Intentional replantation: A viable treatment option for specific endodontic conditions

Prof Navneet Shah, Dr Ajay Logani & Dr Abhinav Kumar

Intentional replantation is defined as the purposeful extraction of a tooth in order to pair adjacent teeth that cannot be treated or cause of treatment failure and thereafter the return of the tooth to its original socket. Any tooth that can beatraumatically removed in one piece is a potential candidate for intentional replantation. However, specific indications include:1–2

- all other endodontic non-surgical and surgical treatments have failed or are deemed impossible to perform;
- limited mouth opening that prevents the performance of non-surgical or peri-radicular surgical endodontic procedures;
- root canal obstructions; and
- restorative or perforation root dehiscence.

The contraindications may include:3–4

- long, curved roots;
- advanced periodontal diseases that have resulted in poor periodontal support and tooth mobility;
- multi-rooted teeth with diverging roots that make extraction and reimplantation impossible; and
- teeth with non-restorable caries.

In order to provide the best long-term prognosis for a tooth that is to be reimplanted intentionally, the tooth must be kept out of the socket for the shortest period possible, and the extraction of the tooth should be atraumatic to minimise damage to the cementum and the periodontal ligament. The periodontal ligament attached to the root surface should be kept moist in saline, Hank's Buffered Salt Solution (HBSS), ViaSpan or Diocycline solution for the entire time the tooth is outside the socket.

We have documented three clinical cases to exemplify the potential of intentional replantation as a viable treatment option in select endodontic cases.

Case I

A 14-year-old male patient presented with a separated Lentulo spiral extending 4 to 5 mm beyond the apex of the mesiogingival root canal of tooth #46. We did not use surgical elevators and took care that the beaks of the forceps did not go beyond the cemento-enamel junction (CEJ), as this may have damaged the cementum and the periodontal ligament.

Following extraction, we kept the tooth moist by immersing it in ViaSpan. With the breaks of the forceps, we held the tooth by its crown and cut the overextended Lentulo spiral. Thereafter, we performed a 5 mm long root-end preparation with an ultrasonic tip, at the apical end of all three canals. A retrograde filling was done with mineral trioxide aggregate (MTA). The extraction socket was then irrigated with normal saline and gently suctioned to remove blood clots. The socket was filled with tricalciumphosphate in order for the tooth to be 2 to 3 mm higher than before. This helped in planning a good post-endodontic restoration.

The tooth was carefully reinserted into its socket and brought into occlusion with digital manipulation and patient bite force. The tooth was stabilised in its socket with a sling suture. The patient was re-evaluated after seven days, and the sutures were removed.

Case II

A 22-year-old male patient presented with a history of trauma to his maxillary anterior region. Clinical examination revealed an Ellis Class III fracture of tooth #12, with the fracture line extending to the root palatally. Once the mobile fragment had been extracted, we realised that the fracture line extended 2 to 3 mm sub-crestally. In order to bring the apical end of the fracture line to a supra-crestal position, we considered two options: orthodontic extrusion and intentional replantation.

The patient did not accept orthodontics as an option owing to the extended treatment time required.

Once the tooth had been atraumatically extracted, it was kept moist in ViaSpan. We inserted tricalcium phosphate in the apical 5 to 4 mm of the socket and reinserted the tooth with a 180° rotation to bring the deep fracture line into a more accessible labial side. The tooth was then splinted with fibre-reinforced composite for a period of three weeks. The root-canal treatment was completed at a later date, and the facial surface was built up with composite. We decided not to proceed with the crown immediately after stabilisation to prevent loading of the tooth. The patient was recalled periodically for follow-up.

Case III

A 25-year-old female patient presented with pain in her upper right anterior tooth. There was no history of trauma, and clinical examination revealed a deep palatal gingival groove (PGG) with respect to tooth #12. The intra-oral peri-apical radiograph revealed a peri-apical radiolucency. We decided to extract the tooth, seal the groove and then replant the tooth. After adequate anaesthesia had been obtained, the tooth was extracted with all the necessary precautions and immersed in ViaSpan. With the help of the forceps, it was then held by its crown. The PGG was debrided with the tip of the ultrasonic scaler and sealed with glass-ionomer cement (GIC). The socket was then gently curedted and the tooth reinserted. Sutures were placed in the inter-dental area and endodontic treatment was completed one week later. The apical 4 to 5 mm of the root were sealed with MTA, and the rest of the root canal was back-filled with thermo-plasticised gutta-percha. The patient was re-evaluated after seven days.

Discussion

Intentional replantation in dentistry has been performed for more than ten centuries and was used extensively to manage odontalgia.2 In 1561, Pare recommended its use when a healthy instead of a diseased tooth was mistakenly extracted.5 In 1712, Pierre Fauchard replanted a tooth and reported it to be stable on follow-up. Several steps in the replantation were debated, for instance the need for amputation of root apices, immediate or delayed replantation, root-canal obliteration before or after replantation, retention or preservation of periodontal ligament cells and the goal of ultimate healing—bony ankylosis or ligament repair.

It was in 1881 that Thompson presented the treatment on replantation of teeth and emphasised the importance of peri-cemental tissues for treatment success. Later, Evedes7 in 1887 and Scheff8 in 1890 addressed the role of periodontal ligament cells with regard to external root resorption after replantation. As the replantation technique became increasingly refined, it was used as an easy alternative for failing root-canal treatment and hence evoked sharp criticism for the technique of reimplantation per se.
“The ninth WEC will help to elevate the technical and scientific standards of endodontic research, practice and teaching”

An interview with IFEA congress president Prof. Hideaki Suda

The last World Endodontic Congress (WEC) in Athens, Greece, in 2010 was one of the most successful events the International Federation of Endodontic Associations (IFEA) has ever organized in its 27-year history. The next edition, to be held in Tokyo in Japan from 23 to 26 May 2013, has attracted even more interest from specialists around the world, according to the organization. Endo Tribune had the opportunity to speak with congress president and Tokyo Medical and Dental University professor Hideaki Suda.

