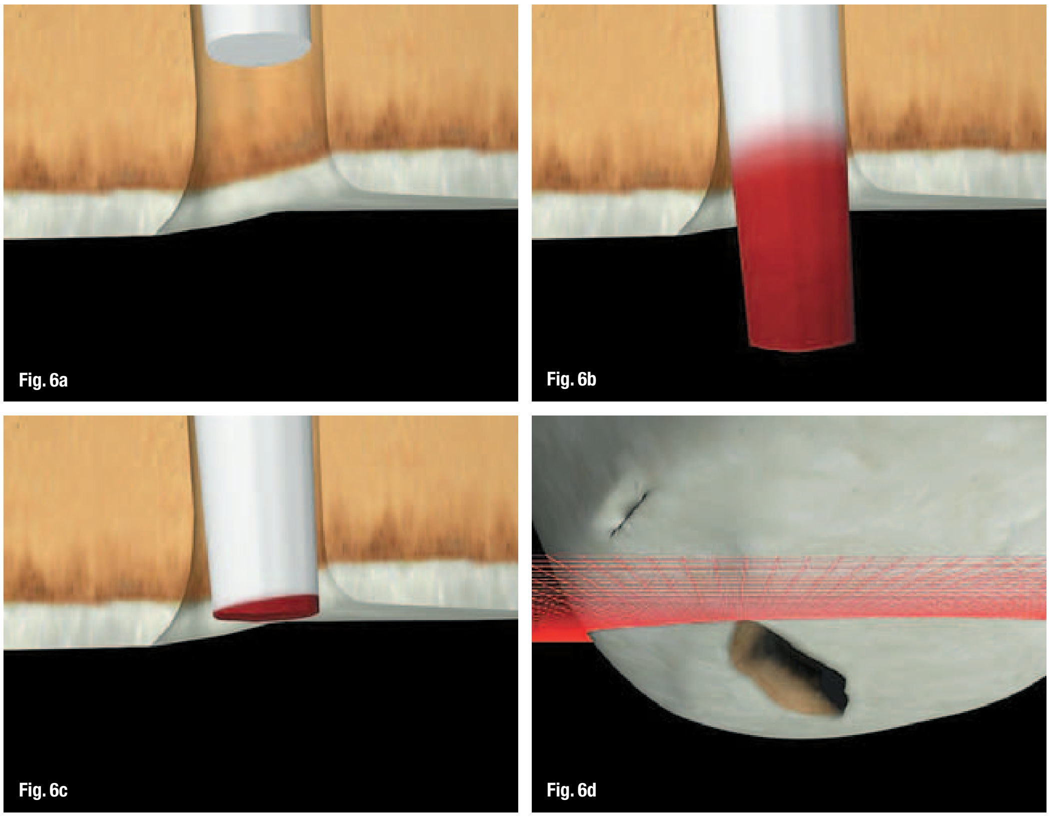
Fig. 6a Fig. 6b Fig. 6c Fig. 6d

Fig. 5:_The graphic shows the technologic difference between the operation of third and fourth generation foramenal locators.
Fig. 6a_The paper point is introduced coronal to the level of the EFL determination. As it is shy of the cavosurface of the canal terminus, it should remain dry (courtesy of Dr. David Rosenberg).
Fig. 6b_Hydrostatics will cause periapical fluids to accumulate on the overextended paper point (courtesy of Dr. David Rosenberg).
Fig. 6c_The angle of the paper point discoloration reflects the three-dimensional orientation of the cavosurface of the apical foramen (courtesy of Dr. David Rosenberg).
Fig. 6d_The terminus of the canal is not a point in space. It is a multidimensional, topographically diverse plane (courtesy of Dr. David Rosenberg).

In 22 out of 22 cases where the reading of the file was taken to 0.0 or into the minus numbers and withdrawn to the 0.5 mark on the scale, the file terminus was consistent with the position of the apical constriction (Fig. 8a). When the file was cemented after going down to the 0.5 mark, in 20 out of 24 cases, the file was positioned a distance of 0.5 mm from the external foramen (Fig. 8b). Of note was the finding that when the device displayed a minus number, the file was always beyond the apical constriction and, in most cases, out of the root structure (Fig. 8c).

Fig. 7

Fig. 7_The Root ZX is a fully automatic, self-calibrating root canal foramenal locator.

_Conclusion

Evolutionary technologic sophistication is the hallmark of all scientific and clinical endeavor. Endodontics is the bedrock of all comprehensive care. As such, it is imperative that predictable endodontic success is projected as close to 100% as biologically possible.

Outcome assessment studies indicate that foramenal position is a pivotal factor, if not the pivotal factor in the most favorable end result. New modes of debridement and disinfection are constantly arriving in the endodontic armamentarium. The fourth generation of foramenal locators will ensure that their usage in evolutionary endodontic protocols is optimized._

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Fig. 8a_When the file glide path is stopped at 0.5 on the digital display, the unit's accuracy in determining the apical foramen is less than 85%.

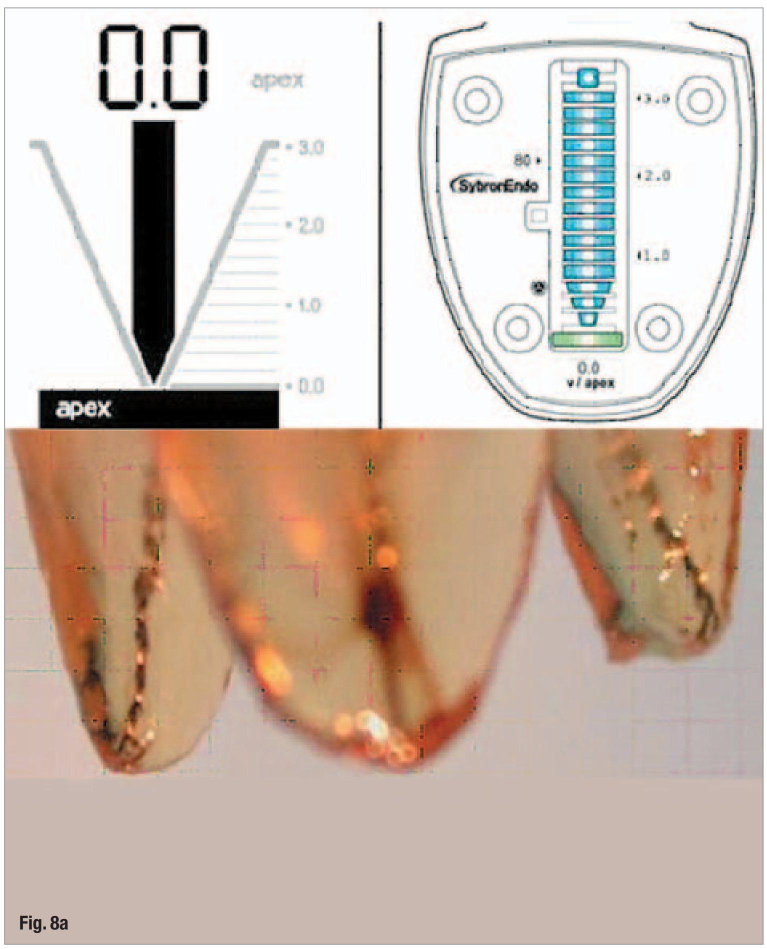

Fig. 8a

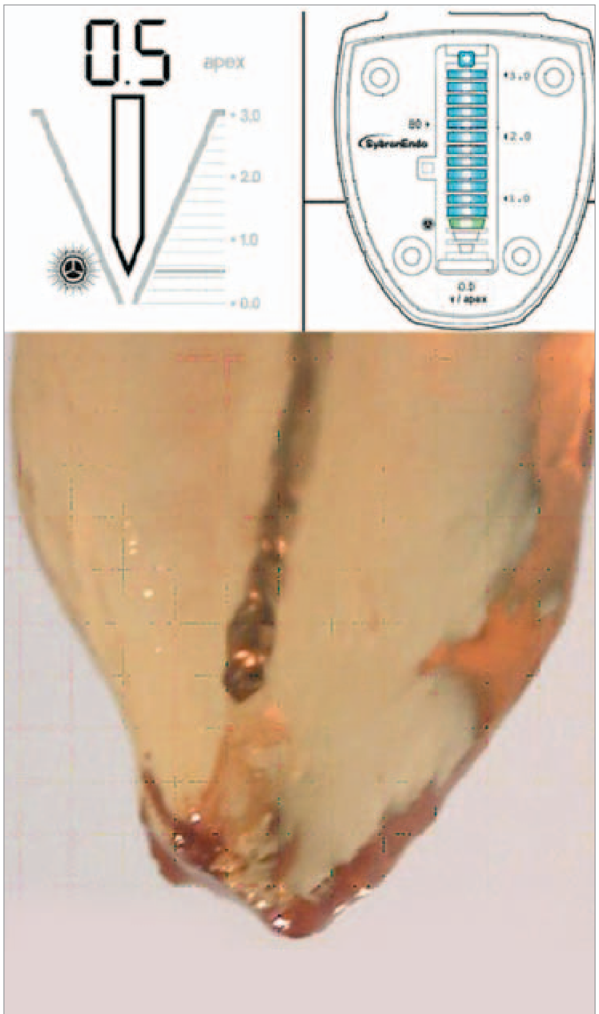

Fig. 8b

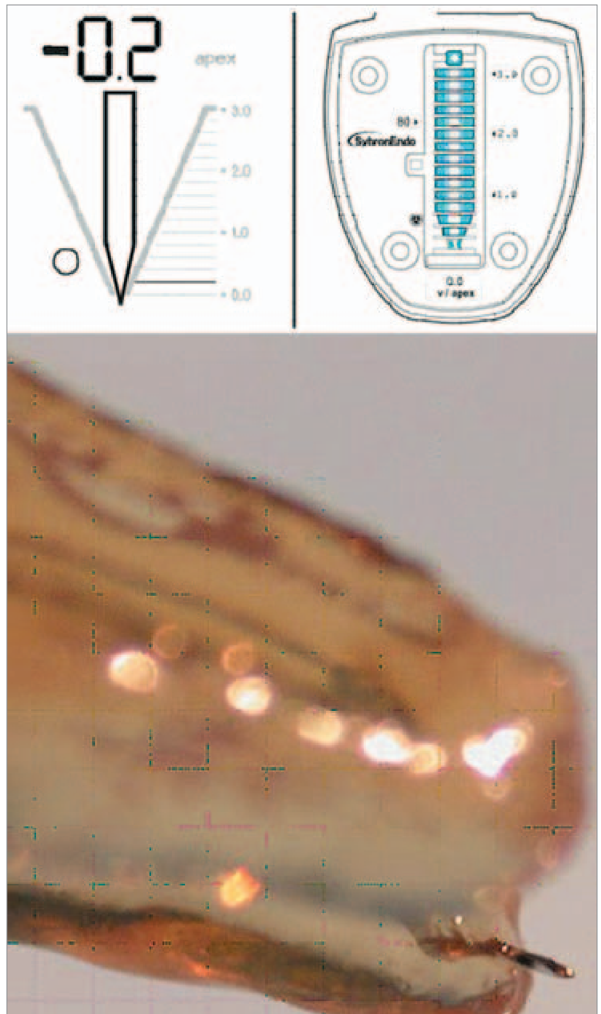

Fig. 8c

Fig. 8b_When the file reaches the periodontal ligament, the digital display shows 0.0. When the file is withdrawn 0.5 mm, an instrumentation terminus point consistent with the apical constriction was the result 100% of the time.

Fig. 8c_When the file glide path is extended into a negative reading on the display, the file was out of the canal in all cases.

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Principles of Endodontics: Trepanation and Optical Control

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In recent years, endodontics has experienced a noticeable upswing within the spectrum of dental maintenance. Trepanation and initial representation of the canal entrances are the most important steps, and also often the most time consuming.

_Compromised treatments during root canal preparation are usually the result of an inadequately executed trepanation opening. Optical aids such as magnifying eyeglasses and an operating microscope facilitate the search for canal entrances. A prerequisite for accurate blur-free imaging is an oral mirror with reflective surfaces.

_Trepanation

Root canal treatment begins with the trepanation of the tooth under a rubber dam. First, straight-line, generous access must be prepared. Difficulties during instrumentation of the root canal are usually the result of inadequate trepanation and a lack of straight-line access to the root canals. The entrance to the root canal must be accessed for examination with the help of a mirror.

Subsequent use of magnifying eyeglasses is also warranted. Mistakes during the shaping of the trepanation opening will bring with them a wealth of difficulties during the entire endodontic procedure. A lack of straight line access to the root canal entrances can lead to a straightening of the curved root canal or, most unfortunately, to a perforation.

In order to shape the trepanation opening, knowledge of the tooth and root canal anatomy is vital as the trepanation opening will give an enlarged image of the pulpa cavum.

At the outset, root canal treatment includes complete removal of all carious lesions together

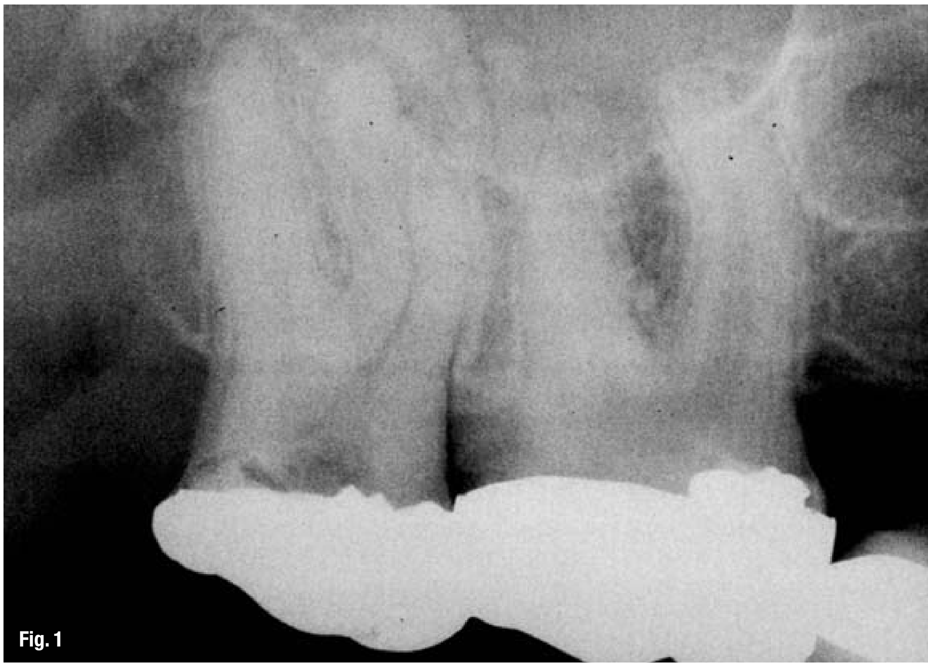


Fig. 1

Fig.1_Pain sensitive upper first molar with massive secondary caries in the distal. The posterior second molar has been trepanned and is to be extracted.

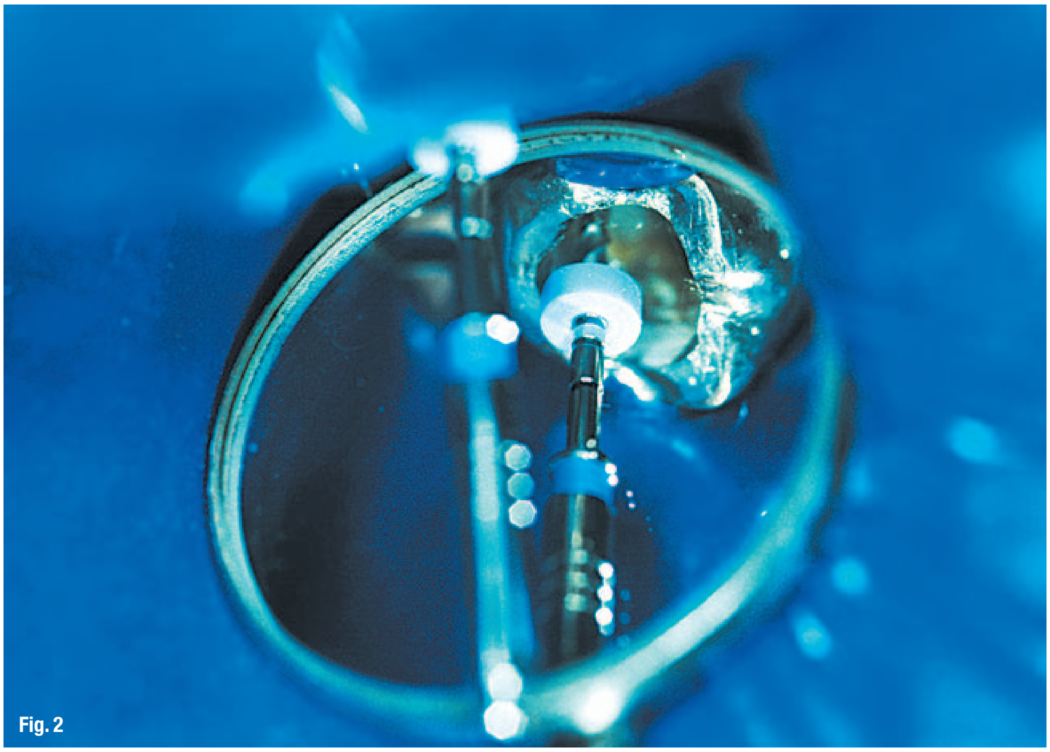


Fig. 2

Fig. 2_Overview after trepanation and exposure of the canal shows the exact optical visualization with the aid of an oral mirror with reflective surfaces.
Fig. 3_The root canals are dried (Fig. 4) after sufficient rinsing.

