Endodontic irrigants and irrigant delivery systems

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By 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 apex and tissues within such canals

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 96 percent 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 root-canal 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 microorganisms 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 microorganisms 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 arborizations, subapical ramifications, interradicular gaps and horizontal tissues and bacterial contaminants (Figs. 1a, b).

The challenge for successful endodontic treatment is always the removal of vital and necrotic remnants of pulp tissue and other biological debris during instrumentation, the dentin smear layer, microorganisms, and the organic elements from the root-canal system.

Even with the use of rotary instrumentation, the nickel-titanium instruments currently available only act on the central body of the root canal, and rely instead on reliance on irrigation to clean beyond what may be achieved by these limitations of instrumentation. Furthermore, Enterococcus faecalis and Actinomyces species are common causes for failures in such techniques, such as Actinomyces israelii—which are both implicated in endodontic failure and in endodontic treatment failure— penetrate deeply into the dentinal tubules, making their removal through mechanical instrumentation impossible.

Finally, E. faecalis commonly expresses multidrug resistance, making endodontic treatment costly. Therefore, a biofilm irrigant must be used because they are essential for efficient irrigation and the success of endodontic treatment. However, root-canal irrigants must not only be effective for dissolution of the organic layer, but also be effective in completely eliminating bacterial contamination and remove the smear layer—the organic and inorganic layer that is created on the wall of the root canal during the instrumentation process. The ability to deliver irrigants to the root-canal terminus in a safe manner is crucial in order to deliver effective treatment to the patient as is important as the efficacy of those irrigants. Over the years, many different irrigants 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 debris and biofilm, bacterial decontamination and a broad antimicrobial spectrum. The ability to enter deeply into the dentinal tubules, biocompatibility 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-cana lar irrigants currently in use include sodium hypochlorite, NaOCl, EDTA, alcohol and chlorhexidine gluconate. Chlorhexidine gluconate is a wide antimicrobial agent, the main bacteria associated with endodontic infections, (E. faecalis and A. naes) are sensitive to it, and it is biocompatible, with no tissue toxicity to the periapical or surrounding tissues. Chlorhexidine gluco-

nate, however, lacks the ability to dissolve necrotic tissue, which limits its usefulness. Hydrogen peroxide as a canal irrigant helps to oxidize the solution. However, while an effective anti-bacterial irrigant, hydrogen peroxide does not dissolve necrotic 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. Alcohol-based canal irrigants have antimicrobial activity too, but they do not dissolve necrotic tissue. The irrigant that satisfies most of the requirements for a root-canal irrigant is NaOCl. It has the unique ability to dissolve material, depending on the organic components of the smear layer. Chlorhexidine is also kills sessile endodontic pathogenic organisms grown in a biofilm. There is no other root-canal irrigant that can meet all these requirements, even with the use of methods such as lowering the pH, increasing the temperature or adding surfactants to increase the wettability of the irrigant.

However, the use of 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. Calcifications hindering mechanical preparation are frequently encountered in the root-canal system, further complicating treatment. De-mineralizing agents such as EDTA have therefore been recommended as adjuvants in root-canal therapy. Thus, in contemporary endodontic practice, dual irrigants such as NaOCl with EDTA are often used instead of simple NaOCl, and final rinses to circumvent the shortcomings of a single irrigant.

These irrigants must be brought into direct contact with the entire canal-wall surfaces for effective action, especially in the apical por-

tions of small root canals. The combination of NaOCl and EDTA has been used worldwide for antisepsis of root-canal systems. The combination of NaOCl used for root-canal irrigation ranges from 2.5 to 6 percent, increased by the addition of calcium hydroxide 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 percent NaOCl. The higher concentration may favor superior microbial outcomes. NaOCl has a broad antimicrobial spectrum, including but not limited to E. faecalis, which limits its usefulness. Hydrogen peroxide as a canal irrigant helps to oxidize the solution. However, while an effective anti-bacterial irrigant, hydrogen peroxide does not dissolve necrotic tissue and exhibits toxicity to the surrounding tissue. This limits its usefulness in clinical practice.

