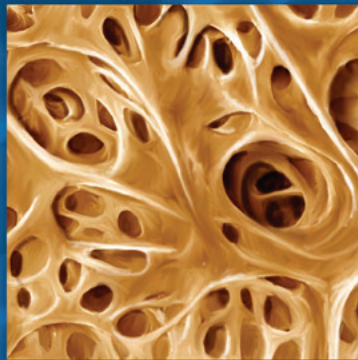


ENDODONTICS



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Excellence*

Winter 2011

Root Canal Irrigants and Disinfectants



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Diagnosis, instrumentation, obturation and restoration are the main steps involved in the treatment of teeth with pulpal and periapical diseases. Elimination or significant reduction of irritants and prevention of recontamination of the root canal after treatment are the essential elements for successful outcomes. Although many advances have been made in different aspects of endodontics within the last few years to preserve natural dentition, the main objective of this field remains elimination of microorganisms from the root canal systems and prevention of recontamination after treatment. The common belief that inadequate obturation is the major cause of endodontic failures has been proven to be fallacious as obturation reflects the adequacy of cleaning and shaping. In other words, what you take out of a root canal may be more important than what you put in it.

What are the Irritants for Pulpal and Periapical Tissues?

The major causes of pulpal and periapical diseases are living and nonliving irritants. The latter group includes mechanical, thermal and chemical irritants. The living irritants include various microorganisms including bacteria, yeasts and viruses. When pathological changes occur in the dental pulp, the root canal space acquires the ability to harbor various irritants including several species of bacteria, along with their toxins and byproducts. Investigations in animals and patients have shown that pulpal and/or periradicular diseases do not develop without the presence of bacteria.^{1,2} Advanced culturing and molecular biology techniques have shown that primary root canal infections are polymicrobial (10-30 bacterial species) in nature and are dominated by obligate anaerobic bacteria.³ The variety of microorganisms present in root canal-treated teeth with persistent periapical lesions is more restricted (1-3 species) in comparison to primary root canal infections, which are dominated by *E. faecalis*, a facultative anaerobic gram-positive coccus that is resistant to intracanal medications, able to form biofilms and able to invade dentinal tubules.⁴ Because the presence of bacteria negatively influences the outcome of root canal treatment,⁴⁻⁶ every effort should be made to eradicate infections during treatment.

What are the Obstacles in Removing Irritants From the Root Canal Systems?

The complexity of the root canal system, presence of numerous dentinal tubules in the roots, invasion of the tubules by microorganisms, formation of smear layer during instrumentation and presence of dentin as a tissue are the major obstacles in achieving the primary objectives of complete cleaning and shaping of root canal systems.⁷ Microscopic examinations of root canals show that they are irregular and complex systems with many cul-de-sacs, fins and lateral canals (Figures 1a and 1b).

In the root, dentinal tubules extend from the pulp- to the cementum-dentin junction (Figure 2). Investigators have reported the presence of bacteria in the dentinal tubules (Figure 3) of infected teeth at approximately half the distance between the root canal walls and the cementum-dentin junction.⁷ The presence of these natural complexities is important for clinicians to consider during cleaning and shaping of the root canal system.^{8,9} In addition to these



Fig. 1a. Internal anatomy of a maxillary second molar after decalcification, dehydration and placement in India ink. Courtesy of Dr. JV Baroni Barbizam.

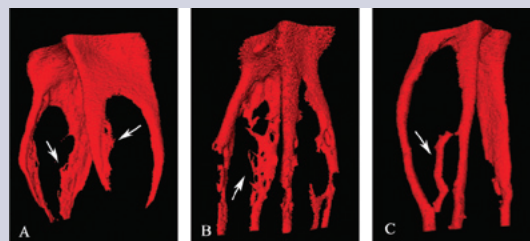


Fig. 1b. Microcomputed tomography images of canal isthmuses in mesial roots of mandibular molars. Courtesy of Dr. L. Gu.

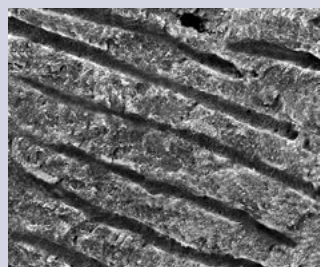


Fig. 2. SEM of dentinal tubules running from the pre-dentin towards the cementum.



Fig. 3. SEM of dentinal tubules containing microorganisms.

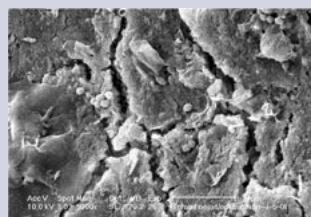


Fig. 4. The smear layer consists of organic and inorganic substances as well as fragments of odontoblastic processes, various species of bacteria and necrotic debris.

natural difficulties, it is known that a smear layer is created during cleaning and shaping that covers the instrumented root canal walls.⁷ This smear layer (Figure 4) contains inorganic and organic substances as well as fragments of odontoblastic processes, microorganisms and necrotic debris. Intracanal irrigants and medications are used

during root canal treatment to reach the natural complexities and remove the smear layer. Intracanal irrigants exert their effects mechanically and chemically. Mechanical effects of irrigants are generated by the back and forth flow of the irrigation solution during cleaning and shaping of the infected root canals, significantly reducing the bacterial load.^{10,11} Studies show that irrigants that possess antibacterial properties have clearly superior effectiveness in bacterial reduction and elimination when compared with saline solution.^{11,12}

What are the Ideal Properties of an Irrigant?

