Intentional replantation: A viable treatment option for specific endodontic conditions

Intentional replantation is defined as the purposeful extraction of a tooth in order to preserve a defect or cause of treatment failure and thereafter the return of the tooth to its original socket. Any tooth that can beatraumatically repositioned in one piece is a potential candidate for intentional replantation. However, specific indications include:

- 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;
- restorative or periradicular root de novo defects that exist in areas that are not accessible via the usual surgical approach with excessive loss of root length or alveolar bone.

The contraindications may include:

- 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 replanted intentionally, the tooth must be kept out of the socket for the shortest period possible, and the extractions 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 Oxinebicarbonate 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 Lenton’s spiral extending 4 to 5 mm beyond the apex of the mesiobuccal root canal of tooth #46 (Figs. 1a–d). The tooth was badly broken and the instrument tightly screwed into the root canal. All efforts to remove the spiral were futile, and we were concerned that it would fracture at the apex.

Apical surgery was ruled out because accessibility to the mesial-gual root would have been limited. We decided to replant the tooth intentionally and discussed this treatment option with the patient, who agreed to our proposal. Since the tooth was badly broken, we planned to reinforce its core with a post in the distal canal prior to extraction.

Once we had obtained adequate anaesthesia, the tooth was extracted atraumatically with an extraction forceps. We did not use surgical elevators and took care that the tooth 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 for-ceps, we held the tooth by its crown and cut the overextended Lenton’s spiral. Thereafter, we performed a 5 mm lase 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 tricalcium phosphate cement 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 the following options: orthodontic extru-sion 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 cement 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 ex-amination revealed a deep palato-gingival groove (PGG) with respect to tooth #12 (Figs. 2a–e). 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 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-iono-mer cement (GIC). The socket was then gently cured 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-plasti-cised gutta percha. The patient was re-evaluated after seven days.

Discussion

Intentional replantation in den-tonia has been performed for more than ten centuries and was used extensively to manage odontalgia. In 1651, Paré recommended its use when a healthy instead of a diseased tooth was mistakenly extracted. In 1712, Pierre Fauchet® 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 obturation before or after replantation, removal 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 technique of replanta-tion of teeth and emphasised the importance of preserving cutaneous innervation for treatment success. Later, Evesède® in 1887 and Schepp® in 1890 ad-dressed the role of periodontal liga-ment 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 tech-nique of replantation.
Endo Tribune: IFEA's ninth WEC is being held in Japan for the first time. What has the organisation 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 2015 was a decision made by the IFEA general assembly in Vancouver, Canada, six years ago. Since then, the local organising 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 organised 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. There-
There are many reasons for an adverse outcome of a replantation: the tooth can fracture during extrac-
tion and may be completely lost, peri-
cemental tissues can be damaged, reducing the likelihood of reattac-
chment, 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 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-oral be-
fore the tooth is extracted to
minimise 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 breaks
of the extraction forceps 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, Viaspam, to name
a few, are widely used. Viaspam unsed
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 burs. Commonly used
root-end filling materials are amal-
gam, Intermediate Restorative Mat-
erial (IRM), Super EBA, GIC, Diaket,
composite and MTA. The sealing
ability and marginal adaptation of
MTA have been proven to be su-
perior and not adversely affected
to blood contamination. In addition,
MTA promotes deposition of new ce-
mentum and stimulates osteoblastic
adherence to the retro-filled surface.

In two of our cases, tricalcium
phosphate was placed in the apical
few millimeters 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
antibacterial 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 seepage of potentially harmful
root-filling materials into the traui-
matised periodontal ligament.
Fina-

tal restoration of the tooth was de-
layed to avoid loading and to use
that proper healing of periodontal
ligament took place.

In recent years, several bio-mod-
ulators, such as enamel matrix pro-
tin, hydroxyapatite and platele-
rich plasma, have been used in
intentional 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.