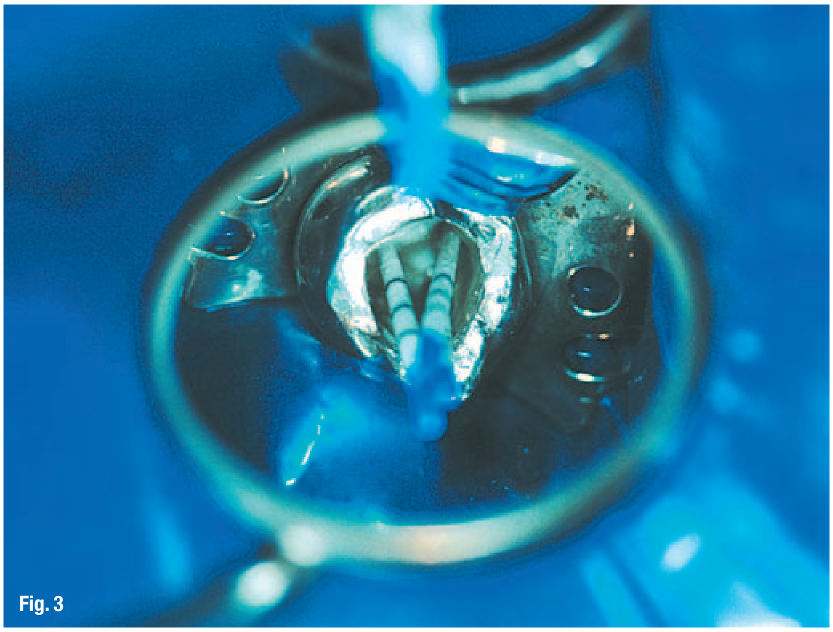


Fig. 3

with any defective prosthetic materials. This measure prevents a penetration and, with it, contamination of the root canal by bacteria. In the long term, bacteria can cause endodontic failure—they penetrate into the dentin tubules, establish themselves there and multiply relatively unrestrained. The possible result is a periapical inflammation with destruction of the bone.

_Opening the pulpa cavum

In order to prevent a perforation or excessive preparation on the cavity floor, the length of the diamond file can be determined from an X-ray. H. Martin's Endo Access Bur (Dentsply Maillefer) is a sensible combination of round and tapered diamond instruments for the whole trepanation. If the canal entrances cannot be located, one takes one's bearings from the largest root canal. The crown pulp floor offers indications to the number and positioning of canal entrances through variations in shading, fine lines and indentions, but the roof must first be completely removed.

Staining the cavity floor with methylene blue is also recommended. After applying a few drops of color, any excess is carefully sprayed off and the cavity floor dried. Thus, better differentiation of the canal entrances against the dentin is possible, as well as localization of fracture lines that allow bacteria to penetrate. The outlines of the endodontic access cavity correspond to the outline of the pulp chamber roof.

_Straight-line access

After initial penetration of the pulp chamber roof by way of the palatal canal entrance, the extension is completed. In the maxilla, the position of the palatal root canal of the molars is an aid in locating the other canal entrances. The diamond file is moved buccally once contact has been made with the pulp chamber floor in order to remove the overhanging roof and expose the mesial and distal buccal canals. Final preparation is with a smooth-tipped diamond file. The cavity is prepared with a slight divergence.

The final form facilitates unhindered access to all root canals. Only then is straight-line introduction of the root canal instruments possible. As many root canals are curved at the onset of the coronal portion, the cervical guide and the coronal pulp chamber may need to be removed carefully. If the pulp chamber is difficult to locate, preparation is made to a depth of 2 mm into the dry cavity with a slow action access bur Size 1, in the direction of the presumed canal entrances.

_Probing the root canals

After penetration of the pulp chamber roof and preparation of the access cavity, the root canal entrances must be probed. With the aid of an endoprobe, it can be determined whether all the dentin has been worn away. Visually aided by magnifying eyeglasses with 6–8 times magnification, and an oral mirror with reflective surfaces, an examination should be made as to whether unhindered access to the canals has been prepared. The canal entrance is explored with a DG16 probe (Dentsply Maillefer, HuFriedy and others). If the probe becomes lodged, a Hedström file size 15 is used to examine whether this is a root canal.

Only after this is the area at the entrance slightly widened. Narrow root canals are widened starting from the coronal portion before deep preparation can begin. With the assistance of a chelat imager (for instance, File Care: EDTA and carbamideperoxide), the root canal is widened in stages with an introfile. After the passage has been freed can the straight coronal root canal areas be prepared with a Gates-Glidden drill. Finally, trouble-free instrumentation of the whole root canal is possible.

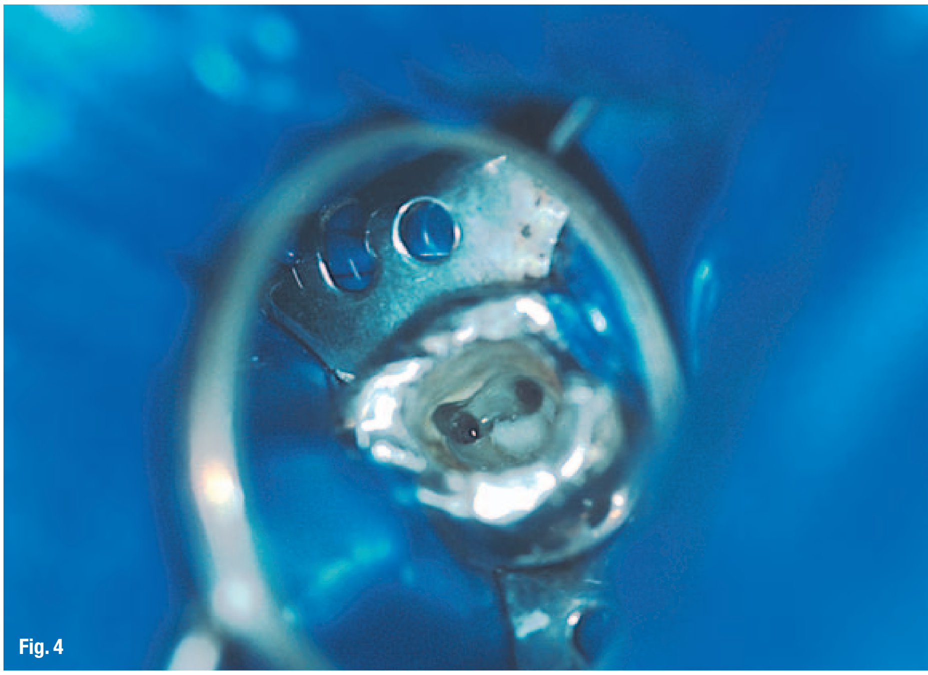


Fig. 4

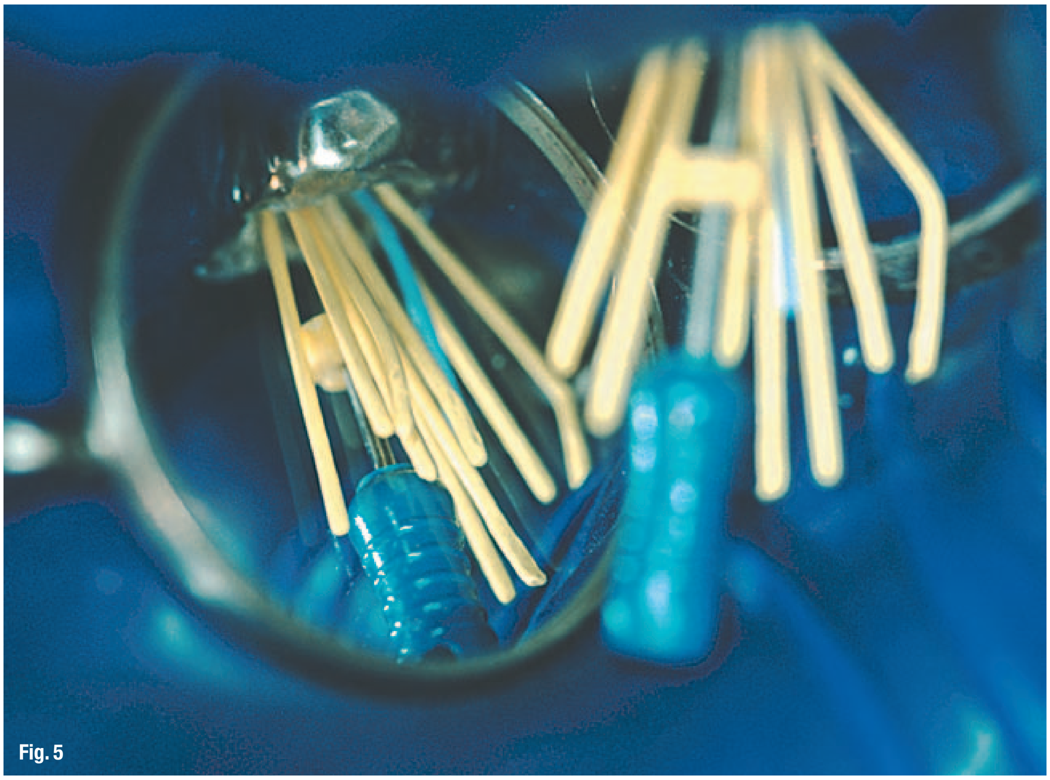
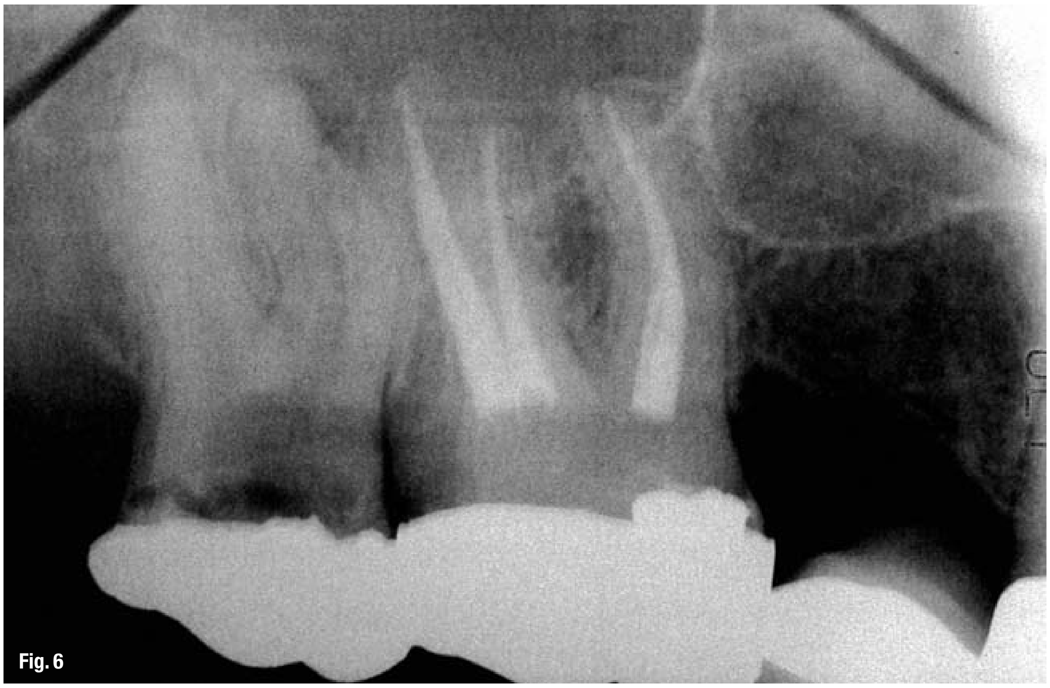


Fig. 5

Fig. 4_Optical control of the completed root canal preparation by means of an adequately enlarging mirror, here as overview with an HR-Front (Roder-Dental) oral mirror.
Fig. 5_If there is no pain, a gutta percha filling can be done in the same session.

Fig. 6_X-ray control of the successful root canal filling to be followed up by restoration of the bridge construction.



_Failures & optical control

Overlooked root canals are the primary cause of endodontic failures. Lower incisors have two roots canals in 40% of cases, but in only 1% of cases is there a separated apical foramen. Approximately 84% of first and 58% of second upper premolars show a further root canal. Furthermore, 8% of first premolars have three or more primary canals.

Based on the embryonic development, the mesio-buccal and mesio-palatal root canals of the upper first molar originally have one main canal. During development, extensions for invagination and storage of hard tissue establish themselves with the result that the mesio-buccal root remains underdeveloped and is partially or completely obliterated.

If there is a failure with the upper molars, a likely cause is insufficient instrumentation with canals and foramina remaining untreated. As an example, according to the investigative method used, the presence of a fourth root canal in the first upper molars can vary from 19–77%, and in the second maxillary molars from 1–38%. More recent studies even show two root canals in the mesio-buccal root in 90% of first and 70% of second upper molars, which means that the majority of these teeth have four root canals. In 52.4% there were two separate canals that co-joined shortly before the apex, 33% had two separate canals. In 4.8% there was a canal that divided apically into two separate canals. A mesiopalatal canal entrance with a diameter of 0.49 or 0.42 millimeters was revealed in 81% of first molars and in 59% of second molars.

_Clinical recommendations

Undesired failures are caused by sometimes unpredictable canal anatomy. In order to keep these to a minimum, a sufficiently large trepanation opening is necessary with good visibility control provided by specialist oral mirrors and magnifying eyeglasses, complemented by solid X-ray evaluations, also in excentric visualization.

The opening is made in the region of the largest and most easily located canal. From there the cavity is prepared in its entirety. Indentations and discolorations on the floor of the cavities are important indications for further canals._

_author info roots

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Endodontic Obturation Utilizing Adhesively Bonded Obturator & Post Systems

Author_ Gregori M. Kurtzman (DDS) & J. Anthony von Fraunhofer (PhD), U.S.A.

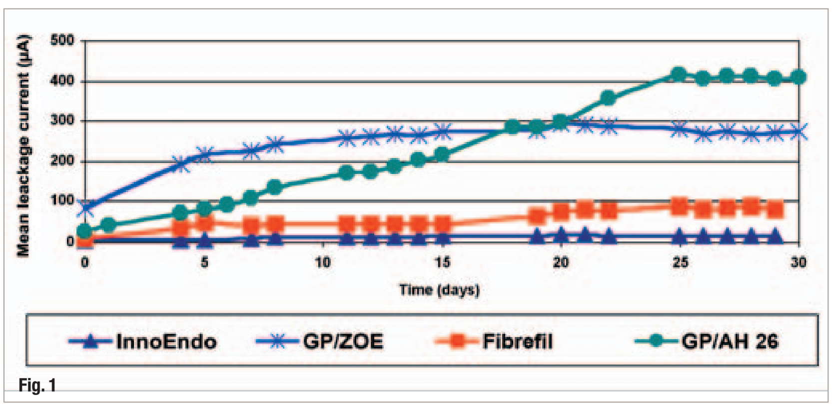
Endodontic therapy provides opportunities to maintain teeth in function and improve the health of the dentition. The long-term prognosis for endodontically treated teeth is greatly influenced by how well the coronal and apical seal are achieved.

_Reinfection can result from coronal leakage through temporary fillings to the apex and may be a significant contributing factor to endodontic failure. Khayat[1] found that significant coronal dye and bacterial leakage following exposure of sealed root canals to artificial and natural saliva occurred within 30 days through to the apex.

Root fracture, another reason for endodontic failure, may result from forceful obturation techniques such as lateral or vertical condensation of gutta percha.[2–4] Lateral and vertical condensation with zinc oxide and eugenol (ZOE) or epoxy sealers, which has been the standard obturation method, have demonstrated high fracture rates. A study by Meister et al.[5] suggested that excessive force during lateral condensation of gutta percha resulted in 84.38 % of the fractures noted in a study of 32 cases of vertical fracture. In contrast, obturation with a single cone of gutta percha and a passive fit with a strong resin sealer resulted in more favorable results.[6]

This communication reports on the clinical use and in vitro studies performed with a fiber-reinforced obturator combined with an adhesive and sealer. These materials are available as Fibrefill (Pentron Clinical Technologies, Wallingford, CT), and InnoEndo (Heraeus Kulzer, Armonk, NY) which strengthens the root structure, decreases apical and coronal leakage and provides anchorage for a restorative core.

Fig. 1_30-day leakage behaviour of fiber obturators compared to conventional obturation materials.



_Apical & coronal leakage

Two factors that influence the seal of the canal are the obturation method and the sealer. Single cone techniques were significantly more effective than lateral condensation techniques based on measurements of the length of dye penetration.[7] The single cone procedure provided an adequate apical seal against dye penetration, sealing the apical portion passively. Leakage was greatest in the laterally condensed samples with leakage most significant in the first 3 mm from the apex.[8]

Carrier delivered gutta percha was found to be superior to the lateral condensation technique in terms of both core/sealer ratio and dye leakage.[9] Condensation techniques (lateral and vertical) may remove sealer from the canal walls during the procedure so forceful obturation may not only increase vertical fracture potential but decrease the sealability of the obturation.[10] It was also noted that cold lateral condensation has a higher proportion of specimens with leakage in canals with curvature greater than 20 degrees than that in canals with curvatures less than 20 degrees. Therefore, gutta percha delivered to the apex in less curved canals had lower leakage.[11] Hence the carrier-delivered gutta percha will allow better placement in the canal and improve sealability. The drawback is that the carrier or a portion of it needs to be removed in order to restore the tooth, possibly disrupting the apical seal in the process.