Endo Tribune: IFEA’s ninth WEC is being held in Japan for the first time. What has the organization been like, and what are your initial expectations for the event?

Prof. Hideaki Suda: The selection of the Japan Endodontic Association to host the congress in 2013 was a decision made by the IFEA general assembly in Vancouver, Canada, six years ago. Since then, the local organizing committee and its five subcommittees have had over 50 meetings concerning the preparations for the congress. Each subcommittee has also held its own meetings. We expect that the ninth WEC will help to elevate the technical and scientific standards of endodontic research, practice and teaching, as well as disseminate them throughout the world in order to improve the dental care standards in many nations.

In what regard will this congress be different from that in Athens?

Looking back at the last congress, one has to admit that it was not only extremely well organized but also very successful both at an academic and social level. At this point, we can already say that the ninth WEC will be much larger in size and participation numbers, as we already have 1,100 preregistrations from 41 member and non-member countries. Almost 500 research papers have been accepted and will be presented in Tokyo. Furthermore, there will be nine symposia and 17 table clinic presentations, where the newest scientific methods and technologies will be on display.

Owing to Japan’s unique hospitality, I am sure that participants will enjoy their stay throughout the event.

Japan is the country where the apex locator was developed, amongst other things. How would you describe the level of endodontic treatment and research in the country?

Another Japanese development was the application of adhesive dentistry principles to endodontic treatment. As you may also know, Prof. Shinya Yamanaka from the Kyoto University was awarded the Nobel prize last year for inducing pluripotent stem cells. Tissue engineering of the dental pulp has become one of the hottest topics for research in Japan and we may see the regeneration of the pulp become a reality in the near future owing to this development.

Unfortunately, there are still only a few general practitioners who are specialised in endodontic procedures, most of which are performed under the Japanese health insurance service. Therefore, the country has tended to be behind other markets regarding the introduction of the latest instruments and materials to daily practice. It is encouraging to see however that endodontic seminars and hands-on courses for general dental practitioners here are always well attended, demonstrating that a large part of the profession is very keen on learning about the latest scientific and technological developments.

The theme of the congress is “Shaping the future of endodontics”. Will the programme be primarily focused on new techniques and treatment methods?

New techniques and treatment methods such as CBCT and the use of lasers and microscopes in endodontics are topics with which many of the papers are concerned. Other topics include pain control, the newest apex locators, MTA, novel root canal irrigation methods, the management of tooth fractures, as well as root canal preparation and filling. Single-file preparation methods in particular will be demonstrated during the pre-congress courses by four world-famous endodontists.

Which presentations are you looking forward to most?

Highlights will definitely be the plenary and keynote lectures, where the latest information on regeneration of the dental pulp, re- and auto-transplantation of teeth, biofilms in endodontics, treatment outcomes, and retreatment will be presented. In addition, we are looking forward to the country representative speakers session, where the current trends in endodontic treatment in each member country will be discussed.

The general assembly will also meet again during the congress. What will be discussed at this gathering?

The IFEA general assembly will select the location of the 12th WEC in 2019. Last time, it was decided that the next congress (in 2016) will be held in Cape Town in South Africa. Future concepts concerning science and business will also be discussed. Through these activities, we hope to foster international professional relationships and the exchange of information in endodontics.

Thank you very much for this interview.
There are many reasons for an adverse outcome of a replantation: the tooth can fracture during extrac-
tion and may be completely lost, peri-
ceal tissues can be damaged, reducing the likelihood of rootattach-
ment, infection, external root resorp-
tion; and ankylosis. Therefore, it is extremely important to understand that intentional replantation should be the last choice, selected only when all the other options of treatment—non-surgical and surgical—have been exhausted. Replantation can be a treatment of choice in cases in which a surgical approach can be dif-
cult, for example on the lingual root of a mandibular molar, or in cases in which a surgical approach would be very invasive, such as the removal of thick bone from the buccal aspect of a second mandibular molar.

Intentional replantation has a better prognosis when the extra-oral time is kept as short as possible and trauma to the periodontal ligament and cementum is minimised. It is advisable to perform routine en-
dodontic treatment intra-orally be-
fore the tooth is extracted to min-
imise the extra-oral time. It is also suggested that a team of two dentists work in tandem to prevent prolonged treatment time, thus improving the chances of success. The use of eleva-
tors should be avoided, and the bucks of the extraction forces should not go beyond the CEJ. The cortical bone integrity should be maintained, and the tooth should be extracted as atraumatically as possible.

The medium in which the tooth is kept must play an important role. Saline, HBSS, milk, Viaspan, to name a few, are widely used. Viaspan is used for organ transplantation and pre-
servation. Owing to its antioxidant activity, the solution keeps the perio-
dontal ligament moist and reduces the likelihood of surface resorption.

We generally use ultrasonic tips to prepare the root-end and the de-
bridement of the PGG. It conserves the tooth structure and produces significantly less smear layer com-
pared with burrs. Commonly used root-end filling materials are amal-
gam, Intermediate Restorative Ma-
terial (IRM), SuperEBA, GIC, Diaket, composite and MTA. The sealing ability and marginal adaptation of MTA have been proven to be su-
perior and not adversely affected by blood contamination. In addition, MTA promotes deposition of new ce-
mentum and stimulates osteoblastic adherence to the retromfilled surface.

In two of our cases, tricalcium phosphate was placed in the apical few millimetres of the socket. This was done in order to bring the defect supragingivally so that the integrity, aesthetics and prognosis of the case were improved. Tricalcium phos-
phate is an osteo-conductive mate-
rial that acts as scaffold for bone growth and is gradually degraded and replaced by bone.

A palato-gingival groove is a de-
velopmental anomaly that repre-
sents an infolding of enamel and Hertwig's epithelial root sheath. PGG can vary in depth, length and complexity, causing varying de-
grees of periodontal defects. Mild grooves terminate at the CEJ, whereas moderate grooves con-
tinue apically along the root surface. A treatment option for a PGG termi-
nating close to CEJ is to expose the groove surgically and to seal it there-
after. As presented, the groove ex-
tended beyond the apex in Case III. Here, the defect was sealed extra-
orally and the tooth replanted. GIC was used to seal the PGG, as it chem-
ically adheres to the tooth structure and has a good sealing ability and anti-bacterial effect.