Editorial note: A complete list of refer-
ences is available from the publisher.
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 83%. 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 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. 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 the ability to disrupt 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 four to six years after non-surgical retreatment. In a systematic review by Torabinejad et al., comparing non-surgical treatment to endodontic surgery, it was demonstrated that non-surgical retreatment had a success rate of 85% versus 71.8% for endodontic surgery after non-surgical retreatment.3 In the Toronto Study showed such success rate to 74% to 86% over the ten years.5 From this, it is evident that endodontic healing is attainable through retreatment procedures, allowing us to maintain our patients’ natural teeth (Figs. 1a–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 microorganisms are the most critical etiology 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 disease and eradication of these bacteria is the primary goal of retreatment procedures. The in vitro antibacterial efficacy of endodontic sealer systems is limited and the majority of bacteria that were once present within the root-canal system can persist after treatment.6 Post-treatment disease6 and eradication of bacteria within a biofilm matrix presents the clinician with a significant challenge to effectively remove infected root-canal and periapical tissue.

Figure 2 shows the complex root-canal anatomy preoperatively (green areas) and the minimal amount of canal wall cleansing 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 present within the canal include untreated pulpal tissue, bacteria and the 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.

The bacteria present in the initial infection of a root canal differ markedly from the bacteria infecting a previously treated tooth. Post-treatment flora is polymicrobial with equal numbers of Gram-negative and -positive bacteria. Post-treatment bacteria are predominantly Gram-positive7,8 and have been shown to be able to survive in harsh environments and 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.9 It is also resistant to calcium hydroxide application in the root-canal system, including the ability to invade dentinal tubules and adhere to collagen.10 It is also resistant to calcium hydroxide application in the root-canal system, including the ability to invade dentinal tubules and adhere to collagen.10 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 evade our best efforts to eradicate it from the root-canal system, including the ability to invade dentinal tubules and adhere to collagen.10 It is also resistant to calcium hydroxide application in the root-canal system, including the ability to invade dentinal tubules and adhere to collagen.10 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 with the calcium hydroxide and neutralises the high pH value.10

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 with the calcium hydroxide and neutralises the high pH value.10

The hydrogen combines with the calcium hydroxide to form calcium hydroxyl apatite and carbonic acid which is an inter-appointment treatment. E. faecalis’s resistance of calcium hydroxide application arises from its ability to pump hydrogen ions from a proton pump. The hydrogen combines with the calcium hydroxide to form calcium hydroxyl apatite and carbonic acid which is an inter-appointment treatment. E. faecalis’s resistance of calcium hydroxide application arises from its ability to pump hydrogen ions from a proton pump. The hydrogen combines with the calcium hydroxide to form calcium hydroxyl apatite and carbonic acid which is an inter-appointment treatment. E. faecalis’s resistance of calcium hydroxide application arises from its ability to pump hydrogen ions from a proton pump. The hydrogen combines with the calcium hydroxide to form calcium hydroxyl apatite and carbonic acid which is an inter-appointment treatment. E. faecalis’s resistance of calcium hydroxide application arises from its ability to pump hydrogen ions from a proton pump.

Dr Brett E. Gilbert—
Fig. 5: Tooth #30 with a radiolucent periapical lesion with evidence of incomplete cleansing, shaping and obturation.—Fig. 6a: Post-op radiograph.—Fig. 6b: Tooth #25 with a radiolucent periapical lesion on the mesiobuccal root apex.—Fig. 6c: Tooth #25 with a radiolucent periapical lesion on the mesiobuccal root apex.—Fig. 6d: Post-op radiograph—Fig. 6e: Thirteenth-month follow-up radiograph. (Courtesy of Dr Brett E. Gilbert)
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with irritants and medicaments, and allows communication between bacteria to aid in survival capabilities. The presence of E. faecalis is well documented; however, it is now known that post-treatment disease has yet to be proven definitively. Its survival mechanisms, however, shine a light on the persistent 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 intracanal bacterial infection. These issues may include perforation, incomplete cleansing and shaping, inadequate canal enlargement, missed canals, ledging, canal transportation, overinstrumentation, as well as obstruction of the canal by debris or separation of instruments. Failure to use or using too small a volume of an appropriate irrigant solution, such as sodium hypochlorite, is an iatrogenic error.

