Endodontic irrigants and irrigant delivery systems

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Endodontic treatment per se is predictable procedure with high success rates. Success depends on a number of factors, including appropriate instrumentation, successful irrigation and decontamination of the root canal system, and postoperative procedures. Several irrigants and irrigant delivery systems are available, which have resulted in excellent outcomes. Many of these systems have achieved 98% success rates, and the use of newer systems has an even greater potential for effectiveness. This review outlines those systems currently available for root canal treatment and their mechanisms of action. The complete removal of vital tissue, debris, and bacteria from the root canal system to prevent apical periodontitis is the ultimate goal of endodontic therapy. The primary aim of irrigation is to effectively eliminate bacterial contamination and to achieve tissue dissolution. The higher concentration may increase efficacy and be more effective than a lower concentration.

In recent years, numerous studies have focused on newer irrigation methods, and newer irrigants have been introduced. This review objective is to provide an overview of the current state of the art in endodontic irrigation and to inform the reader of the advantages and disadvantages of these newer systems.

The choice of irrigation system is important, as it is crucial to achieve proper disinfection of the root canal system to prevent disease recurrence. Several irrigation systems and delivery methods are available, and when selecting an irrigant and technique, consideration must be given to their efficacy and safety.

Endodontic treatment per se 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 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 their 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% percent 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 achievement of a definitive, clinically successful restoration and preservation of the tooth. For these to be achieved, appropriate instrumentation, irrigation, decontamination and a root canal obliteration must occur, as well as attainment of a coronal seal.

There is evidence that apical periodontitis is a biofilm-induced disease.1 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.3 Additional, the root canal system has a complex anatomy that consists of arborizations, obstructions and canals that harbor organic tissue and bacterial contaminants (Figs. 1a, b).

The challenge for successful endodontic treatment always has been the removal of vital and necrotic remnants of pulp tissue. Mechanical instrumentation, the dentin smear layer, microorganisms, and micro-twins from the root canal system.4 Even with the use of rotary instrumentation, the mechanical instrumentation of the root canal system is essential for efficient irrigation and the success of endodontic treatment5,6,7 or adding surfactants and final rinses to circumvent the shortcomings of a single irrigant.8,9 These irrigants must not only be effective for dissolution of the organic of the dentinal tubules, but also be effective in eliminating bacterial contamination and remove the smear layer – the organic and inorganic layer that is created on the wall of the root canal during mechanical instrumentation; the ability to deliver irrigants to the root canal terminus in a safe and effective manner without causing harm to the entire canal-wall surface is of primary importance.

The desired attributes of a root canal irrigant include the ability to dissolve necrotic pulp tissue, bacterial decontamination and a broad antimicrobial spectrum. This ability to enter deep into the dentinal tubules, biocompatibility and lack of toxicity, the ability to dissolve organic matter and remove the smear layer, ease of use, and cost effectiveness. As mentioned above, root-canal irrigants currently in use include sodium hypochlorite (NaOCl), EDTA, alcohol and chlorhexidine gluconate. Chlorhexidine has a wide antimicrobial spectrum, the main bacteria associated with endodontic infections (E. faecalis and A. israelii) are sensitive to it, and it is biocompatible, with no tissue toxicity to the periapical or surrounding tissue. Chlorhexidine gluconate, however, lacks the ability to dissolve necrotic tissue, which limits its usefulness. Hydrogen peroxide as a canal irrigant helps to eliminate tissue in areas such as isthmuses, provide the physical act of irrigation, as well as through effervescence of the solution. While, however, an effective anti-bacterial irrigant, hydrogen peroxide does not dissolve necrotic pulp tissue and exhibits toxicity to the surrounding tissue.

Cases of tissue damage and facial nerve damage have been reported following use of hydroperoxidase as a root canal irrigant.10 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.11,12 It has the unique ability to dissolve necrotic pulp tissue, therefore preventing the formation of a smear layer during instrumentation.13 There is no other root canal irrigant that can meet these requirements, even with the use of methods such as lowering the pH,14 increasing the temperature,15 or adding surfactants and final rinses to circumvent the shortcomings of a single irrigant.18,19 These irrigants must not only be effective for dissolution of the organic of the dentinal tubules, but also be effective in eliminating bacterial contamination and remove the smear layer – the organic and inorganic layer that is created on the wall of the root canal during mechanical instrumentation7 and particularly if an antibiotic is used and a good seal obtained to ensure that no irritant can spill from the pulp chamber into the oral cavity. If deep caries or a fracture is present adjacent to the rubber dam, removing any contaminated material may be crucial to prevent root canal infection.

It is also important to protect the patient’s eyes with safety goggles or a protective shield to prevent damage 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, as demonstrated in a study by Hand et al. comparing 2.5 and 5.25 percent NaOCl.

The combination of NaOCl and EDTA has been used worldwide for antiseptic irrigation of root canal systems.16 The effectiveness of NaOCl and EDTA as a root canal irrigant ranges from 2.5 to 6 percent, 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 increase efficacy and be more effective than a lower concentration.

There are several general precautions that must be followed when performing endodontic treatment. Demineralizing agents such as EDTA have been used by many clinicians in an attempt to increase the wetting efficiency of the irrigant.20 However, although the clinical 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. Denaturalizing agents such as EDTA have been recommended as at least 10% NaOCl is used in an attempt to remove the smear layer and particular in the apical por- tions of small root canals.17 The combination of NaOCl and EDTA has been used worldwide for antiseptic irrigation of root canal systems. The effectiveness of NaOCl and EDTA as a root canal irrigant ranges from 2.5 to 6 percent, 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.