After replantation, the tooth was splinted for ten days. The splint en-
abled physiological movement of the tooth to prevent ankylosis. En-
dodontic treatment was completed one week after replantation in order to prevent inflammatory resorption and ankylosis and to allow splicing of periodontal fibres, which limits the sequestration of potentially harmful root-filling materials into the trauma-
tised periodontal ligament. Fi-
nal restoration of the tooth was de-
layed to avoid loading and to no-
that proper healing of periodontal ligament took place.

In recent years, several bio-mod-
ulators, such as enamel matrix pro-
tein, hydroxyapatite and platelet-
rich plasma, have been used in instrumen-
tal replantation cases to improve the success rates. Guided tissue-regeneration techniques can also be employed along with these supplements to further improve the likelihood of success. We conclude that intentional replantation is a viable treatment option in carefully selected cases in which all other treat-
ment options have been exhausted.

We would like to acknowledge the assistance of Dr Akanksha Gupta and Dr Nikhil Sinha.
Endodontic retreatment
Achieving success the second time around

Dr. Brett E. Gilbert
USA

Root-canal treatment has been shown to have a success rate of 92%. However, as research methodologies move towards higher levels of substantiation, clinicians must rely on the best current evidence available to gain insight into the expected outcomes of their treatment. The highest level and best current evidence we have on the clinical success of endodontic treatment comes from a meta-analysis of the literature.

A meta-analysis done in 2007 by Ng et al. provides a thorough review of endodontic success rates from a variety of classical outcome studies. They found a weighted pooled success rate of 68 to 85%, with at least one year of follow-up.1

This review considers the strictest of criteria for determining that a tooth has healed, and includes many studies that were completed prior to the clinical use of dental operating microscopes and other advanced armamentaria.

When considering treatment for a tooth that has not healed successfully with root-canal therapy, there are significant challenges to address to be able to attain complete healing of the diseased tooth. The armamentarium and techniques available today allow us to disfigure the root-canal system properly after initial treatment has led to post-treatment disease.

The success rate of retreatment has been shown to be in the range of 80%; healing. Phases III and IV of the Toronto Study showed such a healing rate from four to six years after non-surgical retreatment.2 In a systematic review by Torabinejad et al. comparing non-surgical retreatment to endodontic surgery, it was demonstrated that non-surgical retreatment has a success rate to 74 to 86% over the ten years.5 From this, it is evident that endodontic disease continues to be a major problem for a tooth that has not healed after treatment.

The presence of pretreatment apical periodontitis is one factor that has been shown to decrease the success rate. Without apical periodontitis, a ten-year success rate of 92 to 98% has been shown for both initial and retreatment root-canal therapies. With the pre-operative presence of apical periodontitis, there is a decrease in the success rate to 74 to 98%, over the ten years.3 This is evident that endodontic healing is attainable through retreatment procedures, allowing us to maintain our patients’ natural teeth (Figs. 2a-c). Although the alternative clinical treatment option of implant placement can provide an effective method for replacing a missing tooth, healthy maintenance of the natural tooth should remain the overall goal.

Post-treatment disease is, inevitably, a result of bacteria and the host response of the patient to the bacteria. These micro-organisms are the most critical etiological factor of post-treatment disease. As they are present within the root-canal system of a previously endodontically treated tooth owing to a combination of substandard endodontic techniques, iatrogenic treatment issues and restorative failure.

Intra-radicular bacteria are the primary etiology of post-treatment disease6 and eradication of these bacteria is the primary goal of retreatment procedures.

The intra-radicular bacteria present in the previously treated tooth are persistent and resist removal methods. Bacteria are able to hide and survive in canal ramifications, deltas, irregularities (fiss) and dentinal tubules.

Figure 2 shows the complex root-canal anatomy propertively (green areas) and the minimal amount of canal-wall cleaning that was accomplished during canal instrumentation (red areas). The remaining green areas illustrate the space that might be left untreated, thereby providing a source of bacteria and supporting substrate for intra-canal infection. The potential substrates that are found inside the canal and help the bacteria survive include untreated pulpal tissue; the presence of a biofilm and tissue fluid. This may be present in the canal owing to a poor coronal or radicular seal and microbial proliferation. The presence of a poor seal, bacteria and substrate for their growth results in ideal conditions for persistent inflammation and disease.8

The bacteria present in the initial infection of a root canal differ markedly from the bacteria infecting a previously treated tooth. Pre-treatment flora is polymicrobial with equal numbers of Gram-negative and -positive bacteria. Post-treatment bacteria are predominately Gram-positive9 and have been shown to be able to survive in harsh environments and to be resistant to many treatment methods.

There are high numbers of Enterococcus species, Enterococcus faecalis, for example, has been shown to be a common isolate in 27 to 77% of teeth with post-treatment disease.4 A contaminated canal space may result from incomplete cleansing initially or subsequent leakage into root-canal spaces following root-canal treatment. Since present inside the canals, E. faecalis has a variety of characteristics that allow it to evade our best efforts to eradicate it from the root-canal system, including the ability to invade dentinal tubules and adhere to collagen.4 It is also resistant to calcium hydroxide application inside the canal system, which is an inter-appointment treatment technique used to help remove micro-organisms and their by-products, such as lipopolysaccharides, from the canal space.10,11 E. faecalis’s resistance of calcium hydroxide action arises from its ability to pump hydrogen ions from a proton pump. The hydrogen combines with the hydrogen ions of calcium hydroxide and neutralises the high pH value.12

E. faecalis is also able to resist calcium hydroxide by being part of a biofilm. The protection of bacteria within a biofilm matrix prevents the contact of the bacteria...
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with irritants and medications, and allows communication between bacteria to aid in survival capabilities. The presence of E. faecalis is well documented; however, it is important that infection does not yet be proven definitively. Its survival mechanisms, however, can be highly resistant to the peristalsis capabilities of these bacteria, and our clinical techniques must be focused on the challenge of eliminating them.