Full-length 6% sodium hypochlorite shown to be highly antimicrobial and able to dissolve tissue and disrupt bacterial biofilms. 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 incomplete 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 uncover all existing canal anatomy properly to ensure that they are able to cleanse the root-canal system completely. The following clinical case illustrates the extent of the canal space left unattended in the initial root-canal therapy by not opening the mesiobuccal canal adequately and not locating and cleansing the hidden 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 (Asahi, Sylron/Endo) 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 alteration of 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 and EDTA 17% are potent and proven antimicrobial and tissue dissolvers, 2% chlorhexidine has been shown to prevent the adhesion of E. faecalis to dentine. EDTA 17% is often used as an effective smear layer removal agent.22 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 irrigant solution into the pulp chamber and activate it as it is carried down to the apical end of the root canal. The Irrifile tip from Satelec (Acteon, France)
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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 Newton technology in Satelec piezoelectric generators further 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.
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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 have different characteristics and 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. 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. 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 obturation must occur, as well as attainment of a coronal seal. There is evidence that apical periodontitis is a biofilm-induced disease. A biofilm is an aggregate of micro-organisms in which cells adhere to each other and/or to a surface. These adherent cells are frequently embedded within a self-produced matrix of extracellular polymeric substance. The presence of micro-organisms embedded in a biofilm and growing in the root-canal system is a key factor for the development of periapical lesions. Additionally, the root-canal system has a complex anatomy that consists of root canal system, isthmuses and cul-de-sacs that harbour organic tissue and bacterial contaminants (Fig. 1).1

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-torsions from the root-canal system.2

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 chance on irrigation to clean beyond what may be achieved by these instruments.3 In addition, Enterococcus faecalis and Actinomyces prevention or treatment of apical periodontitis such as Actinomyces viscosus – which are both implicated in endodontic infections and in endodontic failure – penetrate deep into dental tubules, making their removal through mechanical instrumentation impossible.4

The success of endodontic treatment5–7 is due not only to effective dissolution of the organic and inorganic dentinal pulpal, 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. 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 dental tubules, bio-compatibility and lack of toxicity, the ability to dissolve organic 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 E. faecium) are sensitive to it, and it is biocompatible, with no tissue toxicity to the periapical or surrounding tissue.1 Chlorhexidine gluconate, however, lacks the ability to dissolve necrotic tissue, which limits its usefulness. Hydrogen peroxide as a canal irrigant helps to remove debris in the physical act of irrigation, as well as through egressing 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 reported following use of hydrogen peroxide as a root-canal irrigant.1,8 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.9–11 It has the unique ability to dissolve necrotic tissue and the organic components of the smear layer.12–15 It also kills sessile endodontic pathogens organised in biofilms.16 There is no other root-canal irrigant that can meet all these requirements, even with the use of methods such as lowering the pH.16–22 Increasing the temperature,16–22 or adding surfactants to increase the wetting efficiency of the irrigant15,23–25 have been advocated, and the use of NaOCl is less desirable endodontic irrigant, although NaOCl appears to be the most desirable single endodontic irrigant. Other chemically active agents, such as EDTA have commonly been recommended as adjuvants in root-canal therapy.26–30 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.30 The combination of NaOCl and EDTA has been used worldwide for the treatment of root-canal systems. The concentration of NaOCl used for root-canal irrigation ranges from 2.5 to 5.25% NaClO. The higher concentration may have greater antimicrobial potential than the 2.5% NaClO concentration, but it also causes more toxic effects within the dentine tubules.31

General safety precautions

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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 cuts 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 spillage.

It is very important to remember 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 enter and occur during canal irrigation. Furthermore, Nalge et al.29 reported in the 1970s that apical extrusion of an endodontic irrigant routinely occurred in vivo.30 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 includes 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), the VibeRinge (VibeRinge), the Rinsendo (Air Techniques), and the EndoActivator (DENTSPLY Tulsa Dental Specialties). Two important factors that should be considered during the process of irrigation are 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 deforming areas that could not be reached with mechanical instrumentation, such as lateral canals and isthmuses. When evaluating irrigation of the apical third, the phenomenon of apical vapour lock should be considered.

Apical vapour lock

Since roots are surrounded by the periodontium, and unless the root-canal orifice is open, the root canal behaves like a closed-ended channel. This produces an apical vapour lock that resists displacement during instrumentation and final irrigation, thus preventing the flow of irrigant into the apical region and adequate debritement of the root-canal system. Apical vapour lock also results in gas entrapment at the apical third. During irrigation, NaOCl reacts with organic tissue in the root-canal system, and the resulting hydrolysis liberates abundant quantities of ammonia and carbon dioxide. This gaseous mixture is trapped in the apical region and quickly forms a column of gas into which further fluid penetration is impossible. Extension of instrumentation into this vapour lock does not reduce or remove the gas bubble, just as it does not enable adequate flow of irrigant.