Although warm lateral condensation resulted in a poor obturation, it was the only thermoplasticized technique analyzed that did not produce significant volumetric changes between 0 and 30 min. All the other thermoplasticized filling techniques showed significant shrinkage during cooling.[12] Filling of the canal with warm gutta percha may show a lower dimensional stability over time than using cold gutta percha. Comparison of the dimensional stability of warm and cold gutta percha found a much higher permanent deformation in warm gutta percha (10 times that of the cold gutta percha) as well as having a variance in dimensional stability (+5.50 to +7.20%).[13,14]

Endodontic sealers can be divided into different groups based on the main component of the sealer, namely calcium hydroxide [$Ca(OH)_2$], zinc oxide and eugenol (ZOE) and epoxy resins. Significantly less leakage has been reported with calcium hydroxide-containing sealers than with the traditional zinc oxide-eugenol sealers.[15] Comparison of calcium hydroxide sealer with zinc oxide and eugenol sealer found $Ca(OH)_2$ has a sealing ability comparable to ZOE and can withstand long-term exposure to tissue fluids without significant leakage.[16] Both laterally condensed gutta percha with $Ca(OH)_2$ as the sealer, or a single master cone with a $Ca(OH)_2$ paste sealer, demonstrated sealing ability.[17]

The greatest dimensional changes with regard to sealers take place within the first four weeks. Zinc oxide-eugenol based sealers generally showed shrinkage ranging from 0.3 to 1%. The epoxy-based materials, AH 26 and AH 26 silver-free, exhibited a large, initial expansion of 4–5%. Calcium hydroxide based materials show only minor variation round a baseline value of –0.14 to +0.19%. Bacterial penetration may be a real threat from sealers shrinking as little as 1%.[18]

Endodontic failure has been associated with coronal leakage within the canal system following obturation. No matter what our intentions are following obturation of the canal system in the tooth, patients may delay restoration of the tooth that has been treated. Financial and time constraints often influence when the final restoration is completed.

Seventy extracted single-rooted mandibular premolars were studied to determine the length of time needed for bacteria present in natural human saliva to penetrate through three commonly used temporary restorative materials and through the entire root canal system obturated with the lateral condensation technique.[19] The average time for broth contamination of access cavities closed with gutta percha (7.85 days), IRM (12.95 days) and Cavit-G (9.80 days) indicate that even in the short periods of time normally seen between visits, complete leakage may result.

Another important consideration with regard to the ability of temporary restorations to prevent coronal leakage is how the material behaves under mechanical load and thermocycling. Non-adhesive temporaries show an increased percentage of marginal breakdown and increased microleakage after thermocycling and loading. There was no significant improvement with increased thickness of the temporary material.[20–22]

Studies confirm that a sound coronal seal is of paramount importance to the overall success of root canal treatment.[23] Regardless of the obturation method, the best rule for successful treatment is that a properly cleaned, shaped, and obturated tooth should be permanently restored as soon as possible.[24] However, between visits, an adhesive material will prevent leakage and contamination of the canal.

A significantly better seal (in both the apical and coronal directions) can be achieved when using a dentin bonding agent and resin obturation material.[25] The better the adaptation and penetration of the dentinal walls, the less leakage is to be expected along the entire root length.

An electrochemical leakage study completed at the University of Maryland, Baltimore College of Dental Surgery Dental School looking at fiber obturators compared to conventional obturation materials found significant leakage resistance. No statistical difference was found between the Fibrefill group (Pentron Clinical Technologies, Wallingford, CT) and the Inno-Endo group (Heraeus Kulzer, Armonk, NY). But a statistically significant difference was demonstrated

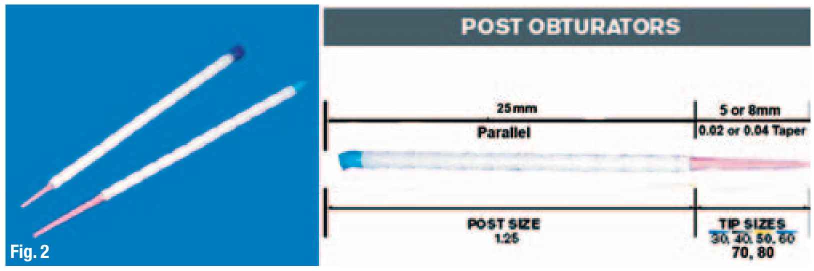


Fig. 2_Fibrefill post style obturators. (Pentron Clinical Technologies).

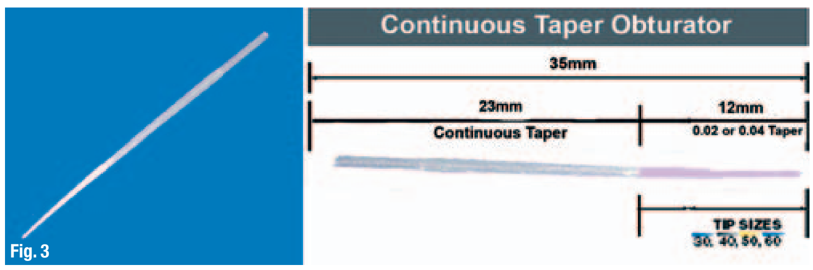


Fig. 3_Fibrefill continuous taper style obturators. (Pentron Clinical Technologies).

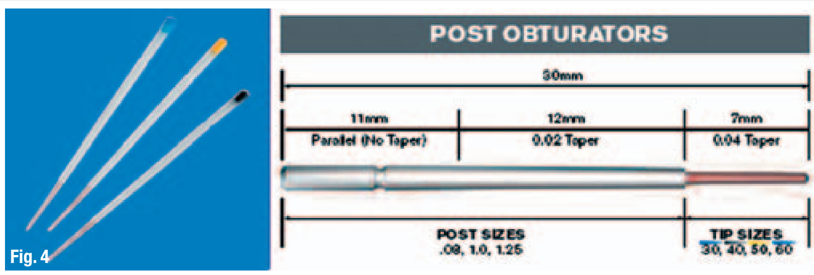


Fig. 4_InnoEndo post style obturators. (Heraeus Kulzer).

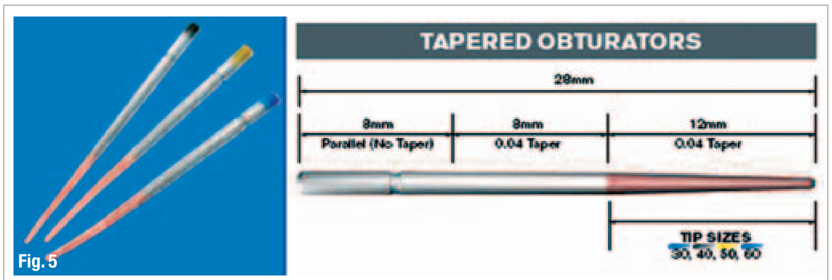
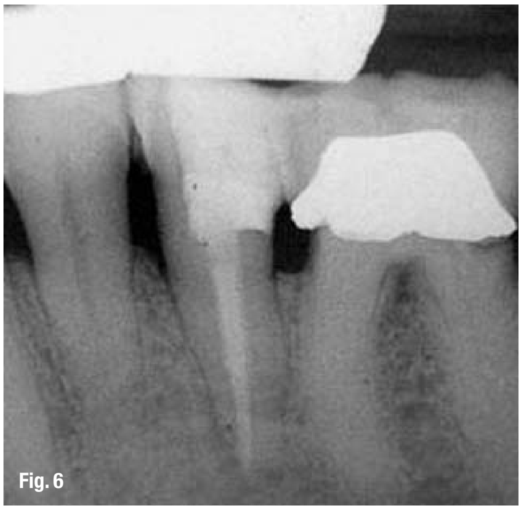


Fig. 5_InnoEndo taper style obturarors. (Heraeus Kulzer).



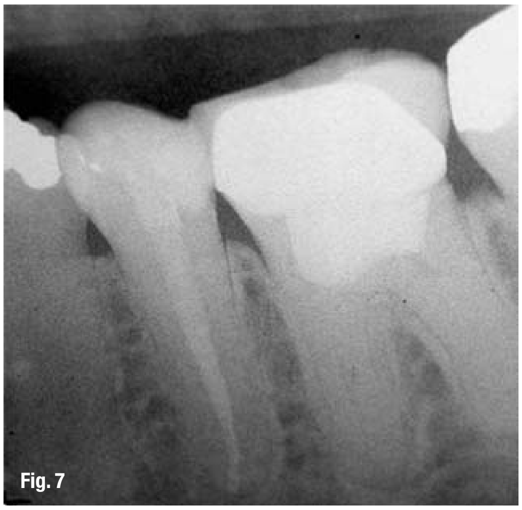


Fig. 6_Obturation of tooth 20 with a Fibrefill parallel post obturator with final size 30 with a 5 mm apical terminal portion.
Fig. 7_Obturation of tooth 20 with a Fibrefill parallel post obturator size 50 with a 5 mm Resilon terminus.

between these fiber obturator groups and obturations performed with gutta percha with ZOE (zinc oxide and eugenol) sealer or AH-26 sealer, Figure 1.[26]

_Root reinforcement

Endodontically treated teeth are under increased possibility of vertical fracture. Most fracture lines occur in a bucco-lingual direction and instrumentation of the root canals significantly weakened the roots.[27] Lertchirakarn found that teeth which had the canal filled with an adhesive material (glass ionomer) resisted vertical fractures.[28] The fracture force for roots obturated with glass ionomer was significantly higher than that for tooth roots obturated with epoxy resin or ZOE sealer. The results suggested that adhesive sealers strengthen endodontically treated roots and may be used for weak roots, which are likely to be susceptible to vertical root fracture. Significant strengthening of the root structure could be demonstrated by use of adhesive sealers. This finding was supported by Trope, who found that bonded resin techniques significantly strengthened teeth against fracture.[29]

_Fiber obturation systems

Two fiber obturation systems are currently available on the market. One is the Fibrefill System (Pentron Clinical Technologies, Wallingford, CT) which offers a parallel sided fiber post with either a 5 or 8 mm gutta percha terminal portion or a tapered obturator with Resilon terminus, Figure 2. The taper obturator has a continuous taper and is available in either .02 or .04 tapers with a 12 mm Resilon terminus, Figure 3.

The InnoEndo system (Hearaus Kulzer, Armonk, NY) offers a post version and a taper version of their fiber obturators. The post version has a 7 mm Resilon terminus with a .02 taper segment for the subsequent 12 mm turning to a parallel-sided post for the remaining 11 mm, Figure 4. The tapered version is available in a 0.04 taper with a 12 mm Resilon terminal portion continuing as a 8 mm tapered fiber portion before becoming a parallel-sided portion for the remaining 8 mm, Figure 5.

Both systems consist of an adhesive bonding agent, a light-curable $Ca(OH)_2$ based resin sealer and a fiber post with an apical terminus of Resilon. A primer included in the system is a self etching two-bottle liquid that allows the sealer to chemically bond to the canal dentin. The primer is a self curing adhesive.

The root canal sealer (RCS) is a radiopaque dual cure resin sealer that contains UDMA, PEGDMA, HDDMA, and BISGMA resins with silane treated barium borosilcate glasses, barium sulfate, and calcium hydroxide together with polymerization initiators. The material is supplied in a two-barrel automix syringe. Once mixed, it provides a working time of 10–12 minutes and a self cure setting time of approximately 25 minutes. It provides a depth of light cure of 1.7 mm with a final Barcol hardness of 80. Biocompatibility was shown in agar diffusion testing at Loma Linda University for RCS and its components.[30]

The fiber obturator is a resin and glass fiber post with a terminal Resilon tip. The Resilon terminus is available either in 5 or 8 mm lengths for the parallel Fibrefill, 12 mm for the continuous taper Fibrefill, 7 mm for the post style InnoEndo and 12 mm for the InnoEndo taper style obturators. The diameter of the Fibrefill obturators available are sizes 30, 40, 50, 60, 70 and 80 in either a 0.02 or 0.04 terminal taper. Whereas, Fibrefill continuous taper obturators are available in sizes 40, 50 and 60 in the 0.02 taper and sizes 30. 40, 50 and 60 with a 0.04 taper. The InnoEndo post style obturator is provided in a choice of a .8 mm, 1.0 mm or a 1.25 mm in sizes 30, 40, 50 and 60 with a 0.04 terminal taper. A taper version of the InnoEndo obturator is also available with a 0.04 taper in sizes 30, 40, 50 and 60.

The canal is instrumented using hand instruments, rotary NiTi files or a combination, and cleaned using standard irrigation methods. An obturator is selected that matches the final apical diameter of the canal. Parallel or post style obturators may require additional use of rotary peeso drills to develop final shaping on the coronal two-thirds of the canal to accommodate the obturators. But in canals where increased strength may be required, these may be the obturators of choice. The canal is irrigated, disinfected and dried.

A drop of primer A and B are mixed in a dish and applied within the canal using the kits' spiral brush and the mix is introduced into the canal to the apical third. An automix tip is placed on the RCS syringe and the sealer is introduced into the canal with a lentulo or other sealer applicator. The obturator is gently seated to working length, allowing excess sealer to be expressed coronally. The dual cure RCS is light cured to stabilize the coronal portion. Additional primer is applied on the protruding portion of the obturator post and over any dentin and enamel that will be in contact with the core build-up material.

A resin core build-up material is then injected around the post, filling the coronal portion of the tooth. The material is light cured and ready for either crown preparation or dismissal of the patient. The result is a durable restoration with a resin/fiber reinforced root that is optimally sealed apically and coronally. Leakage was tested with extracted single-rooted human teeth. There was significantly less coronal leakage for the fiber obturator specimens than the lateral condensation group.[29]

_Case presentations

Case 1

An 85-year-old female patient presented with carious breakdown of the distal, buccal, lingual and occlusal surfaces of the lower left second premolar (tooth 20). The tooth was asymptomatic and the patient indicated that she "had lost an old filling". Pulpal exposure was noted on clinical examination and a periapical area was observed radiographically.

Local anesthetic was administered and isolation was achieved with a rubber dam. Decay was removed and the working length established with a number 15 K file and electronic apex locator. Working length (WL) was determined to be 22 mm. The canal was instrumented sequentially with size 20 and 25 K files. The canal was then irrigated with 17% EDTA, followed by 5% NaOCL solution. The canal was shaped and enlarged with K3 files (Kerr Sybron) with a .04 taper sequentially to a size 30. Re-irrigation with EDTA and NaOCL to remove any remaining organic matter and the smear layer was performed with ultrasonic files. The yellow peeso reamer was measured to 17 mm (5 mm less than the WL) and introduced into the canal. Similarly, the blue peeso reamer was taken to 17 mm. The canal was then rinsed with 2% chlorhexidene and dried with paper points.

A spiral brush was used to apply the primer to the canal walls to the depth achieved by the peeso burs. A paper point was introduced to remove any excess primer. The Fibrefill RCS was introduced into the canal with a Centrix needle tip (Centrix, Shelton, CT) and a lentulo spiral was used to coat the canal walls. A Fibrefill obturator (size 30 with a 5 mm apical portion) was gently seated to working length and light cured. A core was constructed using Buildit FR and the post was trimmed to the desired length with a diamond using a high speed handpiece under water irrigation. The core was shaped to restore the tooth morphology (Figure 6).

Case 2

A 72-year-old female presented with carious breakdown of the distal occlusal of tooth 20. Pulpal exposure was noted upon caries removal and it was determined that endodontic treatment would be required. The canal was debrided and irrigated using NaOCL and EDTA solutions and taken to a final canal size at 50 with an 0.06 taper utilizing EndoSequence rotary files (RealWorldEndo, Brasseler, Savana, GA).

As with the prior case example, adhesive was introduced into the dried canal and Fibrefill RCS was placed. A size 50 parallel post Fibrefill obturator with a 5 mm Resilon terminus was slowly inserted into the canal to

Fig. 8_Obturation of tooth 29 with a Fibrefill parallel post obturator with a final size 40 with an 8 mm apical terminal portion.

Fig. 9_Obturation of tooth 5 with Fibrefill continuous taper obturators size 40 with a 0.02 taper.

Fig. 8


Fig. 9

working length to allow excess sealer to be expressed coronally. A hand-held curing light was applied to the coronal portion and cured for 30 seconds to fixate the fiber obturator. Buildit FR core material was injected around the post in the coronal aspect of the tooth and cured with a curing light. Excess fiber post was cut off using a diamond in a high speed handpiece with liberal water spray. The core was shaped and the occlusion adjusted before dismissing the patient (Figure 7).

Case 3

A 28-year-old male presented with percussion sensitivity on tooth 29. Radiographic examination demonstrated deep decay on the distal of tooth 29. The tooth tested nonvital and root canal therapy was initiated.

The canal was instrumented to a final size 40 with a 0.04 taper using EndoSequence rotary files. The Fibrefill peeso burs were next taken to 8 mm from the working length and irrigation accomplished with NaOCL and EDTA. Paper points were used to dry the canal. Adhesive was mixed and applied to the coronal end of a dry paper point placed in the canal. The moist paper point was removed and RCS placed with a Centrix needle tip. A size 40 parallel post Fibrefill obturator with an 8 mm Resilon terminus was slowly inserted to working length in the canal allowing excess sealer to express coronally.

Buildit FR was injected around the coronal aspect of the obturator filling the missing tooth structure and light cured. Excess obturator was removed with a diamond in a high speed handpiece using water spray. Occlusion was checked and the patient was scheduled for crown preparation (Figure 8).

Case 4

A 75-year-old patient presented with fractured buccal and lingual cusps on tooth 5. After removal of the remaining amalgam, it was determined that endodontic treatment would be necessary to allow a post-retained core to be placed to support a full coverage crown.

Rubber dam isolation was accomplished and the canal orifices identified. Canals were instrumented to a size 40 with a 0.02 taper and irrigated with NaOCL and EDTA. The canals were dried with paper points. Adhesive was applied to the canals and RCS sealer introduced. A continuous taper Fibrefill obturator size 40 with a 0.02 taper was placed into both the buccal and lingual canals. A core buildup was created using additional adhesive and Buildit FR core material. A hand-held curing light was applied. Following setting of the coronal material, excess obturator was removed and the core contoured. Occlusion was adjusted and the patient scheduled for a crown preparation at a subsequent appointment. Radiographically, sealer could be seen in a lateral canal connecting the two canals at mid-tooth, demonstrating the flowability of the sealer (Figure 9).

Case 5

A 53-year-old male patient presented with a fractured buccal cusp on tooth 4. Due to insufficient tooth structure to retain a new filling, it was determined that a full coverage crown would be needed. Preparation for a crown would leave minimal coronal tooth structure so intentional endodontics was indicated to provide a core to support the crown.