Iatrogenic issues encountered during the initial root-canal treatment may be the cause of inter- and intracanal bacterial infection. These issues may include perforation, incomplete-cleansing and shaping, inadequate canal enlargement, missed canals, ledging, canal transportation, over-instrumentation, as well as obstruction of the canal by debris or separation of instruments. Failure to use or use too small a volume of an appropriate irrigant solution, such as sodium hypochlorite, is an iatrogenic error. Full-length 6% sodium hypochlorite should be used to be highly antimicrobial and able to dissolve tissue and disrupt bacterial biofilm. These qualities in an irrigant are ideal for the debridement of residual bacteria and tissue debris. The use of a rubber dam to isolate the treatment field is the standard of care for endodontic treatment. Failure to use a rubber dam may be a fundamental contributor to post-treatment disease. The following case illustrates the ability to overcome prior incompletely treated treatment to achieve successful healing (Figs. 3a-c).

Clinical example
Restorative failure is a common cause of post-treatment disease. Failure to place an effective permanent access restoration in a timely manner can allow for bacterial entry into the root-canal system by coronal leakage. Submarginal leakage on a crowned tooth can also allow bacterial entry to occur. Decay in a previously treated tooth is another source of bacterial contamination. Structural damage to a tooth by trauma, cracking or fracture may provide an entry point for bacterial contamination of the canals. Our patients are responsible for their own oral health and must commit to effective oral hygiene techniques. Failure of the patient to perform effective oral hygiene can result in the failure of even the most well-executed root-canal and restorative treatments.

With the bacterial challenges clinicians have to face, retreatment techniques must be capable of effective elimination of bacteria and their substrates. The use of a dental operating microscope and ultrasonic instruments allows clinicians to recover all existing canal anatomy properly to ensure that they are able to cleanse the root-canal system completely. The following clinical case (Fig. 6a & b) illustrates the extent of the canal space left untreated in the initial root-canal therapy by not opening the mesiobuccal canal adequately and not locating and cleansing the hiden second mesiobuccal canal.

Endodontic ultrasonic tips are highly efficient at removing core build-up material, paste fills, posts and silver point fillings, as demonstrated in Figure 5. These instruments allow clinicians to conserve root dentine by providing excellent visibility under a dental operating microscope, thereby greatly improving the ability to retreat canals (Figs. 6a-c). A heat source such as a System B tip (Axis, SybronEndo) is efficient for the removal of gutta-percha and resin materials from the coronal third. Hand and rotary files can remove root fillings and shape canals to appropriate working lengths. Current NiTi rotary files are highly flexible and resistant to separation and allow us to mechanically enlarge the apical third of root canals safely and efficiently without altering the natural canal morphology, which allows effective irrigation to reach the complex apical root-canal anatomy where bacteria are able to hide and resist debridement.

Once the canals have been located and instrumented, the ability to irrigate becomes essential to successful treatment. The irrigant solutions target the bacteria we are trying to eliminate. While sodium hypochlorite is a potent and proven antimicrobial and tissue dissolver,22 2% chlorohexidine has been shown to prevent the adhesion of E. faecalis to dentine.23 EDTA 17% is often used as an effective smear layer removal agent.24 Therefore, mechanical debridement and canal instrumentation provide a pathway for copious chemical irrigation deep into the canal.

Passive ultrasonic irrigation allows clinicians to place an irrigation solution into the pulp chamber and activate it as it is carried down to the apical end of the root canal. The InSafe tip from Satelec (Acteon, Paris, France) is a non-cutting ultrasonic file that is placed into each canal and is moved up and down in the canal for three cycles of 20 seconds. Passive ultrasonic irrigation has been shown to irrigate lateral root canals better at 4.5 and 2 mm from the working length of canals as compared with needle irrigation.25 It has been demonstrated that passive ultrasonic irrigation can remove dentine debris in a canal up to 5 mm in front of where this tip can apically in straight or curved canals.26 This evidence shows that an effective flow of irrigation can assist in the cleansing of teeth in which canal alteration occurred during the initial root-canal treatment.

The following silver-point case (Figs. 5a–c) with a large distal post and apical transportation in the mesial root, demonstrates the successful healing of post-treatment disease when proper disinfection has been accomplished. This case illustrates the reason that retreatment is the primary treatment option for post-treatment disease.

Once debridement and disinfection have been completed, appropriate obturation methods must be used to seal the canal spaces. The narrow vertical technique using gutta-percha or resin with an appropriate sealer agent provides a thorough seal of the well-cleaned and shaped canal spaces. The final restoration must provide a proper seal of the pulpal chamber to prevent coronal micro-leakage.

Current evidence has demonstrated that we can retreat previously endodontically treated teeth properly and successfully. Literature has also shown that specific bacteria such as E. faecalis, are able to survive inside a previously filled canal. The use of a dental operating microscope, ultrasonic instruments, irrigants, rotary NiTi files and appropriate obturation materials may not be able to achieve healing after retreatment. As we continue to strive to maintain healthy natural teeth for our patients, endodontic retreatment should be the primary treatment option for post-treatment disease.27 A complete list of references is available from the publisher. Dr Brett E. Gilbert has a vast international practice specialising in endodontics in Dallas, Illinois, USA. He also lectures nationally and internationally on clinical endodontics. He can be contacted at kingendo@kingendo.com.
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New tips for non-surgical endodontic retreatment

MÉRIGNAC CEDEX, France: The new EndoSuccess kit from Satelec was designed to address problems that commonly occur during non-surgical endodontic retreatment procedures. According to the French instrument manufacturer, which is part of the Acteon Group, the mini-tips of this product line are made of an alloy especially selected for this specific clinical application.