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Apical vapor lock

Because roots are surrounded by the periodontium, and
less 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 external instrumentation and final irrigation, thus preventing the flow of irrigant into the apex. The irrigation outflow is therefore arrested. Apical vapor lock is also called the isthmus.29 Other investigators have referred to the phenomenon of apical vapor lock as the "apical poproad"30 or the "apical plug.31"

The phenomenon of apical vapor lock has been confirmed by studies in which roots were em- bedded in a polyvinylsiloxane impression material to restrict fluid flow through the apical negative pressure system.42 The apical vapor lock resists displacement during external instrumentation, preventing effective cleaning of the apical 3 mm. It is critically important to deter-
mine which irrigation system will effectively irrigate the api-
cal third, as well as infillusmues and lateral canals, and in a safe manner that prevents the extension of irrigation.

Manual agitation techniques

By far the most common and conventional set of irrigation techniques, manual irriga-
tion involves dispensing of an irrigant into a canal through needles/canulae 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 vol-
ume of irrigant that is flushed through the canal. However, the closer the needle tip is po-
tioned to the apical tissue, the greater the chance of apical ex-
trusion of the irrigant.43,44 This must be avoided; were NaOCl to extrude past the apex, a cata-
strophic accident could occur.45

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-
mented canal, thereby producing a hydrodynamic effect and significant irrigant exchange.46,47 Recent studies have shown that this irrigation technique is signif-
icantly more effective than automated-dynamic irrigation and static irrigation.48,49

Machine-assisted agitation systems

Sonic irrigation

Sonic activation has been shown to be an effective method for disinfecting root canals, operat-
ing at frequencies of 1-6 kHz.50,51 There are several sonic irriga-
tion devices on the market. The Vibrilator delivers a hydrodynamic effect and significant irrigant exchange.52 Recent studies have shown that this irrigation technique is signif-
icantly more effective than automated-dynamic irrigation and static irrigation.53,54

Ultrasonics

Ultrasound energy produces higher frequencies than sonic energy but low amplitudes, os-
cillating at frequencies of 25-50 kHz.55 Two types of ultrasonic irrigation are available. The first type is simultaneous ultrasonic instru-
tion and irrigation, and the second type is referred to as passive ultrasonic endodontic irrigation operating without sim-
ultanous irrigation (PIU).56,57

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 canal systems.58,59 Paiva found that after hand i-
rigations have demonstrated no microbial growth ei-
...
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 this article. The reason this does imply is that it must be de-

servedly safe.

Safety first

In order to compare the safety of six different irriga-
tion delivery devices, an in-vitro test was conducted using the working length of the dental canal, with neutral atmos-
pheric pressure and an open apical foramen. It was found 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 exceeded only a very small volume of irrigant, the clinical significance of which is not known. Mitchell and Baumgartner tested-

ed irrigation of NaOCl from a root canal sealed with a permeable agarose gel. Significantly more irrigant was oc-

curring using the EndoVac sys-
tem compared with positive-

pressure irrigation. A well-con-

trolled study by Gun-
dim et al. found that patients treated with Nac-

clor did not experience any pain, measured objectively and subjectively, when apical neg-

ative-pressure irrigation was performed (EndoVac) than with apical positive-pressure irriga-

tion.113

Sodium hypochlorite inci-

dents

Although a devastating en-
dodonto-logic NaOCl incident is rare,114 the cytotoxic effects of NaOCl on vital tissue are well established.114 The associated

sequence of NaOCl injury have been reported to include life-threatening airway obstruc-
tions,115 facial disfigurement caused by loss of facial muscle control,14 and the least significant consequence of ecchymosis around the eye, particularly involving the pattern of ecchymosis around the eye, the eye, and the sinus region.14

However, the EndoVac, in contrast, irrigant is pulled into the canal at working length and removed by negative pressure. Apical negative pressure has been shown to prevent NaOCl irrigant from reaching the apical third and help overcome apical vapor lock.116,117 In addition, with respect to the is-

suing cleaning, although it is not possible to reach and clean the isthmus region, it is impossible to reach and thoroughly clean these areas with NaOCl when the method of irrigation is safe and effic-

cious, in studies comparing the EndoActivator,118 passive ultrasonic,12 the F File,12 the manual-dynamic Max-i-Probe (DENTSPLY Rinn),12 the Pressure Ultrasonic12 and the EndoVac12 only the EndoVac was capable of cleaning 100 percent of the isthmus area. During irrigation, the Master Delivery Tip and instrument then are used to pull the apical chamber and spacers off the excess irrigant to pre-

vent overflow. Both the Man-

ualDyne and MicroCannula excert negative pressure that pulls fresh irrigant from the apical foramen down the canal to the tip of the cannula, into the can-

nula, and out through the suc-
tion hose. Thus, a constant flow of irrigant is provided that maintains the apical area.

During conventional root-ca-

nal irrigation, clinicians must be careful when determining how far an irrigation needle is placed into the canal. Rec-

ommendations avoiding NaOCl incidents include not binding the needle in the canal, not allowing the needle to close to working length, and using a gentle flow rate when using positive pressure.12 With the EndoVac, in contrast, irrigant is pulled into the canal at working length and removed by negative pressure. Apical negative pressure has been shown to prevent NaOCl irrigant from reaching the apical third and help overcome apical vapor lock.116,117 In addition, with respect to the is-

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