General safety precautions

In addition to irrigation and instrumentation, irrigation and instrumentation is employed, and particularly if an irrigant with tissue toxicity is used, there are several general precautions that must be fol- lowed. Before damaging the tissue regimen including irrigation and instrumentation, a temporary sealant material must be used prior to performing the procedure to ensure no root canal is exposed. It is also important to protect the patient’s eyes with safety goggles when irrigation is taking from irrigant splatter or spill. It is very important to note that while NaOCl has unique properties that satisfy most require-

ments for a root-canal irrigant, it also exhibits tissue toxicity that can result in damage to the adjacent tissue, including nerve damage to the periapical tissues. Root-canal irrigants can be divided into two categories: manual agitation techniques and machine-assisted agitation techniques. Manual irrigation techniques include positive-pressure irrigation, which is commonly performed with a syringe and a sidevented needle. Machine-assisted irrigation includes ultrasonic and Er:YAG lasers, as well as newer systems such as the plastic rotary F File (Orange, CA), which delivers apical negative-pressure irriga-

tion, the plastic rotary F File (Plastic Endo), the V-brushing (Vibringe), the Rinsing (Air

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Apical vapor lock
Because the root canal is surrounded by the periodontium, and unless the root canal foramen is opened, the root canal behaves like a closed-ended channel. This produces an apical vapor lock that resists displacement during the instrumentation and final irrigation, thus preventing the flow of irrigant into the apical foramen and narrowing of the luminal area, which further fluid penetration is impaired.74–76

The result in these studies was incomplete debridement of the root canal system.26–28 Apical vapor lock also results in gas entrapment at the apical third.77 During irrigation, NaOCl reacts with organic tissue to generate abundant quantities of ammonia and carbon dioxide.55 This results in gas production that forms a column of gas into which further fluid penetration is hindered.56–59 Externally introduced instruments in this vapor lock do not reduce or remove the gas, and hence do not enable adequate flow of irrigant. The phenomenon of apical vapor lock has been confirmed in studies in which roots were embedded in a gelatin matrix and subjected to impression material to restrict the flow of irrigant through the root canal.28,56,58–61 The gaseous mixture is trapped in the closed-ended channel and forms a column of gas into which further fluid penetration is impaired.56–59

Micro-CT scanning and histological tests conducted by Tay et al. have also confirmed the presence of apical vapor lock.62 In fact, studies conducted with optical coherence tomography imaging channel cannot be regarded as conclusive as the efficacy of odontoblasts and the root canal system.63 Apical vapor lock may also explain why in many studies of root canal instrumentation, it was unable to demonstrate a clean apical third in sealed root canals.62,64–66

In a paper published in 1985 based on research by Chow, determinants that traditional positive-pressure irrigation had virtually no effect on apical to the orifice of the root canal system.67 Fluid exchange and debris displacement in the root canal system.67 Equally important to his primary findings, Chow set forth an infallible method of achieving negative 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 vapor 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 infundibulae and lateral canals.68,69 Thus, it seems safe to prevent the extension of irritant.

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/canals 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. However, the closer the needle tip is positioned to the apical tissue, the greater the chance of apical extrusion of the irritant.44–46 This must be avoided; were NaOCl to extrude past the apex, a cata- strophic accident could occur.69,70

Manual-dynamic irrigation
Manual-dynamic irrigation involves gently moving a well-fitting gutta-percha master cone up and down in short 2- to 3-mm strokes within an instru- mental canal, thereby pro- ducing a hydrodynamic effect and significant irrigant exchange.29 Recent studies have demonstrated that this irrigation technique is signifi- cantly more effective than automated dynamic irrigation and static irrigation.30,31

Ultrasonic energy produces higher frequencies than sonic energy but low amplitudes, oc- cillating at frequencies of 25–50 kHz.69–72 Two types of ultrasonic irrigation are available. The first type is simultaneous ultrasound sono- sonic instrumentation and irriga- tion, and the second type is referred to as passive ultrasonic energy operating without sim- ultaneous irrigation (PUI).69,70 The literature indicates that it is more advantageous to apply this issue with both systems by testing their ability to eliminate micro-organisms during clinical treat- ment from infected root canals.73,74 Paiva fund that after sonic irrigation has been described for one minute with an irrigating solution of NaOCl.75,76

The common reasons given for the lack of awareness of the apical negative pressure irrigation system are: (a) the lack of scientific evidence of its effi- cacy, (b) the lack of scientific understanding of its physiologic effects, (c) the lack of scientific understanding of the effectiveness of this endodontic treatment, and (d) the lack of scientifi- cally proven clinical efficacy of this system.77,78

The plastic rotary F File.
Although sonic or ultrasonic in- strumentation is more effective in removing residual canal de- bris than rotary endodontic files are,79 irrigation solutions do not remain in the canal during this endodontic treatment, many clinicians still do not in- corporate it into their endodont- ic instrument armamentarium. The common reasons given for not using sonic or ultrasonic instrumentation are: (a) the ultrasonic file is consuming to set up, an unwill- ingness to incur the cost of the equipment, the lack of aware- ness of the benefits of this final instrumentation step in endo-dontic treatment. It is for these reasons that an endo-dontic polymer-based rotary file was developed. This new, single-use, plastic rotary file has a unique file de- sign with a diamond abrasive embedded into a non-toxic polymer. The F File will remove canal wall debries and agitate the NaOCl without enlarging the canal further.79–81