A major innovation, the use of Niobium-titanium an alpha-beta microcrystalline structure alloy, is claimed to allow optimal handling with ultrasound in even the most challenging circumstances and with the best mechanical and clinical performance. Even under intensive usage, it provides good stability/time ratios, the company said. With only a diameter of 3 µ, three to four times smaller than that of standard steel, the grain of the alloy has excellent ultrasound transmission, allowing practitioners to work efficiently and with the required resistance at high power.

The Newtron technology in Satelec piezoelectric generators furthermore gives the tips unbeatable efficiency, as the instruments are driven with great precision and respond specifically to the power settings chosen by the practitioner. According to Satelec, EndoSuccess tips are compatible with all Suprasson generators.

Obturators entirely made of gutta-percha

MUNICH, Germany: VDW’s latest innovation makes use of the advantages commonly associated with gutta-percha, as the new GUTTAFUSION carriers for the thermoplastic obturation of root canals are now made entirely of this material. These obturators now feature a core made of cross-linked gutta-percha that remains stable even when heated and therefore simplifies post space preparation procedures, according to the German specialist company.

In addition, they are coated with gutta-percha, which flows evenly when heated in the GUTTAFUSION oven, for example, filling the whole root-canal system, including ramifications, isthmuses and the apex. Root canal fillings done with GUTTAFUSION can be removed easily for retreatment, the company said. Specially designed for use with tweezers and fingers, the obturator handle allows for easy application of the obturators in molars. According to VDW, no other instruments are required for separation.

GUTTAFUSION has a high radiopacity and is compatible with most rotary NiTi systems. The three obturator sizes correspond to the R25, R40 and R50 instruments. The correct obturator size can also be determined with a NiTi size verifier, which is available in sizes 20 to 55. GUTTAFUSION obturators for RECIPROC are particularly convenient.
FKG, tools to keep smiling

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Endodontic irrigants and irrigant delivery systems

Dr Gary Glassman
Canada

Endodontic treatment is a predictable procedure with high success rates. Success depends on a number of factors, including appropriate instrumentation, successful irrigation and decontamination of the root-canal space to the apices and in areas such as isthmuses. These steps must be followed by complete obturation of the root canals, and placement of a coronal seal, prior to restorative treatment.

Several irrigants and irrigant delivery systems are available, all of which behave differently and have relative advantages and disadvantages. Common root-canal irrigants include sodium hypochlorite (NaOCl), chlorhexidine gluconate, alcohol, hydrogen peroxide and ethylenediaminetetraacetic acid (EDTA). In selecting an irrigant and technique, consideration must be given to their efficacy and safety.

With the introduction of modern techniques, success rates of up to 98% are being achieved.1

The ultimate goal of endodontic treatment per se is the prevention or treatment of apical periodontitis such that there is complete healing and an absence of infection.2 While the overall long-term goal is the placement of a definitive, clinically successful restoration and preservation of the tooth. For these to be achieved, appropriate instrumentation, irrigation, decontamination and root-canal obturation must occur, as well as attainment of a coronal seal. There is evidence that apical periodontitis is a biofilm-induced disease.3 A biofilm is an aggregate of micro-organisms in which cells adhere to each other and an absence of infection,2 while the root-canal system has a complex anatomy that consists of arborisations, isthmuses and cul-de-sacs that harbour organic tissue and bacterial contaminants (Fig. 1).4

The challenge for successful endodontic treatment has always been the removal of vital and necrotic remnants of pulp tissue, debris generated during instrumentation, the dentine smear layer, micro-organisms, and micro-tors from the root-canal system.5

Even with the use of rotary instrumentation, the nickel-titanium instruments currently available only act on the central body of the root canal, resulting in a reliance on irrigation to clean beyond what may be achieved by these instruments.6 In addition, Enterococcus faecalis and Actinomyces prevention or treatment of apical periodontitis such as Actinomyces spp which are both implicated in endodontic infections and in endodontic failure—pene-trate deep into the dentinal tubules, making their removal through mechanical instrumentation impossible.

Fig. 1 Root-canal complex (Device courtesy of Dr Ronald Ordinala Zapata, Brazil, www.facebook.com/TheInternalAnatomyOfTheHumanTeeth).

Regardless of which irrigant and irrigation system is used, and particularly if an irrigant with tissue toxicity is used, there are several general precautions that must be followed. A rubber dam must be used and a good seal obtained to ensure that no irrigant can spill from the pulp chamber into the oral cavity. If deep caries or a fracture is present adjacent to the rubber dam on the tooth being isolated, a temporary sealing material must be used prior to performing the procedure to ensure a good rubber dam seal. It is also important to protect the patient’s eyes with safety glasses and protect clothing from irrigant splatter or spill.

The success of endodontic treatment20,21 root-canal irrigants must not only be effective for dissolution of the organic of the dental pulp, but also effectively eliminate bacterial contamination and remove the smear—layer—the organic and inorganic layer that is created on the wall of the root canal during instrumentation. The ability to deliver irrigants to the root-canal terminus in a safe manner without causing harm to the patient is as important as the efficacy of those irrigants.

Over the years, many irrigating agents have been tried in order to achieve tissue dissolution and bacterial decontamination.21 The desired attributes of a root-canal irrigant include the ability to dissolve necrotic and pulpal tissue, bacterial decontamination and a broad antimicrobial spectrum, the ability to enter deep into the dentinal tubules, bioocompatibility and lack of toxicity, the ability to dissolve necrotic material and remove the smear layer, ease of use, and moderate cost.

As mentioned above, root-canal irrigants currently in use include hydrogen peroxide, NaOCl, EDTA, alcohol and chlorhexidine gluconate. Chlorhexidine gluconate offers a wide antimicrobial spectrum, the main bacteria associated with endodontic infections (E. faecalis and F. nucleatum) are sensitive to it, and it is biocompatible, with no tissue toxicity to the peripheral or surrounding tissue.5 Chlorhexidine gluconate, however, lacks the ability to dissolve necrotic tissue, which limits its usefulness. Hydrogen peroxide as a canal irrigant helps to remove debris from the root canal, as well as through expectoration of the solution. However, while an effective anti-bacterial irrigant, hydrogen peroxide does not dissolve necrotic intra-canal tissue and exhibits toxicity to the surrounding tissue. Cases of tissue damage and facial nerve damage have been reported following use of hydrogen peroxide as a root-canal irrigant.22 Alcohol-based canal irrigants have antimicrobial activity too, but do not dissolve necrotic tissue.