Isolation was accomplished and the canal orifices located. The canals were instrumented to a size 40 using 0.04 taper EndoSequence rotary files. The canals were irrigated with NaOCL and EDTA. Paper points were used to dry the canals and apply adhesive. A Centrix needle tip was used to place RCS. A continuous taper Fibrefill obturator size 40 with a 0.04 taper was inserted into each canal. A hand held light was applied to cure the coronal sealer and stabilize the obturators. Buildit FR core material was injected into the matrix band around the coronal aspects of the obturators and cured. Excess material was removed with diamonds and occlusion adjusted. The patient was appointed for a crown preparation (Figure 10)


Fig. 10

Fig. 10_Obturation of tooth 4 with Fibrefill continuous taper obturators size 40 with a 0.04 taper.

Case 6

A 61-year-old male presented with the complaint of pain on mastication. Examination revealed a fractured amalgam restoration with radiographic widening of the periapical periodontal ligament. The loose portion of amalgam on the occlusal surface was removed and following excavation of the underlying decay, pulpal exposure was noted. It was recommended that endodontic therapy be performed.

The canal was instrumented using EndoSequence rotary files to a size 40 and an 0.04 taper. Irrigation was performed with NaOCL and EDTA, followed by drying with paper points. A dry paper point sized 40 with a 0.04 taper was placed to working length in the canal and a drop of adhesive was applied coronally with a pipette. The moist paper point was removed and RCS placed with a Centrix needle tip. An InnoEndo post style obturator size 40 with a 0.04 taper was slowly inserted and excess sealer allowed to express coronally. A hand-held light was utilized to coronally set the sealer. Additional adhesive was placed on all surfaces in the access opening and air thinned. Following light curing of the adhesive, InnoEndo buildup material was injected into the coronal and cured. Excess obturator was removed by cutting with a diamond in a high speed handpiece with water irrigation and the occlusion adjusted. The tooth was treatment planned for a full coverage crown (Figure 11).

Case 7

A 40-year-old male patient presented with a fractured buccal cusp on tooth 5. To provide added support for a full coverage crown intentional endodontics was recommended.

Rubber dam isolation was placed and canals identified. Instrumentation was performed with EndoSequence rotary files and canals were taken to size 40 at 0.06 taper to working length. As with previous cases presented here, canals were irrigated and dried. Adhesive was placed and RCS applied. A size 40 tapered InnoEndo fiber obturator with a 0.04 taper was placed in each canal. The discrepancy in the coronal aspect between the obturator and canal preparation was filled with RCS as the obturator was inserted slowly allowing excess sealer to flow coronally. InnoEndo buildup was injected into the matrix band and light cured. Excess obturator was removed and the core contoured. The patient was scheduled for a crown preparation appointment at a later visit (Figure 12).

_Conclusion

So how do we define success in endodontics? Clinical absence of pain was found not to be indicative of endodontic success and a better evaluation may be the absence of continued or new periapical pathology.

$Ca(OH)_2$-based sealers have been shown to be non-cytotoxic, well accepted by the periapical tissue, bacteriostatic and stable dimensionally following placement. Carrier-introduced gutta percha can provide predictable obturation of the canal with minimal force compared to lateral condensation techniques. It has also been documented that resin reinforcement of the root structure can significantly increase the fracture resistance of the tooth.

Fiber obturation systems have incorporated these factors into their design, offering a safe, predictable and simple obturation method. Coronal leakage is eliminated by use of an adhesive sealer that is non-irritating to periapical tissue with a pH in the alkaline range, thereby creating a bacteriostatic environment in the canal.

Fig. 11

Fig. 11_Obturation of tooth 4 with InnoEndo post style fiber obturator, size 40 with 0.04 taper.

The obturator, a fiber post (fiber posts having been used to restore hundreds of thousands of teeth over the past ten years) is adhesively bonded within the tooth during the obturation, effecting a seal of the coronal portion and providing retention for the core. The Resilon terminus on the obturator permits retreatment of the canal should it become necessary. In multi-rooted teeth, the taper obturators may be used on the smaller canals or when greater than moderate curvature is present.

_Acknowledgement

Dr. Kurtzman has consulted for Pentron Clinical Technologies. Clinical cases presented in this article were performed by Dr. Kurtzman._

_Literature

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Fig. 12

Fig. 12_Obturation of tooth 5 with InnoEndo taper style fiber obturators, size 40 with 0.04 taper.

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"Biologic" Master Apical File Sizes: The Next Endodontic Revolution

Author_ Dr. Richard Mounce, U.S.A.

The past 15 years have brought significant and profound changes to the specialty of endodontics. This time frame has seen the introduction and popularization of surgical microscopes, ultrasonics, warm obturation techniques, rotary nickel titanium instrumentation and bonded obturation materials. Each of these advances in their own right has transformed the service into a highly predictable treatment if performed correctly and the tooth is restored properly with a coronal seal after treatment. Inherent in making this statement is the caveat that the treatment was performed on teeth that were initially restorable as well as free of vertical fracture.

_While these noted advancements alone are profound, the specialty has evolved significantly with what has accumulated over the years as a convincing body of evidence that instrumenting root canal systems to a larger master apical diameter is desirable. This article was written to address the subject, describe the existing literature qualitatively and provide a description of how such larger sizes might be created clinically and give a rationale for doing so.

In addition to the above, the pre rotary nickel titanium endodontic literature did not address to any significant degree the subject of larger master apical diameters. In contrast, the literature of the past decade has addressed and supported larger final diameters. The issue just wasn't addressed before with any authority. As evidence has accumulated, the need and or desirability to create larger master apical diameters has become better understood by clinicians and researchers. With the combination of products, literature and evolution in endodontic thought and practice, larger apical diameters are now possible and more importantly understood and considered vitally important by many.

Traditionally, average molar canals have been enlarged to approximately a size 30 with some preparations being as small as a 20 and generally no larger than a 35, all things being equal. This

Fig. 1_ Excellent coronal third shapes created with K3 shapers, (SybronEndo, Orange, CA, USA).

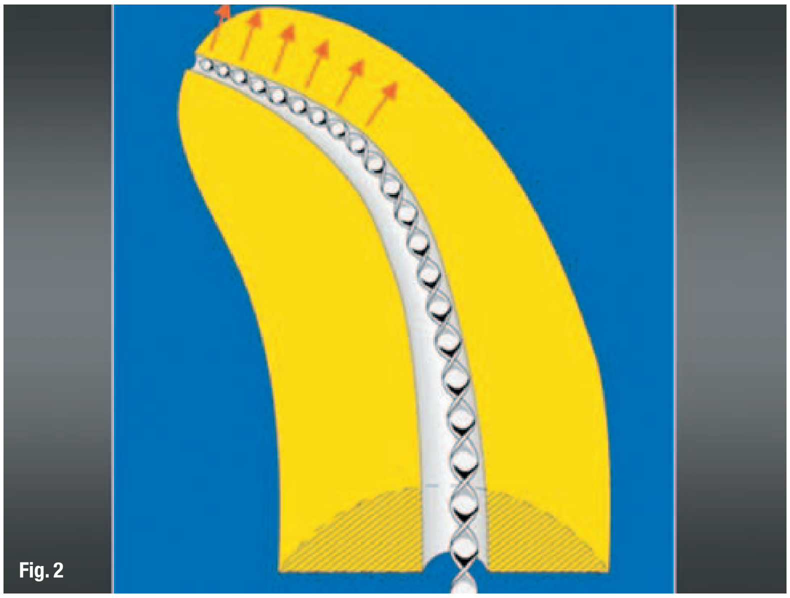

Fig. 2_Force applied to the canal wall by the tendency of a stainless steel K file or reamer against the canal wall to straighten itself.

nal third of restrictive dentin can more fully allow the placement of files of all types, hand and rotary, to have unfettered access to the apical third. Rotary nickel titanium orifice openers have gone far to more efficiently and safely open the coronal third of root canal systems and eliminate this problem. The author has used the K3 Shaper (orifice openers) for several years in lieu of Gates Glidden drills due to their cutting efficiency and resistance to strip perforation when used correctly with much success (Fig. 1).

In addition, preparations to such smaller apical diameters are a function and limitation of the existing rotary nickel titanium instruments available. Instruments of larger taper (.06 and above and those of variable taper) are more challenging to advance apically into the middle and apical thirds of root canal systems. Getting the larger tip sizes into the apical third of a root canal system requires that the larger taper of the file be able to rotate freely at a more coronal level in the canal. Creation of larger master apical diameters requires ideal coronal third and middle third instrumentation before the apical third can be instrumented to the ideal diameter.

common diameter of preparation can be viewed in several ways. First, these diameters traditionally stemmed from the concrete and significant limitations of hand instrument in their abilities to negotiation delicate curvatures in the apical third of root canal systems. Simply put, with conventional endodontic instruments, it was difficult to create larger master apical diameters. For example, a 35 K file is a relatively stiff instrument that is difficult, if not impossible, to use in a canal of any significant apical three-dimensional curvature. The term three-dimensional curvature is used to describe the buccal to lingual component that is unseen on dental radiographs, which is in truth blended with the mesial to distal curvature that is seen. With some exceptions, ledging, apical canal transportation of all types, blockage with dentin debris, as well as apical perforation are all significant risks of making apical preparations with large K files in the apical third.

Part of the limitation of using such hand K files and reamers in the apical third stemmed from the challenges present in employing Peezo reamers and Gates Glidden drills to shape the coronal and middle thirds of root canal systems. Such coronal shaping determines, in large measure, how freely the hand files will be allowed to spin in the apical third of root canal systems as well as how much restrictive dentin the files will have to work through. Risk of strip perforation certainly limited the use of both Peezo reamers and Gates Glidden drills. Said differently, if the coronal and middle third of the canal system haven't been shaped correctly first before apical third shaping, the K file will be asked to instrument along its entire length (coronal and middle third) as well as the apical third reducing tactile sensation and generating ledging and possibly other forms of iatrogenic problems. Relieving the middle and coro-

Also, K files exert a force against the outer wall of the curvature of the canal leading to the aforementioned ledging and canal transportation (Fig. 2).

Ideally, the debris created during instrumentation is irrigated out of the canal frequently and completely. Again, ideally, patency should be frequently reassessed through recapitulation after each pass of the instrument. It is difficult to generalize about teeth and to give one menu for instrumentation that is applicable to all teeth. Anatomy, the hardness of the given dentin, degree of calcification amongst many factors can all create challenges in instrumentation with regard to allowing the creation of larger apical diameters. Simply put, it is relatively easy to achieve a size 25 .06 tapered preparation that might appear satisfactorily to the traditional eye on a radiograph, but it is a valid question if that created master apical file size is truly "biologic" in relation to the initial anatomy and what the goals of root canal treatment are within the tooth. Such goals being the three-dimensional cleansing, shaping and obturation of the entire pulp space to a meaningful size from the orifice of the canal to the minor constriction of the apical foramen. Unrestrained use of rotary files in the coronal and middle thirds of root canal systems in the attempt to facilitate larger apical diameters can lead to the increased frequency of instrument separation as well as possible canal transportation if not performed properly. How the canal is instrumented in relation to the creation of a larger master apical diameter is vital and several strategies for use of rotary files to create these larger apical diameters will be introduced later in this article.

The advent of rotary nickel titanium instrumentation opened a wide range of possibilities for the creation not only of better and more predictable shaping of the coronal and apical third but for the creation of larger master apical file sizes without the limitations of hand files. Rotary orifice openers of all types have allowed for relatively easy negotiation of the coronal third of virtually all roots (except extremely calcified ones) and in doing so have removed one of the impediments to use of hand K files deeper in the root canal system. Said differently, working through significant distances of dentin made use of hand K files less efficient and susceptible to great iatrogenic risk, especially due to the difficulty of predictably shaping the coronal and middle thirds of some roots with Peezo reamers and Gates Glidden drills. In addition, the use of the surgical operating microscope has allowed far better visualization than ever and facilitated more precise removal of tooth structure and canal location, both factors allowing instrumentation to be achieved to a higher standard.

In short, the development of rotary nickel titanium files, especially orifice openers and the surgical operating microscope have facilitated along with the actual files (to be described below) creation of larger master apical diameters, efficiently and ultimately safely, especially if used correctly.

As mentioned, there is a conclusive body of evidence that larger master apical diameters are both desirable and biologically advantageous to promote endodontic healing and success. The references cited specifically promote the notion that the creation of larger MAF's perform two vital functions: 1) allow the ingress of greater volumes of irrigant deeper into the root canal system and 2) remove dentin around the circumference of the canal with its attendant elimination of pulp debris as well as dentin to allow the aforementioned increased volume of irrigant to dissolve debris and float it out of the canal (Figs. 3–5). There are significant portions of the canal wall that the files never touch and in which we are completely dependent on irrigation to achieve cleaning of the root canal system. As such, with traditional materials and ideas there are significant limitations to present methods of root canal instrumentation as well as irrigation, each being dependent on the other.[1–8] Optimally, the correct volume of irrigant is

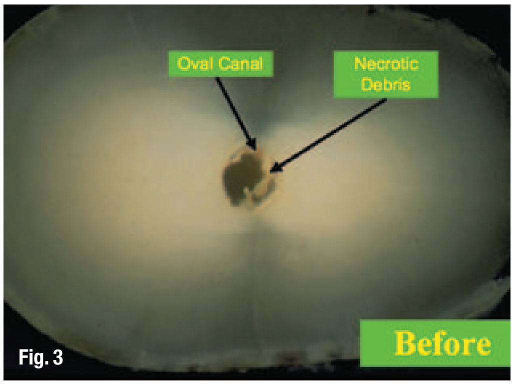

Fig. 3

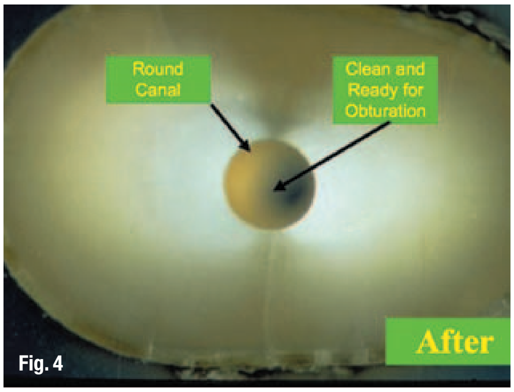

Fig. 4

Fig. 5

Fig. 3_Standard instrumentation sizes with remaining necrotic tissue.

Fig. 4_The effect of larger apical diameters on potential for canal cleanliness.

Fig. 5_Section of a root that demonstrates both transportation under preparation and a lack of adequate irrigation.

being used and delivered into the root canal system where it is most effective.

In practical terms, several things need to be addressed. It is essential that such larger apical diameters be prepared safely and not in any way predispose the canal to iatrogenic events including, but not limited to, apical transportation or perforation of the apex and file separation, especially with the larger diameters created. Next, once larger master apical file sizes are created, it is essential for the clinician to prevent as much as possible through excellent technique, the extrusion of irrigant through the apical foramen. Then, it is vital that the clinician know to what diameter such a "biologic" preparation must be taken, i.e., to what size is any given canal instrumented where it might be considered ideal. Finally, the obturation phase including cone fit must be managed to a very high standard to reap all of the possible benefits of a larger apical diameter. Managing all these clinical issues will be touched upon later in the article.

The literature, as mentioned, is quite conclusive as to the desirability of larger apical diameters, a point proven from various perspectives. It is axiomatic that no single rotary technique combined with any given rotary technique consistently cleans canals and renders them bacteria free. But, it is clear that the use of larger apical diameters creates more effective irrigation and reduces bacteria in a statistically significant manner relative to smaller diameters.

_How is the technique achieved clinically?

Instrumentation might be considered biphasic. There is the achievement of a "basic" preparation that then sets the stage for the creation of a larger apical diameter. It is helpful to conceptualize larger apical diameters as a natural extension of the preparations which might now be considered ideal and which are instrumented to a diameter of a 30 or 35. It is simply not possible to create larger apical diameters without iatrogenic outcomes if the basic preparation is not created first. Such a basic preparation would ideally have all the characteristics that are by design inherent in excellent canal preparation: maintaining the original location of the canal, creating a tapering funnel and leaving the apical foramen at its original position and size. It is essential to realize that creation of larger diameters neither endorses nor advocates transporting the foramen. In other words, all of the enlargement that occurs does so above the minor constriction of the foramen and does not by intention create enlargement beyond this line. Inherent in treating the minor constriction in this manner, it is essential that the clinician be able to accurately locate the minor constriction and limit, by virtue of the instrumentation that takes place, the extrusion of debris and irrigants past this level of the canal (Fig. 6).

Fig. 6_Ideal canal preparation shape.

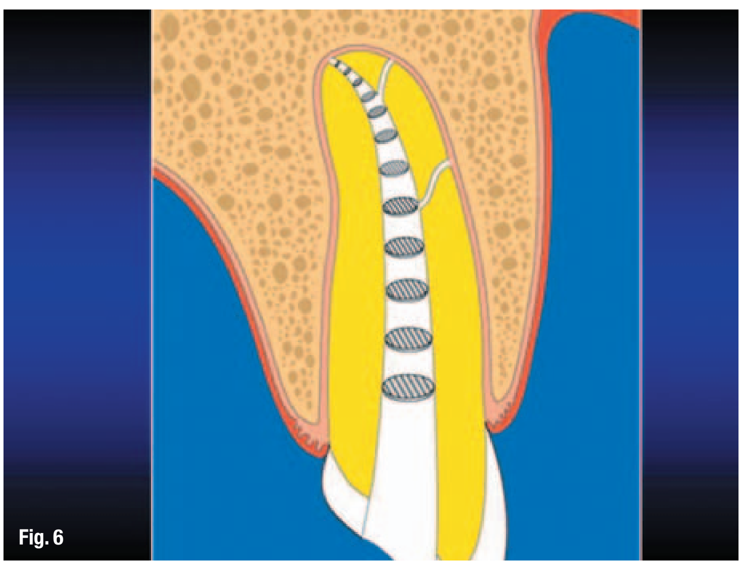

Fig. 6

With the above considerations in mind, there are two excellent systems that alone or in combination can provide the creation of larger master apical diameters safely and efficiently. One system is the K3 rotary nickel titanium file system (SybronEndo, Orange, CA, USA) and the other is the LightSpeed file system (LightSpeed U.S.A., San Antonio, TX, U.S.A.) (Figs. 7, 8).