Pressure-alternation devices
Rinsendo irrigates the canal by using pressure-suction tech- nology. Its components are a handpiece, a cannula with a 7/0014 cc. Paiva described place- ement of NaOCl via a NaviTip 4 mm during instrumentation and irrigation.93 demonstrated that both sonic and ultrasonic irrigant is sonically activated, as the result of the ultrasound en- ergy creating mechanical pres- sure changes within the canal.30,31 Sonic irrigation has been shown to be an effective method for disinfecting root canals, operating at frequencies of 1–6 kHz.64–66 There are several sonic irrigation devices on the market. The Viritene delivers active and sonic irrigation of the activator in solution in one step. It employs a two-piece syringe with a rechargeable battery. The ir- rigant is sonically activated, as is the needle that allows the user to control the pressure delivered to the syringe. The Activator is a more recently introduced sonically driven irrigation system.30,31 It consists of a port- able handpiece and three types of disposable polymer tips of different sizes. The EndoActivator has been reported to effec- tively clean debris from lateral canals, remove the smear layer and dislodge changes of biofilm within the curved canals of mo- lar teeth.30,31 Sonic irrigation produces higher frequencies than sonic energy but low amplitudes, oc- cillating at frequencies of 25–50 kHz.69–72 Two types of ultrasonic irrigation are available. The first type is simultaneous ultrasound sono- sonic instrumentation and irriga- tion, and the second type is referred to as passive ultrasonic energy operating without sim- ultaneous irrigation (PUI).69,70 The literature indicates that it is more advantageous to apply this issue with both systems by testing their ability to eliminate micro-organisms during clinical treat- ment from infected root canals.73,74 Paiva fund that after sonic irrigation has been described for one minute with an irrigating solution of NaOCl.75,76

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This does not imply that NaOCl can or should be excluded as an endodontic irrigant; in fact, its use is critical, as has been discussed in prior articles.20-22 This does imply that it must be de- livered safely.

Safety first
In order to compare the safety of six-canal-irrigation delivery techniques, an in-vitro test was conducted using the working length of the canal. Extreme apical extravasation, with neutral atmos- pheric pressure and an open apical stop, was conducted to ensure that the EndoVac did not ex- trude irrigant after deep intra- canal delivery and suctioning of the irrigant from the chamber to full working length, whereas other devices did. The Endo- Activator extruded only a very small volume of irrigant, the clinical significance of which is not known. Mitchell and Baumgartner tested a manual system (Cavitron) from a root canal sealed with a permeable aseptic gel.23 Significantly more NaOCl incidents occurred using the EndoVac sys- tem compared with positive- pressure irrigation. A well-controlled study by Gon- dim et al. found that patients tolerated signs and symptoms of acute pain, measured objectively and subjectively, when apical neg- ative-pressure irrigation was performed. The study concluded that carrying the irrigant to the apical termi- nation with NaOCl acts with positive pressure irrigation. In vitro and in vivo studies have demonstrated greater removal of debris from the apical wall when this system is used.24 When using apical negative pressure irrigation in closed root-canal systems with sealed apices, in an in vivo study of 22 teeth by Siu and Baumgartner, less de-bris removal was found from working length using apical negative pressure compared with conventional needle irrigation, while Shin et al. found in an in vitro study of 69 teeth that apical negative-pressure irrigation with apical negative pressure that these methods do not remove root can- nula, but that apical negative pressure resulted in less debris remaining at 1.5 and 3.5 mm from working length.20-22,101-103

When comparing root-canal debridement with natural dy- namic agitation or the EndoVac for final irrigation in a closed root-canal system, it was found that the presence of a sealed apical foramen ad- visably affected debridement efficiency.20,22 Dynamic agitation was used, but did not always remove the entire debris from root canals, but that apical negative pressure resulted in less debris remaining at 1.5 and 3.5 mm from working length.20-22,101-103

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Microbial control
Hockey et al. tested the abili- ty of apical negative pressure to remove a thick biofilm of E. Faecalis, finding that these biofilms are composed of nega- tive cultures obtained within 48 hours, while those irrigated using traditional positive-pres- sure irrigation were positive at 48 hours.20

One study found that apical negative-pressure irrigation resulted in similar bacterial re- duction to use of apical positive- pressure irrigation and a triple antibiotic in immature teeth.18 In a study comparing the use of apical negative-pressure irriga- tion and a triple antibiotic that has been utilized for pulp regeneration/vascularization in teeth with incompletely formed apices (Trinity × Cipro, Minuca, Flagyl) versus use of apical negative-pressure irriga- tion with NaOCl, it was found that the results were statistically equivalent for mineralized tissue formation and the repair process. T. Factors influencing the long- term results of endodontic treat- ment: a review of the literature. Int Dent J. 2002;52:281-8.


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