The irrigant that satisfies most of the requirements for a root-canal irrigant is NaOCl.23,24 It has the unique ability to dissolve necrotic tissue and the organic components of the smear layer.24 It also kills sessile endodontic pathogens organised in biofilms.25 There is no other root-canal irrigant that can meet all these requirements, even with the use of methods such as lowering the pH.26 Increasing the temperature,24 or adding surfactants to increase the wetting efficacy of the irrigant25 have, however, although NaOCl appears to be the most desirable single endodontic irrigant, it cannot dissolve inorganic dentine particles and thus cannot prevent the formation of a smear layer during instrumentation.25

Calculations hindering mechanical preparation are frequently encountered in the root-canal system, further complicating treatment. Demineralising agents such as EDTA have therefore been recommended as adjuvants in root-canal therapy.26,27 Thus, in contemporary endodontic practice, dual irrigants such as NaOCl with EDTA are often used as initial and final rinses to circumvent the shortcomings of a single irrigant.21,28 These irrigants must be brought into direct contact with the entire canal-wall surfaces for effective action.29,30 In particular in the apical portions of small root canals.

The combination of NaOCl and EDTA has been used worldwide for antiseptic of root-canal systems. The concentration of NaOCl used for root-canal irrigation ranges from 2.5 to 6%, depending on the country and local regulations. It has been shown, however, that tissue hydrolysis is greater at the higher end of this range, as demonstrated in a study by Hand et al. comparing 2.5 and 5.25% NaOCl.31 The higher concentration may also favour superior microbial outcome in comparison with 2.5% endodontic spectrum,29 including but not limited to E. faecalis. NaOCl is superior among irrigating agents that dissolve organic matter, EDTA is a chelating agent that aids in smear layer removal and increases dentine permeability,40,41 which will allow further irrigation with NaOCl to penetrate deep into the dentinal tubules.

General safety precautions

Regardless of which irrigant and irrigation system is used, and particularly if an irrigant with tissue toxicity is used, there are several general precautions that must be followed. A rubber dam must be used and a good seal obtained to ensure that no irrigant can spill from the pulp chamber into the oral cavity. If deep caries or a fracture is present adjacent to the rubber dam on the tooth being isolated, a temporary sealing material must be used prior to performing the procedure to ensure a good rubber dam seal. It is also important to protect the patient’s eyes with safety glasses and protect clothing from irrigant splatter or spill.

It is very important to note that while NaOCl has unique properties that satisfy most requirements for a root-canal irrigant, it also exhibits tissue toxicity that can result in damage to the adjacent tissue, including nerve damage should NaOCl incidently occur during canal irrigation. Furthermore, Nalgeber reported in the 1970s that apical extrusion of an endodontic irrigant routinely occurred in vivo.5 This highlights the importance of using devices and techniques that minimise or prevent this. NaOCl incidents are discussed later in this article.
Irrigant delivery systems

Root-canal irrigation systems can be divided into two categories: manual agitation techniques and machine-assisted agitation techniques. Manual irrigation involves positive-pressure irrigation, which is commonly performed with a syringe and a side-vented needle. Machine-assisted irrigation techniques include sonic and ultrasonic systems, as well as newer systems such as the EndoVac (SybronEndo), which delivers apical negative-pressure irrigation, the plastic rotary F File (Plastic Endo),75 the VibeRinge (VibeRinges),8 the RinseEndo (Air Techniques), and the EndoActivator (DENTSPLY Tulsa Dental Specialties). These two important factors should be considered during the process of irrigation: whether the irrigation system can deliver the irrigant to the whole extent of the root-canal system, particularly to the apical third, and whether the irrigant is capable of delivering areas that could not be reached with mechanical instrumentation, such as lateral canals and isthmuses. When evaluating irrigation of the apical third, the extent of the root-canal system, particularly the apical foramen, is critically important to determine which irrigation system will effectively irrigate the apical third, as well as isthmuses and lateral canals, and in a safe manner that prevents the extrusion of irrigant.

Manual agitation techniques

By far the most common and conventional set of irrigation techniques, manual irrigation involves dispensing an irrigant into a canal through needles/cannulae of variable gauges, either passively or with agitation by moving the needle up and down the canal space without binding it on the canal walls. This allows good control of needle depth and the volume of irrigant that is flushed through the canal.12,19 However, the closer the needle tip is positioned to the apical tissue, the greater the chance of apical extrusion of the irrigant.12,19 This must be avoided; were NaOCl to extrude past the apex, a catastrophic accident could occur.25

Manual-dynamic irrigation

Manual-dynamic irrigation involves gently moving a well-fitting gutta-percha master cone up and down in short 2 to 5 mm strokes within an instrumented canal, thereby producing a hydrodynamic effect and significant irrigant exchange.19 Recent studies have shown that this irrigation technique is significantly more effective than anchor- and dynamic irrigation and static irrigation.19,21,22

Machine-assisted agitation systems

Sonic irrigation

Sonic activation has been shown to be an effective method for...
disinfecting root canals, operating at frequencies of 1-4 kHz. There are several sonic irrigation devices on the market. The Varios allows delivery and sonic activation of the irrigation solution in one step. It employs a two-piece syringe with a rechargeable battery. The irrigant is sonically activated at the needle that attaches to the syringe. The EndoActivator is a more recently introduced sonically driven canal irrigation system. It consists of a portable handpiece and three types of disposable polymer tips of different sizes. The EndoActivator has been reported to effectively deliver debris from lateral canals, remove the smear layer, and dislodge clumps of biofilm within the curved canals of molar teeth.75