The two systems are very different and yet both, for various reasons and with slightly different mechanisms, can facilitate the creation of larger apical diameters. K3 is a fixed tapered instrument that comes in three tapers of .02, .04 and .06 with a variety of tip sizes (15–60). In addition, the system has orifice openers known as Shapers (mentioned above), which are available in three tapers of .08, .10, .12. These files of greater taper have a common 25 tip size. Because of their excellent cutting ability, fracture resistance and flexibility, these files are my chosen system. The files are asymmetric in all of their design characteristics (helical angle, cross section, flute width and depths, etc.). The .02 tapers are available up to a size 45, the .04 and .06 to a 60-tip size. With diligence and the proper touch, it is possible to use these files to create the larger apical diameters discussed in this paper. Such a creation of these diameters would imply that the file be used gently, with sparing engagement against canal walls (ideally 1–2 mm, certainly no more than 4–6 mm), passively, and never forced to place at any level of the canal system. In addition, it is optimal for the canal to be patent, for a glide path to have been created first and irrigation and recapitulation to be frequent and/or copious.

As an adjunct to the use of K3 files or individually, the LightSpeed system can be used to create larger master apical diameters. The file is run at a higher RPM than other rotary systems (2,000 rpm). The system is available in half sizes from a 20–100. The files are smooth shafted and only cut on their tips. As a result, they encounter less torque related resistance as they move apically and they move easily down canals. For example, a size 30 LightSpeed will often drop to the true working length very quickly where a .06 30 file will not. Moving up the various LightSpeed files to a larger MAF is easily done. As a matter of actual practice, having the 30, 35, 40, 45, 50, 55, 60 LightSpeed files can, simply with these instruments alone, enlarge the vast majority of canals to a larger master apical diameter. LightSpeed can certainly be used alone without the use of a system like K3. Some believe and prefer that using a system like K3 to perform the bulk of dentin removal upon which a preparation is finished with LightSpeed to be the most efficient manner to instrument canals. The K3 in such a scenario is doing the "heavy lifting" in dentin removal and the LightSpeed is doing the final shaping in the

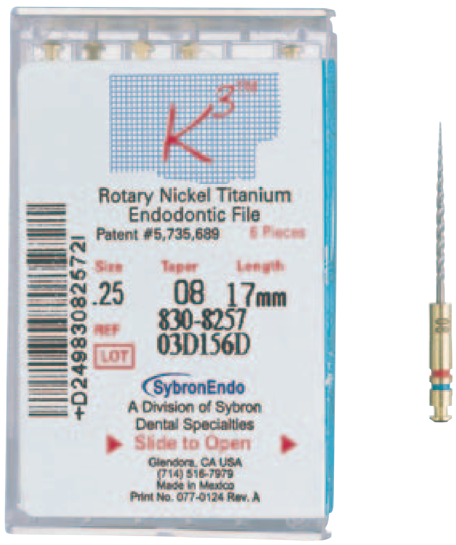

Fig. 7

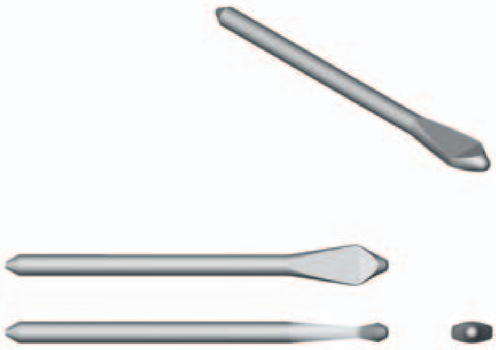

Fig. 8

Fig. 7_The K3 rotary nickel titanium system by SybronEndo, Orange, CA, USA.

Fig. 8_The LightSpeed rotary nickel titanium system by LightSpeed Technologies, San Antonio, TX, USA.

apical third of the canal system. In the empirical opinion of the author, this is the ideal means upon which to blend these various systems if such blending is deemed necessary.

For example, if a tooth with significant curvature is instrumented to a .06 25 or 30 K3 preparation, such a preparation can then be gauged and instrumented with LightSpeed to a larger MAF (as desired) or it can be performed with a .04 tapered K3.

Clinically and empirically, while not all canals might be instrumented this way, the author will use the K3 system to create the largest apical diameter possible and refine the final preparation with LightSpeed as desired. Interestingly, the LightSpeed often only encounters minimal resistance to go from a 30–60 apical preparation. Only a minor amount of shaping need be done or dentin be removed to allow the canal to be opened to a larger master apical diameter (Figs. 9, 10).

The only drawback to LightSpeed instrumentation which might be viewed as the objection of a purist is that because the instrument only cuts at its tip end, the preparations which result using LightSpeed only in the apical third might tend to be more parallel over those few millimeters of preparation. Such parallelism is not of clinical significance and can be adjusted for if the apical preparation with LightSpeed is tapered appropriately and/or blended correctly with a file like K3.

Is it possible to use other rotary systems in lieu of K3 for the creation of the basic preparation? Yes, but in the author's empirical opinion several important points must be addressed. First of all, some systems are only available to a MAF of 30 or 35 and by their very design they have limited the clinician away from the creation of larger master apical diameters. Without the extended range and capability of a system like K3 or LightSpeed, the clinician is limited by the largest file size available in a given system. This is absolutely vital if one considers the amount of irrigation, which will be allowed to reach the apical third given the preparation in its entirety, is limited at its apical extent to a 25 or 30 MAF.

In addition, not all rotary file systems have equal fracture resistance. Taking some rotary systems around significant pigtail curvatures inappropriately is likely to lead to disappointment in ledging (and transportations of all types) as well as instrument fracture. Without the flexibility of a K3 or LightSpeed system or something of similar flexibility, one quickly is limited in the possibilities in creation of excellent canal shapes. Viewed in another light, one would not want to attempt to create larger master apical file sizes with some of the other systems available on the market because they lack significant flexibility to negotiate the given curvature, especially a small radius of curvature.

And finally, in creation of larger diameters, it is important for the clinician to be absolutely sure of the true working length so as to not violate the minor constriction of the apical foramen. Placement of large volumes of irrigant into the apical third in canals that have been perforated or transported are far more susceptible to morbidity. Such misadventure in the apical third is to be avoided at all costs, irrespective of which canal third is involved.

_Frequently asked questions

_What would be the average MAF for a molar canal such as the MB of a lower molar?

50–60, case dependent. Taking the average molar canal to a 06-tapered size 35 tip size, K3 could easily in most cases be taken to a 50 or a 60 MAF with either LightSpeed or a combination of K3 files.

Fig. 9

Fig. 10

Figs. 9, 10_Cases instrumented to a larger master apical diameter in the manner described with a K3 and LightSpeed hybrid technique.

_Is it essential to apically gauge canals?

Gauging the apex is a term used to describe the process of determining the size of the minor constriction of the apical foramen prior to preparation of the final master apical diameter. It is clearly easier to determine an ideal master apical diameter if the clinician knows the initial starting diameter of the foramen. That said, there is no literature-based evidence that gauging the apex is correlated with greater long-term success in endodontic treatment. Without gauging though, the clinician cannot know if the enlarged canal size is ideal relative to the particular foramen. In practical terms, if the initial foramen diameter is a 25, empirically, a size 50–60 would most certainly be more optimal than a size 25 or 30 preparation.

_Once gauged, should I instrument to three file sizes larger than the first file to bind at the minor constriction of the apical foramen?

While the concept of instrumenting canals to three sizes larger than the first file to bind at the true working length is a time honored teaching method to instruct clinicians as to the ideal master apical diameter, there is no literature-based proof that such an instrumentation is correlated with clinician success. What is relevant is that the larger the master apical diameter created, the greater the cleanliness of the resulting canal and the greater the volume of irrigation that reaches the apical third where it is most desirable.

A rationale for instrumenting root canal systems to larger master apical diameters has been presented. The primary benefits of doing so are the increased volumes of irrigation and cleanliness of canals creating the potential for greater long-term success in combination with coronal seal. A general guideline for use of K3 rotary nickel titanium files and LightSpeed files in creating such larger diameters has been presented. The author welcomes your questions and feedback._

Dr. Mounce would like to thank Dr. Arnaldo Castellucci for figures 2 and 6 and LightSpeed U.S.A. for figures 3–5, 8.

Dr. Mounce has no commercial interest in any of the products mentioned in this paper.

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Successful Mechanical Root Canal Conditioning

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Endodontics has changed considerably in the last decade with the introduction of new methods. On one hand, working techniques have been simplified (mechanical root canal conditioning with instruments made of nickel-titanium alloys, electrometric length measurement). On the other hand, closer attention is being paid to biological aspects (new root filling techniques, new sealers with minimum cell toxicity).

_The introduction of the surgical microscope and the advantages associated with this (30 times magnification when there is optimal illumination of the treatment site) have also fundamentally changed modern endodontics.

_Conditioning & cleaning of the root canal

Conditioning of curved root canals in particular was made much easier and faster by the introduction of rotary instruments made of nickel-titanium alloys (otherwise known as NiTi instruments). Even though the cutting performance of NiTi files is up to 40% less than that of stainless steel files (Tepel & Schäfer 1996), root canals can be conditioned faster with NiTi instruments.

Clinical and *in vitro* studies show that NiTi instruments enable a uniformly conical preparation shape even in highly curved canals (Fig. 1). This can be attributed to the high flexibility and high elastic recovery ("memory effect" without permanent deformation) of NiTi instruments (Gressmann, Hülsmann 2001).

When conditioning is done with rotary NiTi instruments, undesired changes to the canal shape (stripping, zip, elbow, etc.) occur less frequently

Fig. 1

Fig. 1_Mechanical conditioning of canals according to their anatomical curvature (Flex-Master System) and tight gutta-percha root filling (soft core).

Fig. 2_Optimal cleaning and good apical stop after conditioning with the Flex-Master system (SEM view).
Fig. 3_Insufficient root filling in tooth 36.

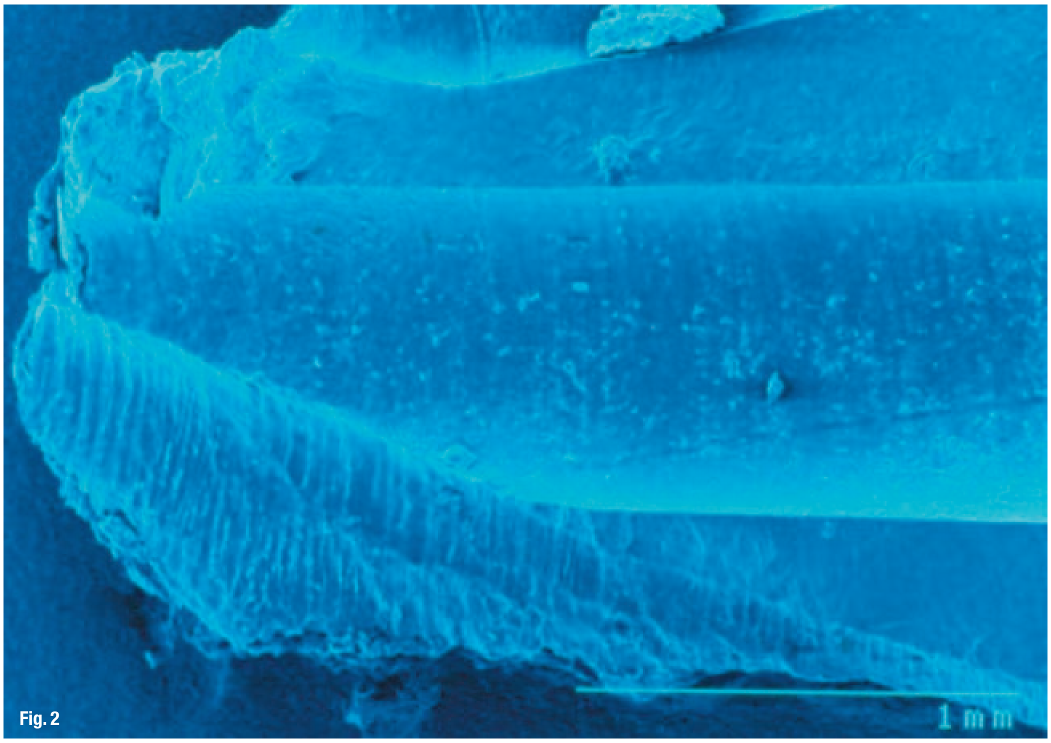
Fig. 2


Fig. 3

than is the case when conventional manual instruments are used (Beer 2002).

At the beginning of the twentieth century, a maxim of endodontics was formulated that still holds true today: "What you get out of the canal is more important than what you put in." Until about five years ago, the best mechanical cleaning of canals was done with handheld instruments, so these still serve as the standard today in comparative studies.

Because of wide lateral guiding surfaces ("radial lands") in particular, first generation NiTi instruments (e.g., Quantec, Pro-File, Mity Rodo) were inferior to handheld instruments (e.g., reamers, K-files, Hedström files) when it came to removing debris and the smear layer. However, the most recent studies (Baumann 2001, Tulus 2002) show that the new generation of NiTi instruments (e.g., Flex-Master instruments, VDW Antaeos, Munich) are superior to conventional conditioning by hand (Fig. 2).

_Instrument fracture

Opponents of mechanical conditioning complain, not entirely without justification, of an increased risk of fracture when rotary NiTi instruments are used. In the early days (1988), fracturing occurred 10–40% of the time, which was unacceptable from a clinical standpoint (Kavanagh 1998, Schäfer 1999).

But back then, angled handpieces with large motor speed reductions and an excessively high torque were used. To reduce the incidence of instrument fractures, special torque-limiting endodontic motors were developed. At first, these displayed relatively crude degrees of torque limitation whereby individual instruments were still placed under too much stress and fractured more often.

To further reduce instrument fractures (and eliminate them if possible), motors with programmed torque limitation were subsequently developed, which guarantee a constant speed and individual torque value for each file used. Among this latest generation of motors are the S.E.T. EndoStepper (S.E.T., Olching), VDW EndoStepper and Endo IT Control (both made by VDW of Munich, Germany), and ATR Tecnika (Maillefer, Constance, Germany). With proper application (use of a lubricant, correct adjustment of the motor for each instrument, sorting of instruments in accordance with the manufacturer's specifications), the risk of fracture today is so low that even revisions can be carried out successfully with rotary NiTi instruments (Figs. 3, 4).

Between October 2000 and October 2002, a total of 1,401 root canals (289 of which were endodontic revisions), were mechanically conditioned on 748 teeth in 578 patients using the VDW EndoStepper and the Endo IT Control, or with Pro-File, GT Rotary File (both made by Maillefer of Constance, Germany), or Flex-Master (VDW, Munich, Germany).

During this time, instrument fracture occurred in only nine root canals (0.6% of the conditioned canals or 1.2% of the treated teeth). In two cases, orthograde removal of the instrument fragment from the canal could be done with ultrasound. In four cases, the fragment was eliminated during an apicectomy, and in just three cases (0.4% of treated teeth) did the instrument fracture force an extraction of the affected tooth.

_Evaluation of mechanical conditioning

In spite of an observation period that is still too short for a conclusive statement to be made (no more than two years so far), the evaluation of mechanical conditioning is turning out to be favorable.

From a total of 748 teeth that were conditioned within a period of two years with NiTi instruments using the latest generation of torque-limiting motors and either filled thermo-

Fig. 4_Result after revision of the root filling from Figure 2 (conditioning with Flex-Master instruments, Endo IT Control motor, gutta-percha root filling with Soft Core system).

Fig. 5_Tooth 37 with distinct C-shaped canal. The root was filled (thermoplastically) after mechanical conditioning.

chemical conditioning of the root canal systems through irrigation (especially with sodium hypochlorite solution) and facilitates later compact filling with gutta percha, which is a crucial benefit for long-term preservation of the teeth. The high success rate of these endodontic treatments confirms the reports of other authors (Raab, Johnson, Schwarze, Schäfer).

Clinical experiences with mechanical root canal conditioning (Machtou 1999, Tulus 2002) show that there have been advantages compared with conditioning by hand. Even difficult root canal configurations (Fig. 5) can generally be mastered by a treating dentist with a high assurance of success, time saved, and a low level of fatigue.

When converting the endodontic treatment technique to mechanical conditioning, the dentist should no longer need a detailed introduction or practice exercises on extracted teeth. For reproducible and successful treatment results, the manufacturer's instructions (i.e., pertaining to rotation speed, file sequence, torque limiting, timely sorting of used files) should be strictly followed._

plastically or with condensed gutta percha, 729 teeth (97.5%) have been fully preserved without additional endodontic or surgical measures being required up until now. Twelve teeth (1.6%) required an apicectomy after endodontic treatment. In four of these cases, an instrument fracture during conditioning was responsible. In five of the eight other cases, the histological examination of the periapical tissue showed that a cystic change had occurred. Only seven teeth (0.9%) have thus far needed to be extracted, three of them due to an instrument fracture during conditioning, and four because of other complications.

_Conclusion

Full mechanical conditioning of root canals with rotary NiTi instruments enables good

The Literature list is available from the publisher.

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Use of Laser Systems in Endodontics

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In recent years, laser systems have been used increasingly more often in numerous fields of dentistry. The kinds of lasers currently offered are soft lasers, the supporters of which postulate a "biostimulant" effect on soft tissue, and hard lasers for performing invasive treatment steps.