The phenomenon of apical vapour lock has been confirmed in studies in which roots were embedded in a polyvinylalcohol impression material to resist fluid flow through the apical foramen, simulating a closed-ended channel. The result in these studies was incomplete debritement of the apical part of the canal walls with the use of a positive-pressure syringe delivery technique. Micro-CT scanning and histological tests conducted by Tay et al. have also confirmed the presence of apical vapour lock. In fact, studies conducted without ensuring a four-ended channel cannot be regarded as conclusive on the efficacy of irrigation and the irrigant system. The apical vapour lock may also explain why in a number of studies investigators were unable to demonstrate a clean apical third in sealed root canals.

In a paper published in 1983, based on research Chow determined that traditional positive-pressure irrigation had virtually no effect apically to the orifice of the irrigation needle in a closed-root-canal system. Fluid exchange and debris displacement were minimal. Equally important to his primary findings, Chow set forth an invariable paradigm for endodontic irrigation: “For the solution to be mechanically effective in removing all the particles, it has to: (a) reach the apex; (b) create a current (force); and (c) carry the particles away.” The apical vapour lock and consideration for the patient’s safety have always prevented the thorough cleaning of the apical 5 mm. It 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 of an irrigant into a canal through needles/cannulas of variable gauges, either passively or with agitation by moving the needle up and down in 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. However, the closer the needle tip is positioned to the apical tissue, the greater the chance of apical extrusion of the irrigant. This must be avoided; were NaOCl to extrude past the apex, a catastrophic accident could occur.

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 extrusion. Recent studies have shown that this irrigation technique is significantly more effective than unidirectional dynamic irrigation and static irrigation.

Machine-assisted agitation systems

Sonic irrigation

Sonic activation has been shown to be an effective method for root-canal irrigation. Sonic agitation 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 extrusion.
Ultrasonic energy produces higher frequencies than sonic energy but low amplitudes, oscillating at frequencies of 25-50 kHz. Two types of ultrasonic irrigation are available. The first type is simultaneous ultrasonic instrumentation 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.1-5,8,10,35 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.4 There is consensus that PUI is more effective than syringe irrigation and removing pulpal tissue remnants and dentinal debris.5-7 This may be due to the much higher velocity and volume of irrigant flow that are created in the canal during ultrasonic irrigation.5,9,10 PUI has been shown to remove the smear layer; there is a large body of evidence with different concentrations of NaOCl.6-9 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.7,8,10,11 or achieves significantly better results than syringe needle irrigation.12,13

Studies have demonstrated that effective delivery of irrigants to the apical third can be enhanced by using ultrasonic and sonic devices that demonstrate acoustic micro-streaming and cavitation.9,10,11 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 vapor-filled bubbles or cavities in a fluid. The Apical Vapor Lock theory, proven in vitro by Tay, has been clinically demonstrated12 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, more recently Munoz13 demonstrated that both: passive ultrasonic irrigation (PUI) and EndoVac are more effective than the conventional endodontic needle in delivering irrigant into WL of root canals. This begs the efficacy question. Two recently published studies examined this issue with both systems by testing their ability to eliminate microorganisms during clinical treatment from infected root canal systems.14,15 Patra fund that after a supplementary irrigation procedure using PUI with NaOCl 25 % of the samples produced positive cultures. Colombo’s study examining the clinical efficacy of the EndoVac fund no microbial Rums.16,17 Thus, in the Pressure Stream instrumentation or at the on the 28 week obturation appointment.

When questioning these data, one must remember that microbial hydrolysis via NaOCl is an equilibrium reaction. Hand demonstrated that a 50 % reduction of NaOCl concentration resulted in a 500 % reduction in dissolution activity. Accordingly, one must consider both the delivery of the irrigant to full working length, via PUI, and the negative pressure and total volume of NaOCl exchanged. The volume of an instrumented root canal 19 mm long shaped to a # 35 with a 5 % instrument equals 4.102 ml.18 Paiva described placement of PUI via a NanoTip (ULTRATIP) at WL – a mandatory irrigation and discussed using PUI with R K < 15 ml at WL – 1 mm. Prior to PUI, 2 ml of NaOCl are delivered into the root canal. However, this could not have filled the apical four millimeters19 due to the apical dead space. According to Munoz, the canal was most likely immediately filled with ultrasonically activated NaOCl for one minute20 but as just described – to its coronal aspect – have been effectively available for this ex- change and activation. In contrast, two recently published protocols described by Colonna et al. approximately 2 ml of NaOCl actively passes through the complete WL, for one minute21. The difference in volumetric exchange equals 2.014 ± 1.420 % and likely ex- plains the disinfection differential.