Ultrasonics
Ultrasonic energy produces higher frequencies than sonic energy but low amplitudes, oscillating at frequencies of 25–30 kHz.9,76 It is more advantageous to apply ultrasound at frequencies of 1–6 kHz.73,74 There are several sonic irrigation devices available. The first type is simultaneous ultrasonic instrument and irrigation, and the second type is referred to as passive ultrasonic irrigation operating without simultaneous irrigation (PUI). The literature indicates that it is more advantageous to apply ultrasonics after completion of canal preparation rather than as an alternative to conventional instrumentation.85–87 PUI irrigation allows energy to be transmitted from an oscillating file or smooth wire to the irrigant in the root canal by means of ultrasonic waves.2 There is consensus that PUI is more effective than sonic irrigation in removing pulpal tissue remnants and dentine debris.84,88,89 This may be due to the much higher velocity and volume of irrigant flow that are created in the canal during ultrasonic irrigation.90,91 PUI has been shown to remove the smear layer; there is a large body of evidence with different concentrations of NaOCl.90,91 In addition, numerous investigations have demonstrated that the use of PUI after hand or rotary instrumentation results in a significant reduction in the number of bacteria,91,92 or achieves significantly better results than syringe needle irrigation.93,94

Studies have demonstrated that effective delivery of irrigants to the apical third can be enhanced by using ultrasonic and sonic devices that demonstrate acoustic microstreaming and cavitation.95–97 Acoustic micro-streaming is defined as the movement of fluids along cell membranes, which occurs as a result of the ultrasound energy creating mechanical pressure changes within the tissue. Cavitation is defined as the formation and collapse of gas and vapour-filled bubbles or cavities in a fluid.98

The Apical Vapor Lock theory, proven in vitro by Tay, has been clinically demonstrated99 to also include the middle third by Vera: “the mixture of gases is originally trapped in the apical third, but then it might grow quickly by the nucleation of the smaller bubbles, forming a gas column that might not only impede penetration of the irrigant into the apical third but also push it coronally after it has been delivered into the canal.” However, according to Munoz, the canal was most likely immediately filled with ultrasound-activated NaOCl94 for one minute2 but as just described – its clinical application has not been effectively available for this ex- change and activation. In contrast, the clinically available protocol described by Colombo et al.100,101 approximates 2 of NaOCl actively passes through the complete WL for one minute.2 The difference in volumetric exchange equals 2/0.14 or 14.29 % and likely explains the disinfection differential.

The plastic rotary F File
Although sonic or ultrasonic instrumentation is more effective at removing debris than rotary endodontic files are, and more effective rotary files are often unable to remove this during endodontic treatment, many clinicians have found it useful to incorporate their endodontic instrument armamentarium. The common reasons given for not using sonic or ultrasonic filing are that it can be time-consuming to set up, an unwillingness to incur the cost of the equipment, and lack of awareness of the benefits of this final instrumentation step in PUI or sonic treatment.

It is for these reasons that an endodontic polymer-based rotary finishing file was developed. This new, single-use, rotary file has a unique file design with a diamond abrasive embedded into a non-toxic polymer.102 The File will remove dentinal walls and agitate the NaOCl without enlarging the canal.3

Pressure-alternation devices
Rinsendo irrigates the canal by using pressure-alternation technology. Its components are a handpiece, a cannula with a 7 mm exit aperture, and a tip carrying irrigant. The handpiece is powered by a dental air compressor and has an air pressure of 100 psi/min.75 Research has shown that it has promising results in cleaning the root-canal system, but more research is required to provide scientific evidence of its efficacy. Periapical irrigation of irrigant has been reported with this device.103,104

The EndoVac negative-pressure irrigation system
The EndoVac is an ultrasonic negative-pressure irrigation system that has three components: the Master Delivery Tip, MicroCannula and MasterCan. The Master Delivery Tip simultaneously delivers and evacuates the irrigant.3 Figure 2. The MicroCannula is used to suction irrigant from the chamber to the canal and evacuate the irrigation fluid. The MacroCannula or MicroCannula is connected via tubing to the high-speed suction of a dental unit. The Master Delivery Tip is connected to a syringe of irrigant and the evacuation hose is connected via tubing to the high-speed suction of a dental unit.3 The MacroCannula has an open end of size 0.55 mm in diameter with a 0.02 mm orifice and is attached to a handpiece for gross, initial flushing of the canal. The canal is most likely immediately filled with ultrasound-activated NaOCl3 for one minute,2 but as just described – its clinical application has not been effectively available for this exchange and activation. In contrast, the clinically available protocol described by Colombo et al.100,101 approximates 2 of NaOCl actively passes through the complete WL for one minute.2 The difference in volumetric exchange equals 2/0.14 or 14.29 % and likely explains the disinfection differential.

During irrigation, the Master Delivery Tip delivers irrigant to the pulp chamber and sinus and the excess irrigant is evacuated from the chamber, through the apical foramen and out through the suction hose.102 Thus, a constant supply of fresh irrigant is delivered by negative pressure to working length.102 A recent study showed that the volume of irrigant delivered was significantly higher than the volume delivered by conventional syringe needle irrigation.103 With the EndoVac, in contrast, irrigant from the chamber to working length is 100 µm in diameter and spaced 100 µm apart. This is attached to a fine piece of irrigation along the apical foramen of the canal when it is positioned at working length. The MicroCannula can be used in cans that are enlarged with endodontic files to ISO size 55.04 or larger.

Delivery Tip, MacroCannula and MicroCannula are used by the manufacturer with different concentrations of NaOCl at WL – 1 mm. Prior to PUI, 2 ml of NaOCl is injected into the root canal. The MicroCannula contains 12 microscopic holes and is capable of evacuating debris to full working length.102 The ISO size 0.52 mm di- ameter stainless-steel MicroCan- nula has four to five sets of three laser cut, laterally positioned offset holes adjacent to its closed end, with diameter 100 µm and spaced 100 µm apart. The MacroCannula is used to suction irrigant delivered to ISO size 55.04 or larger.