_Hard lasers are used primarily in dental surgery, for therapy of marginal periodontal diseases, and endodontics. The ability to sufficiently damage or even kill "problematic pathogens" with monochromatic laser light makes the use of lasers as a part of endodontic measures look appealing and promising. A multitude of monochromatic light applications in endodontics with various wavelengths are described this way in the literature. This article will report on experiences with established hard lasers in dentistry.

_Laser wavelengths used in endodontics

The use of lasers for endodontic measures includes a substantial list of possible laser applications:

1. performing laser vitality tests on teeth by measuring the pulp's blood supply with HeNe and diode lasers;
2. treating oversensitive tooth cervices with diode, Nd:YAG and CO_2 lasers;
3. pulp capping when artificial exposure is done with Nd:YAG and CO_2 lasers;
4. filling root canals;
5. endosurgy;
6. root canal cleaning and making changes to root morphology.

The first five laser applications are rare in endodontics and are of an "exotic" nature. The low quantity of available scientific data also limits the value of these applications.

The susceptibility of results to adulteration by disruptive exogenous factors, which is very pronounced for instance when pulp vitality is tested with laser Doppler flow measurement, also raises doubts about the clinical application of such procedures. However, hard lasers are more frequently used in endodontics as an auxiliary or exclusive measure for preparing and working on gangrenous root canals. Two different therapeutic approaches are taken here.

Supporters of ablative lasers, which cause morphologically identifiable changes to the inner wall of the canal of the particular root to be treated, now even claim that they no longer regard a root filling in the proper sense (gutta-percha sealer combination or something similar) as necessary because bacterial density is achieved by the vitrification of the canal's inner wall after the laser has been used. Proponents of non-ablative and purely decontaminating hard lasers dispute this assessment. They assert that the significance of the hard laser in endodontics should be placed on the way it fights gram-negative anaerobic bacteria, and maintain that

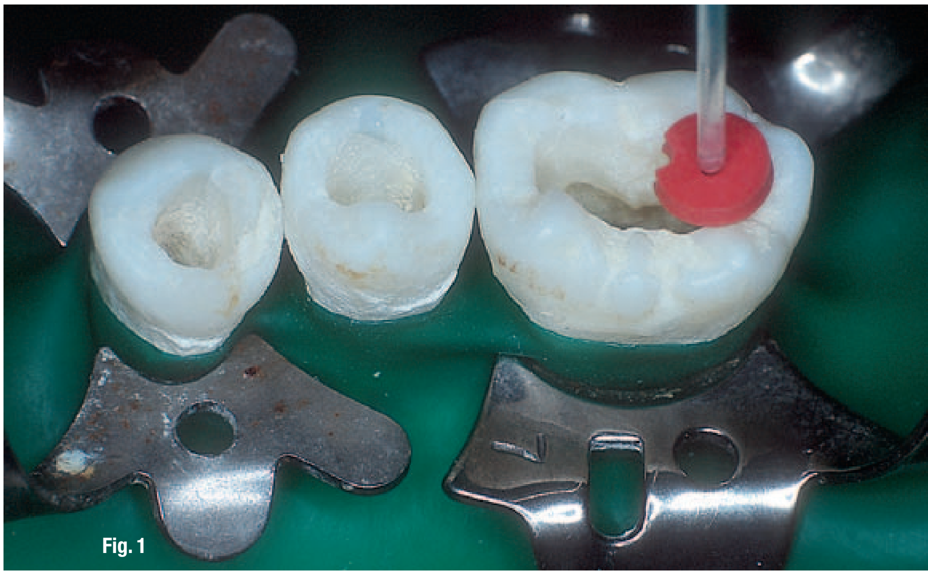
Fig. 1

Fig. 1_Typical image of a laser endodontic procedure. The fiber that has been marked (to prevent over-instrumentation) is inserted in the canal of the tooth treated with a trephine.

Fig. 2_Fiber-guided systems involve a risk of the fibers being fractured if they are inserted in the canal. Fracturing of brittle fibers often occurs because of tilting in an inadequately prepared canal.

Fig. 3a & Fig. 3b_To prevent a fiber fracture, the tooth must be prepared in accordance with the IAF-MAF-FF pattern, whereby the master apical file must have an ISO thickness of at least 20. Over-instrumentation can be prevented by marking the target length [fiber marking (3a) or with an endostop (3b)].

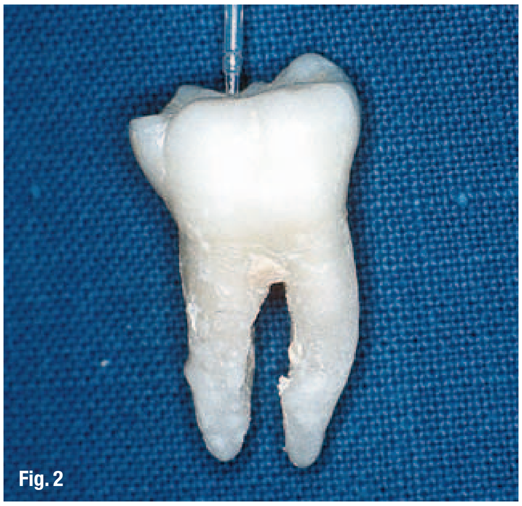
Fig. 2

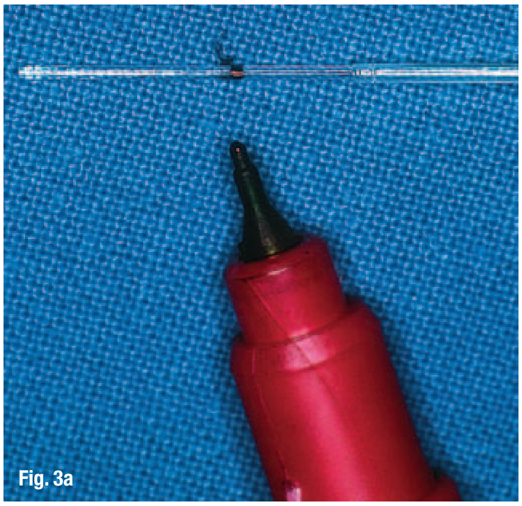
Fig. 3a

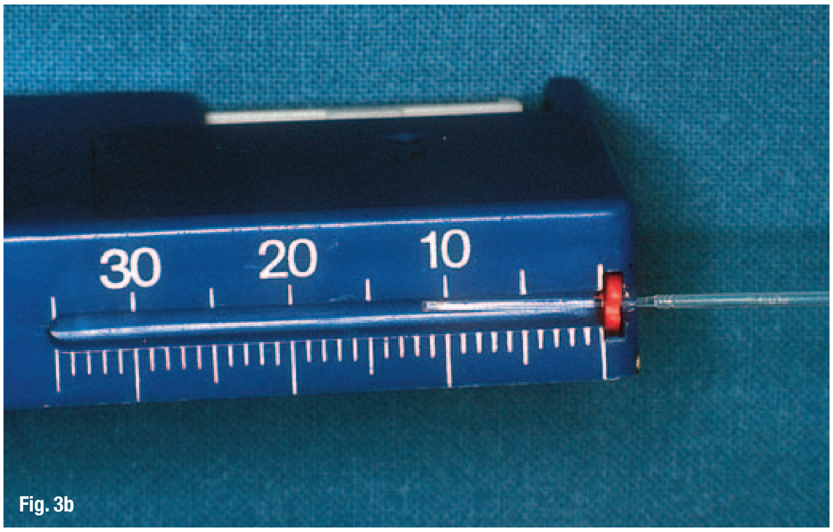

Fig. 3b

a root filling should still be carried out after the canal has been sterilized.

_Erbium:YAG laser

The notion of being able to work on tooth structure without rotating instruments is a long-cherished dream in dentistry. Already in the late 1970s and early 1980s, attempts were being made mainly in Asia to prepare cavities in teeth or excavate caries by using lasers. However, the group headed by Yamamoto gave up these experiments in disappointment and came to the conclusion that it was not possible to work on tooth structure with the laser systems available at that time.

The first breakthrough came in the mid 1980s, when the German research team of Keller and Hibst succeeded in establishing the Erbium:YAG laser. To date, it is the only laser that, based on scientific evidence, can be described as suitable for working on tooth structure. Thanks to these aforementioned authors, as well as other research teams headed by Schwarz (Düsseldorf) and Reich (formerly based in Homburg), there is now also scientific evidence for the use of lasers in endodontics.

The Erbium:YAG laser light made it possible to morphologically modify the canal's inner wall and decontaminate it at the same time, thereby achieving a lasting effect for the root treatment. In the meantime, the world's most successful manufacturer of Er:YAG devices, Biberach firm KaVo, has also made a special endodontic handpiece available for its unit.

_Gas lasers

Gas or CO_2 lasers have been on the market the longest and have been used in dentistry since the late 1980s. They emit laser light with a 10.6 µm wavelength and are absorbed exceptionally well by water, which explains their good "cutting effect" in intraoral tissue (which contains water). The laser light is guided to the target location by an articulated mirror arm or hollow fiber, which sometimes causes a certain amount of handling problems in the lateral tooth region, especially with teeth that have been operated on with a trephine.

Older CO_2 lasers have only very limited use in endodontics. Now, the latest generation of gas lasers is also used here. The breakthrough for this wavelength came with the introduction of the "super pulse". This ability to work with extremely high pulse frequencies allows gas lasers to be used despite unfavorable absorption behavior.

The studies by Deppe (Munich, Germany) and Romanos (Frankfurt, Germany) in particular have confirmed this with their sometimes extremely complex histological and scanning electron microscopic preparations.

_Nd:YAG lasers

Neodymium lasers (Nd:YAG), which are used in periodontology and endodontics, were touted in North America, particularly by Myers and Myers, in the early 1990s. In current studies, Romanos and Nentwig instead stress the sterilizing effect when low amounts of Nd:YAG light are applied.

A particular debt of gratitude is owed to Gutknecht's Aachen group for scientifically supported data on the use of the Nd:YAG laser in endodontics. In complex studies, Gutknecht and associates detected vitrification of the inner canal walls of devitalized teeth after intracanal irradiation with an Nd:YAG laser, which contributes to reducing pathogens and seals accessory canals, thereby greatly increasing the prospects of success for endodontic measures.

Here also, laser power and duration should be selected according to the specifications developed by these authors in order to prevent hard tissue or thermal damage. Because the glass fiber that the laser light guides to the target location is brittle, there is a risk that it could break off. A laser endodontic treatment (canal decontamination) therefore requires a preparation procedure that sticks strictly to the IAF, MAF and FF technique. Teeth with radiologically proven abnormal morphology are therefore contraindicated for laser endodontics.

_Diode lasers

Diode lasers have been available on the dental market since the mid 1990s. They introduce some special material-specific properties that make them appealing for use in dentistry. Laser light is generated directly by coherent coupling after electric energy is connected to a semiconductor. Because power can be converted directly into laser light with this type of laser ("injection laser"), it is garnering a great deal of worldwide attention.

Surfaces with bacterial cultures that cause problems for the therapist, especially with periimplantitis and marginal periodontitis and in endodontics, can be irradiated with diode lasers and thus decontaminated. Bacteria are killed by a photothermal diode laser effect. The great significance of the diode laser in endodontics was impressively verified in numerous studies by the Freiburg laser working group (Bach-Schmelzeisen-Krekeler) as well as associates from Vienna University (Moritz et al.) and Aachen (Gutknecht et al.).

_Other laser wavelengths

Beside the hard laser systems already described, some other wavelengths are also used in endodontics. However, they have so far not yet become fully established.

Fig. 4a

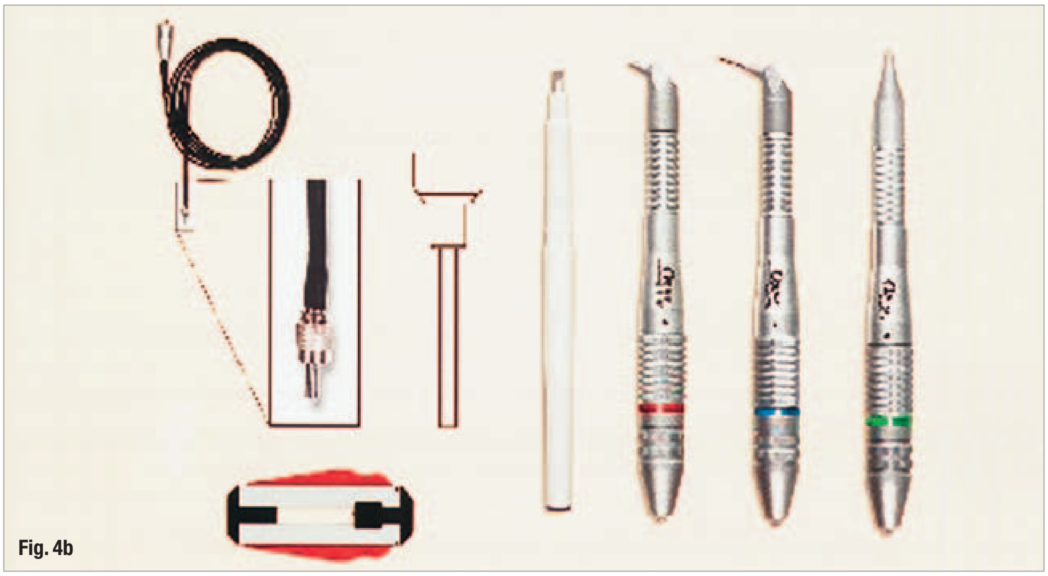

Fig. 4b

Figs. 4a & 4b_Some manufacturers offer special handpieces for endodontics or special endo attachments.

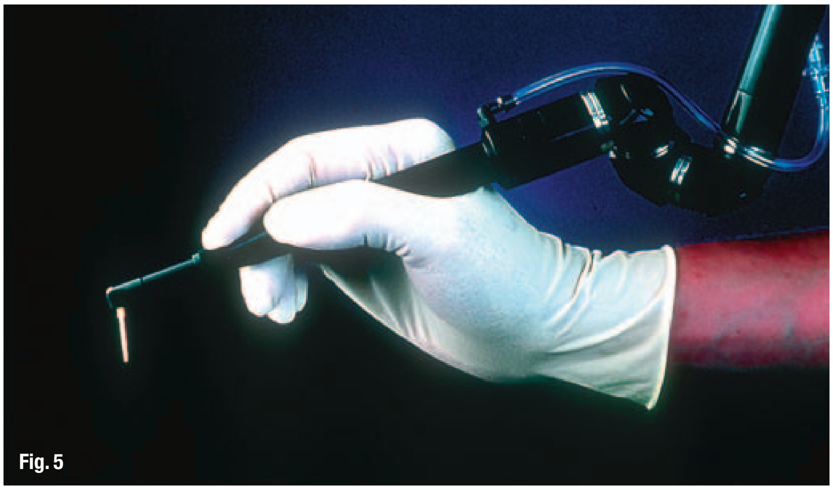
Fig. 5

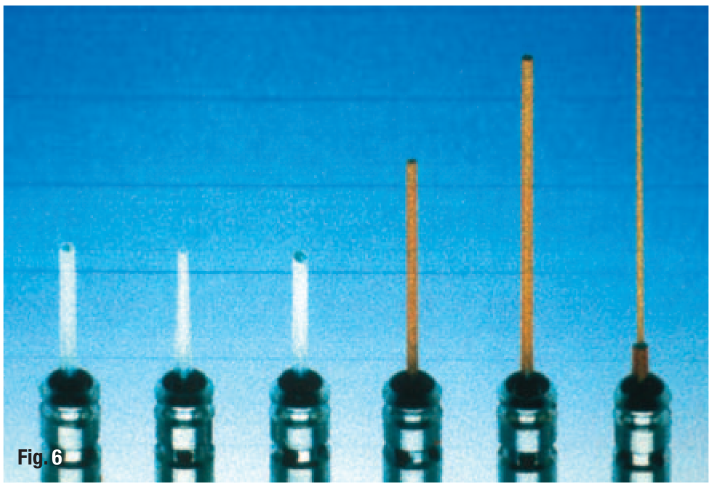
Fig. 6

Fig. 5_The breakthrough for the CO_2 laser in endodontics came with super pulse technology. Despite basically poor absorption of this wavelength in the canal, the super pulsed gas laser can now be used in endodontics.

Fig. 6_The availability of various laser applicator cross-sections and lengths is ideal for laser endodontic measures, meaning that any tooth can be treated.

The argon laser (blue light, 488 nm) can be used for curing composites and laser bleaching (green wavelength, 514.5 nm). The holmium:YAG laser (2,100 nm) is used especially for smaller dental operations. To date there is no scientific data for these two wavelengths that would support their use in endodontics. The Diodium brand diode laser-pumped Nd laser covers the exact range of a conventional Nd:YAG laser.

_Summary

The great interest in and considerable promise of monochromatic light for application in the canal system of a devitalized tooth can be gauged in the multitude of studies, literature data and research projects that deal with lasers in endodontics. Thanks to the results of research, four laser wavelengths can be indicated as suitable for laser endodontics: Er:YAG, CO_2, Nd:YAG and diode.

Two laser application methods are available to a dentist treating a root canal: ablative methods, which alter the morphology of the inner canal wall and target mechanical blocking of problematic accessory canals; and purely decontaminating methods, which affect the assorted gram-negative anaerobic bacteria in the canal.

Both methods can be described as scientifically proven, but it is important to always choose the correct laser parameters in order to prevent thermal damage and/or stress cracks caused by excessively high energy densities.

The two primary indications for using lasers in endodontics are gangrene treatment and perio-endo lesions. The 82–85% success rate of laser endodontic measures is much higher than the 63–71% rate of conventional methods.