The plastic rotary F File

Although sonic or ultrasonic instrumentation is more effective at removing apically occluded debris than rotary endodontic files are,2,3,15 and even passive ultrasonic irrigation is often unable to remove this during endodontic treatment, many clinicians will often inject irrigant into 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 unwieldy process to incur the cost of the equipment, and lack of awareness of the benefits of this final instrumentation step in PUI or irrigation treatment. It is for these reasons that an endodontic pediatric-based rotary finishing file was developed. This new, stainless steel rotary file has a unique file design with a dia- mond abrasive embedded into a non-tapered instrument. The File will remove dental wall debris and agitate the NaOCl without enlarging the canal. Pressure-alternation devices

Rinsing irrigants the canal by using pressure-activated technology. Its components are a handpie, a cannula with a 7 mm exit aperture, with a file carrying irrigant. The handpie is powered by a dental air compressor and has an adjustable speed of 0-6 ml/min. Research has shown that it has promising results in cleaning the root-canal system, but more re- search is needed to provide scientific evidence of its efficacy. Periapical irrigation of irrigants has been reported with this device.22,23,24

The EndoVac apical negative-pressure system

The EndoVac apical negative-pressure irrigation system has three components: the Master Delivery Tip, MicroCannula, and MicroCannula. The Master Delivery Tip simultaneously delivers and evacuates the irrigant (Fig. 2). The MicroCannula is used to suc- tion irrigant from the chamber to the coronal and middle segments of the canal. The MicroCannula 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 evacuation is attached to a handpiece for gross, initial flushing of the canal. The negative pressure is connected via tubing to the high-speed suction of a dental unit.22,23,24 The plastic MicroCannula has an open end of size 0.55 mm in diameter and a length of 25 mm. The delivery system consists of a syringe, tubing, and a needle. The delivery system is designed so that the irrigant flows through the tubing and is delivered to the cannula. The EndoVac is designed to deliver irrigant to the working length without causing their undue introduction into the peri- apical tissues.22,23,24 It avoids NaOCl incidents, it is important to note that it is possible to create positive pres- sure in the pulpal 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 correct use of the Master Delivery Tip.

Sodium hypochlorite irrigation

Although a devastating endodontic NaOCl incident is rare,22,23,24 any, the potential for NaOCl to cause serious injury is real. The root canal system is filled with vital tissue are well established.25,26 The associated sequelae of NaOCl exposure have been reported to include life-threatening airway ob- structions,27-29 facial disfigurement requiring multiple corrective surgi- cal procedures,30,31 permanent para-esthesia,32,33 pulpal necrosis,33,34 and— the least significant consequence— tooth loss.35,36

Although the exact etiology of the NaOCl incident is still uncer- tain, based on the evidence from actual incidents and the location of the associated tissue trauma, it would appear that an intracanal injec- tion may be the cause. The patient shown in Figure 3 demonstrates a widespread necrosis in the periapical tissues that is in contrast to the character- istics of NaOCl incident trauma reported by Fanshawe.37 This ex- tensive trauma, and particularly involving a pulmonary reaction around the ear, could only have occurred if the NaOCl had been intro- duced to the periapical tissues. It is possible to reach the root 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 mm Hg), see Fig. 4. In vitro study, which used a positive-pressure needle irriga- tion technique to mimic clinical situations and techniques, the apical pressure generated was found to be up to eight times higher than the normal venous pressure.38,39

This does not imply that NaOCl can or should be excluded as an apical insult. The real question is critical, as has been discussed in this article. What this does imply is that irrigant delivered safely. Safety first

In order to compare the safety of six current intra-canal irrigation devices, two studies were conducted using the worst-case scenario of apical extrusion, with EndoVac as the reference.40 An open apex was conducted.40 The study con- cluded that the EndoVac did not ex- pose the canal system to any irrigant delivery and suctioning of the
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 terminus. 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 terminus 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. 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.

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, whereas those irrigated using traditional positive-pressure irrigation were positive at 48 hours. 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. 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. Using apical negative pressure and NaOCl also avoids the risk of drug resistance, tooth discoloration, and allergic reactions.