Thus, a constant flow of fresh irrigant from the chamber to working length is possible to reach and clean the isthmus area with instruments, it is not possible to reach and thoroughly clean the isthmus area with the method of irrigation is safe and efficacious. In studies comparing the EndoVac to the Forza,103 the F-File,102 the mammal- dental Dynamic Max-i-Pro (DENTSPLY Rinn), the Pressure Microsonic104 and the EndoVac,106 only the EndoVac was able to deliver and suction the irrigant completely cleansing 100 % of the isthmus area.

Apart from being able to avoid air entrainment, the EndoVac sys- tem is also advantageous in its ability to deliver irrigants safely to working length without causing their undue extrusion into the peri- apices, thereby avoiding NaOCl incidents.102 It is important to note that it is possible to create positive pres- sure in the pulp canal if the Master Delivery Tip is misused, which would create the risk of a NaOCl incident. The manufacturer’s in- structions must be followed for cor- rect use of the Master Delivery Tip.

Sodium hypochlorite irritation
Although a devastating endo- dontic NaOCl incident is rare,107 the clinical implications of a NaOCl vital tissue are well established.107 The associated sequelae of NaOCl irritation have been reported to include life-threatening airway ob- structions,110 facial disfigurement requiring multiple corrective surgi- cal procedures,111 permanent para-esthesia,110 permanent loss of taste control,112 and the least significant consequence—booth loss.112

Although the exact etiology of the NaOCl incident is still unre- tirn, based on the evidence from ac- tual incidents and the location of the associated tissue trauma, it would appear that an intravascular injec- tion may be the cause. The patient shown in Figure 3 demonstrates a widespread area of tissue trauma that is in contrast to the character- istics of NaOCl incident trauma reported by Faulks.113 This ex- tensive trauma, and particularly involving the pattern of ecchymosis around the eye, could only have oc- curred if the NaOCl had been intro- duced into the root canal system via the open apex through which ex- trusion of the irrigant occurred and the irrigant then found its way into the venous complex. This would re- quire positive pressure apically that exceeded venous pressure (10 mg Hg). In one in vitro study, which used a positive- pressure needle irrigation technique to mimic clinical conditions and techniques, the apical pressure generated was found to be eight times higher than the normal venous pressure.114

This does not imply that NaOCl can or should be excluded as an endodontic irrigant. Its role is critical, as has been discussed in this article. What this does imply is that it must be delivered safely.

Safety first
In order to compare the safety of six current intra-canal irrigation techniques, a study was conducted using the worst-case scenario of apical extrusion, with NaOCl delivered to an open apex.115 The study con- cluded that the EndoVac did not ex- clude any of the irrigation techniques and delivery and suctioning of the
ant from the chamber to full working length, whereas other devices did. The EndoActivator extruded only a very small volume of irrigant, the clinical significance of which is not known.

Mitchell and Baumgartner tested irrigant (NaOCl) extrusion from a root canal sealed with a permeable agarose gel. Significantly less extrusion occurred using the EndoVac system compared with positive-pressure needle irrigation. A well-controlled study by Gondim et al. found that patients experienced less post-operative pain, measured objectively and subjectively, when apical negative-pressure irrigation was performed (EndoVac) than with apical positive-pressure irrigation.111

**Efficacy**

In vitro and in vivo studies have demonstrated greater removal of debris from the apical walls and a statistically cleaner result using apical negative-pressure irrigation in closed root-canal systems with sealed apices. In an in vitro study of 22 teeth by Shin and Baumgartner, less debris remained at 1 mm from working length using apical negative-pressure compared to use of traditional needle irrigation, while Shin et al. found in an in vitro study of 69 teeth comparing traditional needle irrigation with apical negative pressure that these methods both resulted in clean root canals, but that apical negative pressure resulted in less debris remaining at 1.5 and 3.5 mm from working length.112,113 When comparing root-canal debridement using manual-dynamic agitation or the EndoVac for final irrigation in a closed system and an open system, it was found that the presence of a sealed apical foramen adversely affected debridement efficacy when manual-dynamic agitation was used, but did not adversely affect results where the EndoVac was used. Apical negative-pressure irrigation is an effective method to overcome the fluid-dynamic challenges inherent in closed root-canal systems.117

**Microbial control**

Hockett et al. tested the ability of apical negative pressure to remove a thick biofilm of E. faecalis, finding that these specimens rendered negative cultures obtained within 48 hours, while those irrigated using traditional positive-pressure irrigation were positive at 48 hours.118

One study found that apical negative-pressure irrigation resulted in similar bacterial reduction to use of apical positive-pressure irrigation and a triple antibiotic in immature teeth.119 In a study comparing the use of apical positive-pressure irrigation and a triple antibiotic that has been utilized for pulpal regeneration/revascularisation in teeth with incompletely formed apices (Trimix = Cipro, Minocin, Flagyl) versus use of apical negative-pressure irrigation with NaOCl, it was found that the results were statistically equivalent for mineralised tissue formation and the repair process.120 Using apical negative pressure and NaOCl also avoids the risk of drug resistance, tooth discoloration, and allergic reactions.121,122

**Conclusion**

Since the dawn of contemporary endodontics, dentists have been striving NaOCl into the root canal space and then proceeding to place endodontic instruments down the canal in the belief that they were carrying the irrigant to the apical termination. Biological, scanning electron microscopy, light microscopy, and other studies have proven this belief to be in error. NaOCl reacts with organic material in the root canal and quickly forms microbubbles at the apical termination that coalesce into a single large apical vapour bubble with subsequent instrumentation. Since the apical vapour lock cannot be displaced via mechanical means, it prevents further NaOCl flow into the apical area.

The safest method yet discovered to provide fresh NaOCl safely to the apical terminus to eliminate the apical vapour lock is to evacuate it via apical negative pressure. This method has also been proven to be safe because it always draws irrigant to the source via suction—down the canal and simultaneously away from the apical tissue in abundant quantities.114 When the proper irrigating agents are delivered safely to the full extent of the root-canal terminus, thereby removing 100 % of organic tissue and 100 % of the microbial contaminants, success in endodontic treatment may be taken to levels never seen before.123

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

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