Along with the upcoming introduction of improved laser methods for thermomechanical root canal preparation, the availability of improved laser applicators ("side-firing fibers") and the ability to use lasers for catheterizing teeth operated on with a trephine, other promising laser applications are going to be introduced in endodontics. A contraindication of laser endodontic measures should be looked for in abnormal root morphologies and open apical foramina._

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Fig. 7a


Fig. 7b

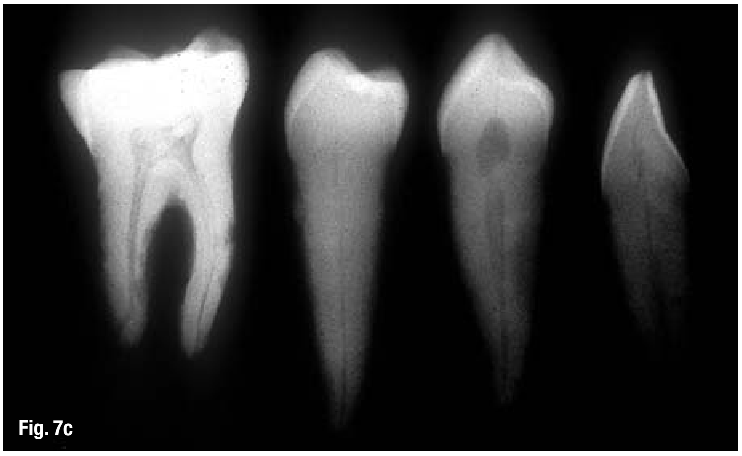
Fig. 7c

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Fig. 7a_Abnormal root configurations, which occur especially in molars, mean a poor prognosis for any laser endodontic measure.
Fig. 7b_This is especially true for accessory roots.
Fig. 7c_In cases of doubt, an X-ray assists the search for abnormal morphological situations. In any case, statements can be made on the number, size and shape of canals.

_author info | roots

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The Use of Ultrasound in Endodontics

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_The use of ultrasonic sources has now gained such importance in the economy of endodontic treatment that I personally believe it to be one of the most interesting innovations introduced into modern endodontics.

In recent years, interest in this type of technique has been increasing, not only in endodontics but also in other branches of dentistry; indeed, ultrasonic tips are used more and more for preparation in prosthetic and restorative dentistry, in bone surgery to take small bone specimens and in the technique of the maxillary sinus lift, as well as more widely in endodontic surgery.

Endodontics is the specialization in which ultrasound has enabled the most visible progress to be made, and some stages of endodontic technique have even been modified, above all when the use of ultrasonic tips is associated with that of the operative microscope; for this reason state-of-the-art endodontics cannot today neglect these two fundamental instruments.

This article describes the most recent knowledge and clinical applications of ultrasonic in endodontic treatment.


Fig. 2


Fig. 3


Fig. 1 bis


Fig. 2 bis


Fig. 3 bis

Fig. 1

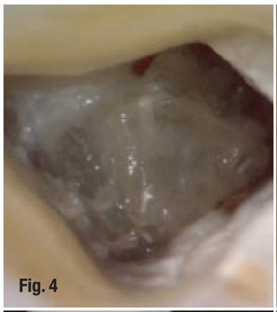


Fig. 4

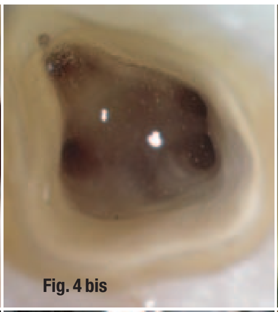


Fig. 4 bis

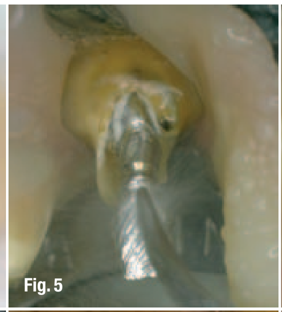


Fig. 5

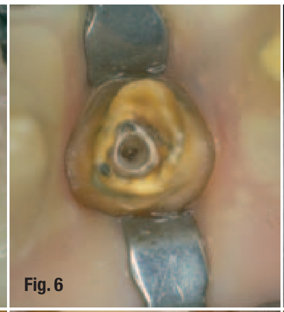


Fig. 6

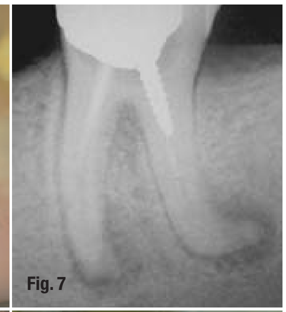


Fig. 7


Fig. 8


Fig. 9

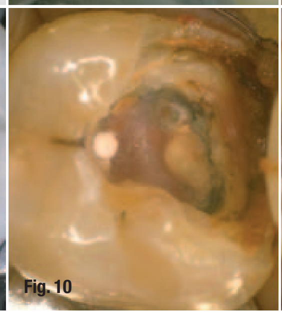


Fig. 10


Fig. 11


Fig. 12

_Equipment

The importance of instrumentation in endodontics has now reached strategic levels, and in the present case athe qualitative improvement of ultrasonic units and the increased availability of new tips goes hand in hand with the refinement of endodontic technique, which is likewise constantly progressing.

Consequently, over recent years we have seen the introduction of more and more highly developed ultrasonic sources that enable optimal utilization of all the tips available on the market which, being very varied, frequently demand specific methods of use.

For this reason, modern ultrasonic units must be able to propose both high power and precision cutting and enable control not only of the frequency but also of the vibration amplitude.

This type of problem is particularly met in the endodontic field, where we use a great variety of tips that are different in terms of shape, length, size and the materials from which they are constructed, and that for these reasons necessarily require different modalities of use.

As a consequence, it is very important that the ultrasonic source is specifically dedicated to endodontics or at any rate that it is a multi-purpose unit offering an "endo" application, that is an operative mode in which the amplitude of the vibrations is limited. Following this type of evaluation, my personal selection is a very simple unit, ergonomically easy to place, being small and compact, but that in any case provides a wide range of uses in the endodontic field thanks to the possibility of varying its operative frequency extensively and precisely: this ultrasonic unit is the Suprasson P5 Booster by Satelec (Fig. 1) or the more sophisticated and recent Suprasson PMax® which uses new technology that allows the unit and its power to be set automatically, according to the tip we will use, optimizing the action of the tip, decreasing the stress and increasing the life of the tip (Fig. 1 bis). The other aspect that must be taken into consideration is the guarantee that it will be possible, on the chosen unit, to mount the greatest number possible of tips.

This is because there are handpieces on the market with thread of different pitches: some are measured under the American system in inches and others in the European system in millimeters. Since the vast majority of endodontic tips are produced in the United States or in any case have pitch measured in inches, the machine of choice for endodontics must of necessity be able to solve this type of problem.

Consequently, it is necessary to avoid acquiring "closed" systems on which only tips specifically produced for that machine may be mounted, or systems in which the use of other tips is highly complex. Rather we should prefer "open" systems in which it is possible to use almost all types of available tip.

This aspect becomes of strategic importance when we analyze the number and variety of terminals available, and realize that it is impossible to cover all clinical situations with a single family of tips. In recent years, due to increasing clinical demands, ultrasonic tips have evolved in parallel with endodontic techniques and thus have inevitably increased in number.

Today, dozens of different types of tip are available on the market; they differ in shape and length but also in the material from which they are made.

For years the only metal used was steel, with which many excellent tips were produced that are still being used profitably today, even if modern

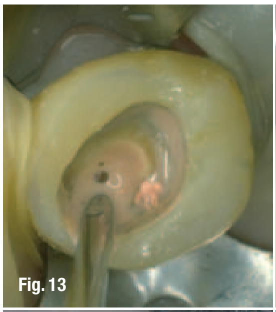


Fig. 13


Fig. 14

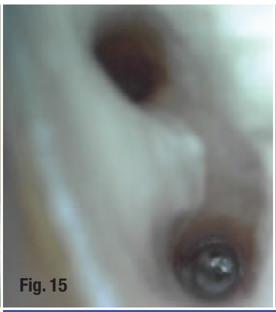


Fig. 15

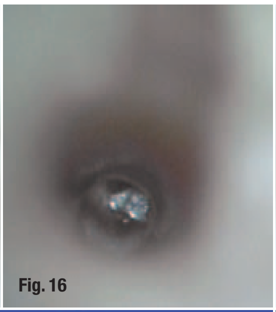


Fig. 16

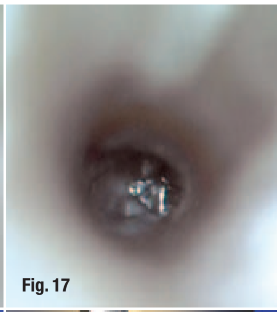


Fig. 17


Fig. 18

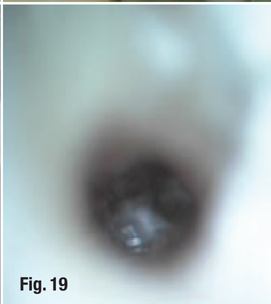


Fig. 19

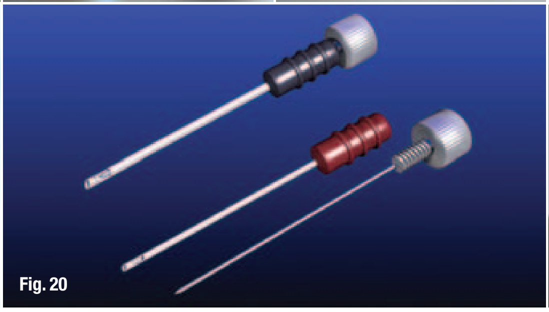


Fig. 20

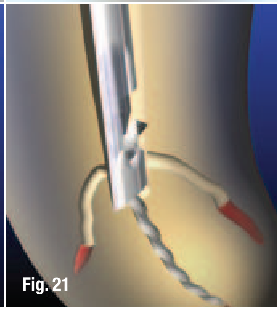


Fig. 21

technology enables instruments to be produced with even higher performance.

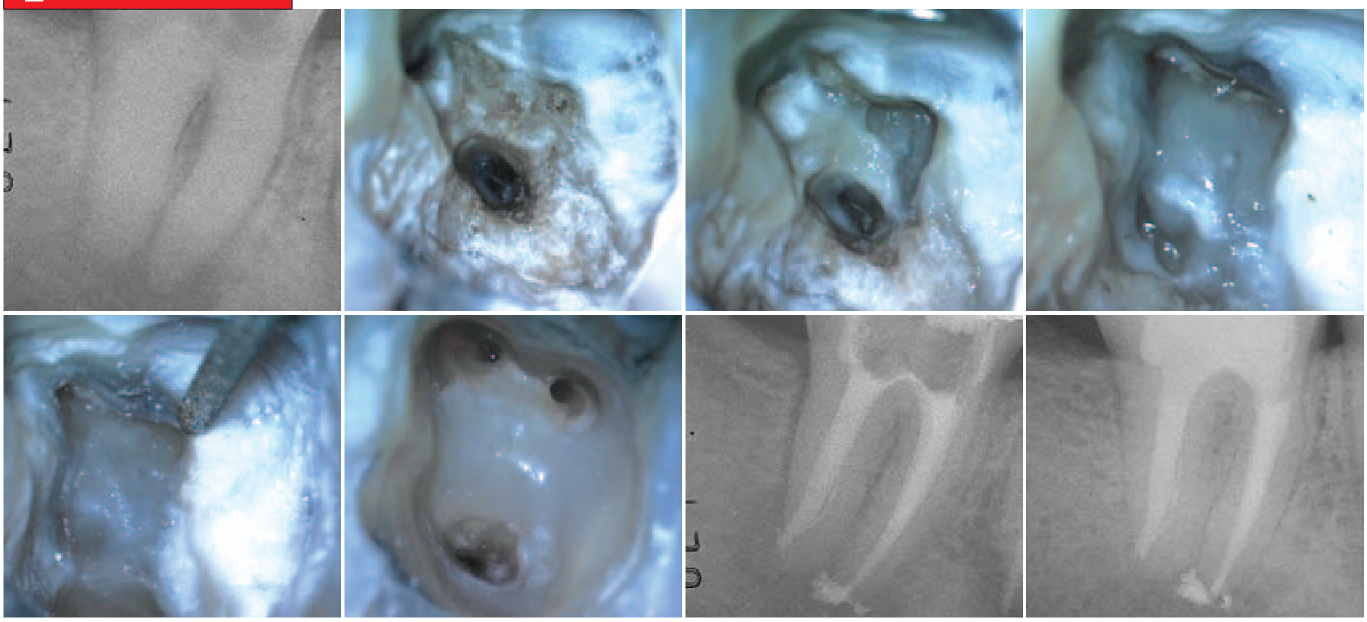
This is for example the case of the new Pro-Ultra tips, coated with zirconium nitride, and those of the Pro-Ultra series made of titanium that, thanks to their considerable differences in length, taper and flexibility, cover a very wide range of utilizations and are extremely useful in various endodontic applications (Figs. 2, 2 bis).

However, the new tips need not entirely replace the old models: frequently they offer different characteristics in terms of performance and open up new working possibilities.

In clinical practice, it may in any case be useful to make use of steel tips whose characteristics are different and with which we can cover the remainder of operative situations. This is the case for example of the spreaders SP1, SP2 and SP3 by E.I.E., which are the longest tips available on the market, and likewise of ET 20, ET 20D, ET 40 and ET 40D from Satelec (Fig. 3), or of the K files (Fig. 3 bis), again made by Satelec that, used for specific purposes, are irreplaceable instruments in some delicate canal situations.

However, the enormous differences existing between all these tips in terms of length and size means that we must be able to control the power supplied by the ultrasonic source very precisely, which confirms how important it is to have a good unit available, not only to use the tips to the best, optimizing their performance, but also to minimize tip breakages.

_Case 1



I will now look at the clinical situations in which the use of ultrasonic techniques improves our endodontic performance, even in some cases being the only treatment possible.

_The clinic

The first clinical situation in which we can gain enormous advantage by using ultrasonic tips is in the preparation of access cavities and in locating the canal orifices.

This first stage of endodontic treatment is often complicated by the presence of pulp chambers that over time have become calcified and in which a neo-deposition of secondary dentin has occurred that has partly or completely obliterated the root anatomy.

We know how complex it is in these situations to make a correct access cavity, respecting the original anatomy of the tooth, not altering the chamber floor, and above all locating all canal entrances.

The advantages offered by using ultrasonic tips in this situation derive from two features: great cutting precision and incomparable view of the operative field.

The control that ultrasonic tips provide is incomparably better than that offered by any rotating instrument, due not only to the ease of guiding an instrument that is not rotating, but also to the size of tip, decidedly smaller, which provides both a very fine cut and better vision; this is the other great difference compared to the use of handpieces: the field of view is greatly improved and freed from all impediments. Typically in these situations we find access cavities that have substantially modified the root anatomy including perforation of the pulpal floor, or cases in which the canal orifices have not been located. These advantages are immediately obvious even at low magnification.

If we also take into account that today these operative stages are frequently carried out under microscopic control, the advantages are further enhanced. Those who use this highly powerful tool know the enormous difficulty of using a rotating instruments at this operative stage, where the head of the handpieces practically cover the entire operative field, impeding proper control of the work.

The most suitable tips for this operative stage are without doubt those with great taper and not excessive length. These are tips with good cutting capability that can be used at high power to speed up the work. Using the operative microscope, it is a pleasure to follow the precise and effective cutting action of the tip, which in a short time enables us to give an excellent preparation to the floor of the pulp chamber, eliminating calculus and calcification and also finishing the axial walls of the cavity.

For this reason, the tips used in these stages must be diamond-coated (ET 20D by Satelec) or zirconium nitride coated (Pro-Ultra Endo 2–3) so that the ultrasonic tip can cut both at the point and along its edges.

The remaining preparation is with smooth and diverging walls, following the rules of the ideal access cavity (Figs. 4, 4 bis).

When treating even more complex cases, in which deposition of neo-dentin has obliterated not only the pulp chamber but also part of the root canal, my preference is for thinner tips that at the same time guarantee adequate cutting capability, such as Endo 4-5 of the Pro-Ultra series or ET40D by Satelec (Case 1).

With these tips used under microscopic control there are no operative limits. We can locate the canal lumen even in cases in which the canal is almost completely obliterated by secondary dentin, or prepare precisely and conservatively the isthmus that connects canals of the same root, as in the mesial canal of the lower molars, where we frequently find a third canal, an "extra orifice", which may be found in this complex endodontic anatomy more frequently than one might think (Cases 2, 3).

Thus today we have the possibility of resolving cases that only a few years ago required surgery, and that today we can resolve brilliantly by non surgical retreatment.

Another important chapter in which ultrasonic techniques find their ideal application is that of removing cast or preformed posts, screwed or cemented.

The posts may be removed using ultrasonic tips alone or together with other tools such as a post extractor kit (PRS Ruddle Post-Extractor) (Figs. 5, 6) (Case 4).

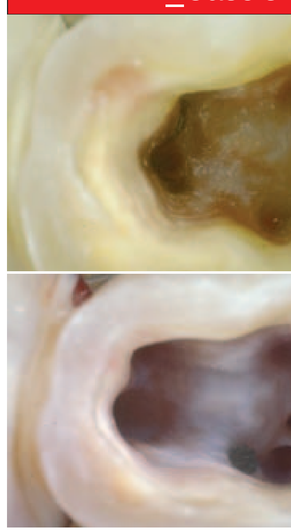
It is now well known that the action of ultrasound may contribute to cement disintegration thanks to the conduction of the vibrations within the metal of the post; in many cases, particularly for preformed screwed-in posts, this may be sufficient to remove the post (Figs. 7, 8).

For this purpose, a specific tip has been created: the Endo 1 Pro-Ultra, which may be vibrated at high power above the surface of the post, thus removing it. Again in the field of removing old restorations, another important application exploits the cutting capability of the stronger tips to eliminate build-up material in teeth treated endodontically. The reconstruction usually involves the floor of the chamber, and to a varying depth also the canal orifices, making elimination of the entire build-up a far from simple operation. The contribution given by ultrasonic tips in removing the reconstruction without altering the anatomy, thus saving dental tissue, is of great help (Fig. 9).

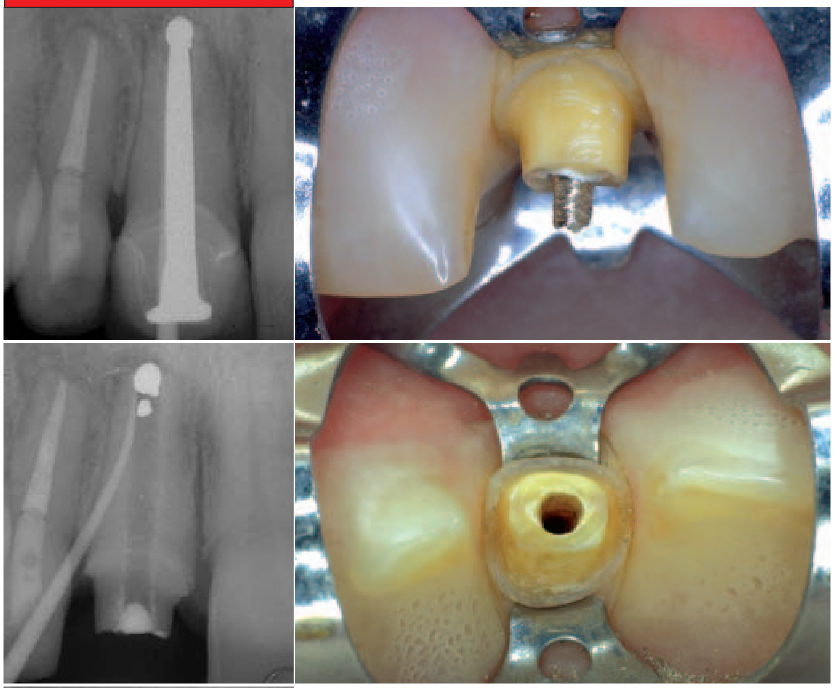
This may be particularly useful above all when the restoration material is composite resin that, due to its adhesive capacities and color, is very difficult

_Case 2

_Case 3



_Case 4



to distinguish from dentin and to separate from the tooth surface; in these cases, ultrasonic power and frequency may both be very high (Figs. 10, 11).

Another important point to stress is that even when using high power, the pressure exercised on the handpiece should be light, with movements similar to those of a brush, to maintain tip integrity and to avoid needlessly overheating the handpiece and the tooth: these tips are designed to work without irrigation, leaving maximum visibility for the dentist.

Finally, I will look at the last important chapter in which we use ultrasonic sources: that of non surgical retreatment.

During retreatment, emptying the canal anatomy of cement, gutta percha or other material has always been very long and laborious.

Today this operation is greatly simplified because the thin tips available easily enter the canal obturation material, enabling it to be removed.

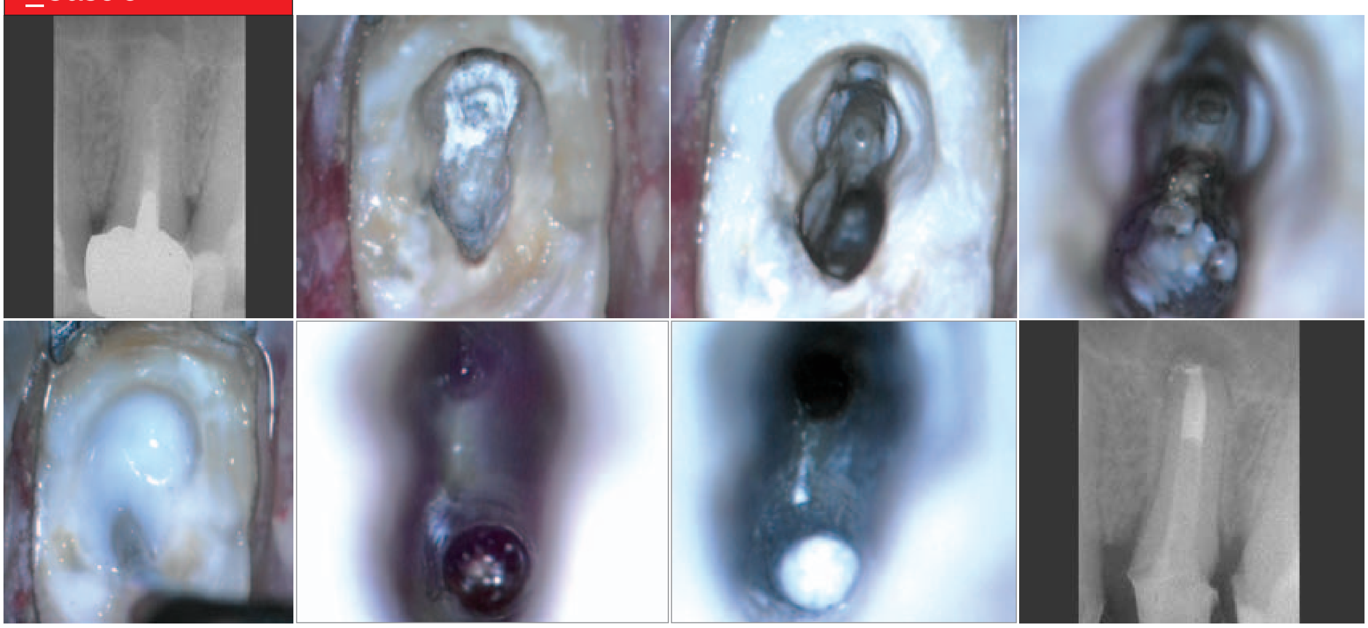
A wide choice of tips is available, and as we go deeper into the canal we can use increasingly thin and flexible ones (Titanium Series Pro-Ultra; Satelec K Files) that enable us to follow the root anatomy more closely.

When canals are filled with gutta percha, the more powerful tips easily enter into the material thanks to the vibration and the heat they produce, but ultrasonic techniques may also be used in combination with solvents: their action amplifies that of the irrigants, facilitating removal of old canal obturation materials (Figs. 12–14).

All of this is highly effective with some materials, such as gutta percha, and on all traditional canal cements, but the situation is different if the cement used within the canal is for definitive cementations, something that unfortunately often happens not only when removing intra-canal restorations such posts or screws, but also in cases of so-called "standard" retreatment.

In this case, the tips we use should be thin, but must also be sufficiently powerful to destroy the large fragments of cement that occlude the root canal system. If in the shallower part of the canal (coronal one-third) it may be possible to do this with the naked eye or under low magnification, as we go deeper into the canal it is absolutely necessary to control the cutting action of these tips so that they can work exclusively on the cement and not on the canal walls.

_Case 5



The control we can obtain using the operative microscope is so precise that it enables us to completely empty the canal right to the apex even in cases in which very hard cement completely fills the canal.

Once the canal is completely empty of obturation material, or during this operation, it is extremely useful to associate the cleaning action of ultrasound with sodium hypochlorite (Case 5).

The quality of cleansing obtained thanks to ultrasonic waves acting on and heating the sodium hypochlorite enables us to eliminate all canal debris, leaving smooth walls that are free even of microscopic detritus; in using this procedure we also exploit the well-known antibacterial action of ultrasonic waves, a phenomenon known as "acoustic streaming".

The contribution that today we can obtain from this type of technology is very high, and enables us to succeed even in particularly difficult situations, such as where we have stops, ledges or broken instruments that make up a separate chapter in non surgical retreatment.

In these cases, the goal is to create access above the broken instrument, enabling the microscope to give us an optimal view of the canal and of the fragment; dentin must be removed with great care using ultrasonic tips of various sizes.

In my experience, use of ultrasonic tips is differentiated: we use a tip with better cutting power to create the space above the fragment, and a gentler tip for precision work around the broken instrument, where I prefer less power but greater control, difficult to obtain with a more aggressive tip.

In this connection I prefer to associate a number of tips, choosing steel or titanium when the work becomes more delicate; these have the advantage that their shape can be modified, as they are less rigid, which enables us to have different angles available that enormously facilitate access.

For this purpose, K Files pre-mounted for ultrasonic use can be very useful; they were designed for specific jobs but are suitable also for other work thanks to their great elasticity, which enables us to obtain a very gentle but effective action, not comparable to that of any other tips available commercially.

With our chosen tip, we slowly create space lateral to the instrument, enabling us to dislocate it and subsequently to remove it by making it gently vibrate with the ultrasonic action until it comes out of the canal (Figs. 15–19).

The more apically the broken instrument is located, the greater the difficulty of applying this type of approach, although with some experience we should succeed even in removing instruments located in the apical third, sometimes even beyond the curvature (Case 6).

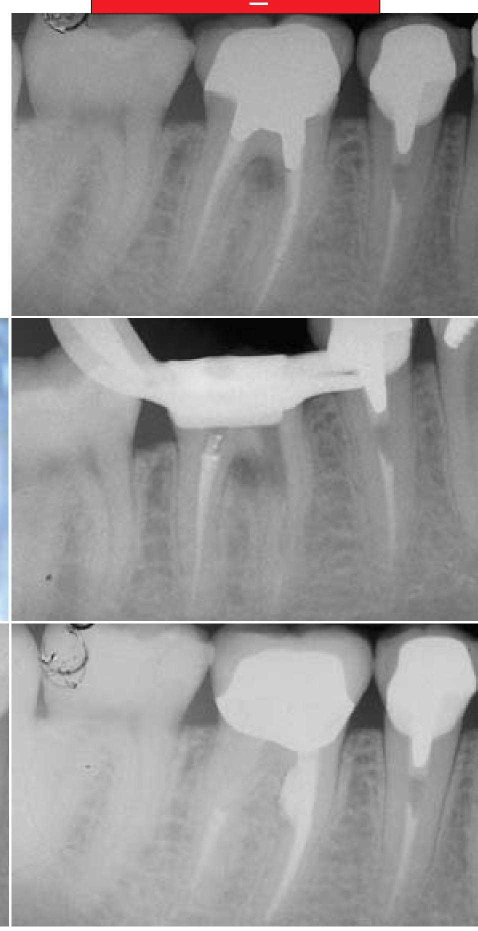
The canal curvature is not, in my opinion, an absolute limit, because thanks to the use of pre-curvable K files we can also work around the curvature of the canal, maintaining reasonable control of the tip; furthermore, when the fragment breaks in the curve, at least a very small portion of it is usually visible, thus enabling us to apply the above-described technique.

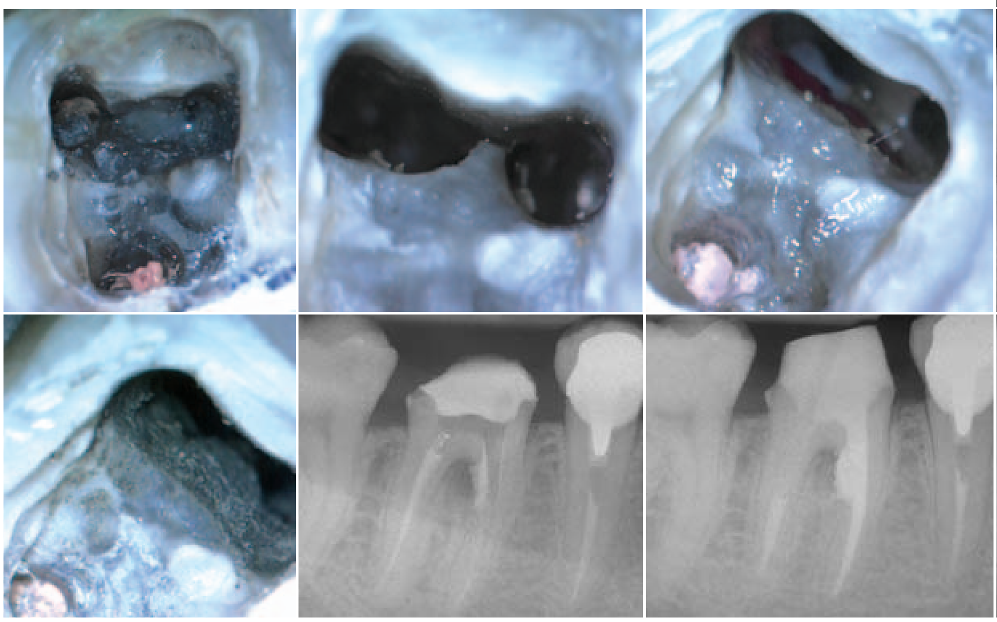
In situations in which this is not sufficient due to the excessive length of the broken instrument we can, as for posts, combine it with use of a specific extraction kit to remove these fragments.

Kits such as Cancellieri or the new instrument designed by Cliff Ruddle, the IRS (Instrument Removal System) are an interesting option that offer some advantages without any real risk.

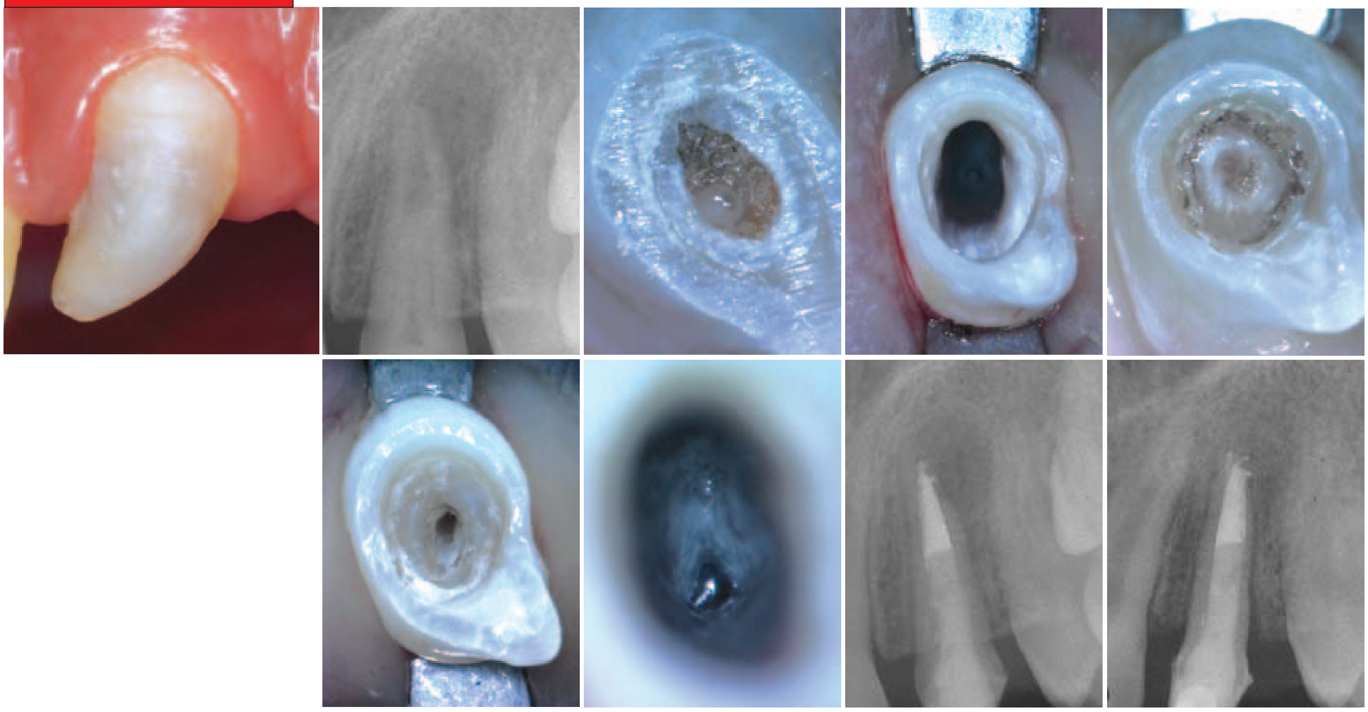
_Case 6

_Case 7





_Case 8



They consist of a series of hollow points of different sizes that, inserted into the canal, can be made to enclose the free portion of the broken instrument and hook onto the fragment, thus extracting it. With this system we can apply considerable force axially to the instrument, thus overcoming the resistance of the dentin walls (Figs. 20, 21).

The last application of ultrasonic endodontics is that connected with preparation of the root canal system itself. Shaping with ultrasonic files, a common technique in the early 1980s, has now long been abandoned, and we can now exploit the cutting action of these tips in specific clinical situations that require a particular preparation of the anatomical defect, leaving aside canal shaping as such.

A typical example of this condition is perforation; in these cases it is indicated to exploit the controlled cutting action of ultrasonic tips to clean the defect of granulation tissue and to regularize the edges so as to predispose the cavity for correct obturation.

Today the use of ultrasound may also be indicated to vectorize obturation material in these specific cases, where the most commonly used material to fill the defect is M.T.A. (Pro-Root Dentsply-Maillefer) which under pressure of the vibrations adapts well to the prepared cavity, leaving a smooth and compact surface that gives an optimal seal to this serious anatomical defect (Case 7).

In conclusion, I will illustrate a clinical case of dens-in-dente that was brilliantly resolved thanks to the use of ultrasound combined with the operative microscope; that is, thanks to these technologies, the market makes it increasingly possible for us today to perform endodontics under the sign of excellence (Case 8). _

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Active member of the Italian Society of Endodontics, of the Italian Accademy of Microscopic dentistry, Specialist Member of the European Society of Endodontology and member of the American Association of endodontists, from 1994-1998 he was a member of the admission commitee of the S.I.E. From 1998-2001 he was the cultural secretary of the Italian Society of endodontics, the president from 2003 to 2005. At the moment he is the past-president of the S.I.E.
He has lectured on various Endodontic topics all over the world he has also published on many national and international journals and he has also produced scientific videos.
With C.J. Ruddle he has pubblished a series of videos called "The endodontic game" disributed in Europe, USA, Canada, Australia, and Asia.
He has is own private practice in Milan and he is specialized mainly in Endodontics and surgical Endodontics with particularly focusing for the micro dentistry.

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