To effectively clean and disinfect the root canal system, an irrigant should be able to disinfect and penetrate dentin and its tubules, offer long-term antibacterial effect (substantivity), remove the smear layer, and be nonantigenic, nontoxic and noncarcinogenic. In addition, it should have no adverse effects on dentin or the sealing ability of filling materials.⁷ Furthermore, it should be relatively inexpensive, convenient to apply and cause no tooth discoloration.⁷ Other desirable properties for an ideal irrigant include the ability to dissolve pulp tissue and inactivate endotoxins.¹³

What are the Types, Advantages and Disadvantages of Current Irrigants?

The irrigants that are currently used during cleaning and shaping can be divided into antibacterial and decalcifying agents or their combinations. They include sodium hypochlorite (NaOCl), chlorhexidine, ethylenediaminetetraacetic acid (EDTA), and a mixture of tetracycline, an acid and a detergent (MTAD).

Sodium Hypochlorite (NaOCl)

Sodium hypochlorite (household bleach) is the most commonly used root canal irrigant. It is an antiseptic and inexpensive lubricant that has been used in dilutions ranging from 0.5% to 5.25%. Free chlorine in NaOCl dissolves vital and necrotic tissue by breaking down proteins into amino acids.¹⁴ Decreasing the concentration of the solution reduces its toxicity, antibacterial effect and ability to dissolve tissues.¹⁴ Increasing its volume or warming it increases its effectiveness as a root canal irrigant.¹⁴

Advantages of NaOCl include its ability to dissolve organic substances present in the root canal system and its affordability. The major disadvantages of this irrigant are its cytotoxicity when injected into periradicular tissues, foul smell and taste, ability to bleach clothes and ability to cause corrosion of metal objects.¹⁵ In addition, it does not kill all bacteria,^{12,16-18} nor does it remove all of the smear layer.¹⁹ It also alters the properties of dentin.^{20,21} The results of a recent *in vitro* study show that the most effective irrigation regimen is 5.25% at 40 minutes, whereas irrigation with 1.3% and 2.5% NaOCl for this same time interval is ineffective in removing *E. faecalis* from infected dentin cylinders.²² Based on the findings of this study, the authors recommend the use of other irrigants to increase the antibacterial effects during cleaning and shaping of root canals.

Sodium hypochlorite is generally not utilized in its most active form in a clinical setting. For proper antimicrobial activity, it must be prepared freshly just before its use.^{23,24} In the majority of cases, however, it is purchased in large containers and stored at room temperature while being exposed to oxygen for extended periods of time. Exposure of the solution to oxygen, room temperature and light can inactivate it significantly.²⁴

Extrusion of NaOCl into periapical tissues (Figures 5a and 5b) can cause severe injury to the patient.^{25,26} To minimize NaOCl accidents, the irrigating needle should be placed short of the working length, fit loosely in the canal and the solution must be injected using a gentle flow rate. Constantly moving the needle up and down during irrigation prevents wedging of the needle in the canal and provides better irrigation. The use of irrigation tips with side-venting reduces the possibility of forcing solutions into the periapical tissues. Treatment of NaOCl accidents is palliative and consists of observation of the patient as well as prescribing antibiotics and analgesics.

Chlorhexidine

Chlorhexidine gluconate has been used for the past 50 years for caries prevention,²⁷ in periodontal therapy and as an oral antiseptic mouthwash.²⁸ It has a



Fig. 5a. NaOCl was inadvertently expressed into the periapical tissues through the apical foramen of the right maxillary cuspid during cleaning and shaping.



Figure 5b. No treatment was necessary for the hematoma and swelling. Reprinted with permission from *Endodontics: Principles and Practice* 4th ed., Torabinejad and Walton, 2009.

broad-spectrum antibacterial action, sustained action and low toxicity.¹⁴ Because of these properties, it has also been recommended as a potential root canal irrigant.^{14,27} The major advantages of chlorhexidine over NaOCl are its lower cytotoxicity and lack of foul smell and bad taste. However, unlike NaOCl, it cannot dissolve organic substances and necrotic tissues present in the root canal system. In addition, like NaOCl, it is unable to kill all bacteria and cannot remove the smear layer.^{29,30}

Ethylenediaminetetraacetic Acid (EDTA)

Chelating agents such as ethylenediaminetetraacetic acid (EDTA), citric acid and tetracycline are used for removal of the inorganic portion of the smear layer.⁷ NaOCl is an adjunct solution for removal of the remaining organic components. Irrigation with 17% EDTA for one minute followed by a final rinse with NaOCl is the most commonly recommended method to remove the smear layer.¹⁴ Longer exposures can cause excessive removal of both peritubular and intratubular dentin.³¹ EDTA has little or no antibacterial effect.³²

MTAD

An alternative solution to EDTA for removing the smear layer is the use of BioPure™ MTAD™ (DENTSPLY Tulsa Dental Specialties, Tulsa, Okla.), a mixture of a tetracycline isomer, an acid (citric acid) and a detergent.³³ MTAD was developed as a final rinse to disinfect the root canal system and remove the smear layer. The effectiveness of MTAD to completely remove the smear layer (Figure 6) is enhanced when a low concentration of NaOCl (1.3%) is used as an intracanal irrigant before placing 1 ml of MTAD in a canal for 5 minutes and rinsing it with an additional 4 ml of MTAD as the final rinse.³³ It appears to be superior to CHX in antimicrobial activity.³⁰ In addition, it has sustained antibacterial activity, is biocompatible and enhances bond strength.¹⁴ Table 1 shows the advantages and disadvantages of current irrigants utilized during root canal treatment.

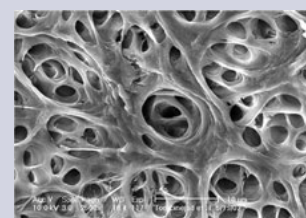


Fig. 6. SEM of dentinal tubules after removal of the smear layer by MTAD.

Irrigation Devices and Techniques

For many years various methods have been proposed and developed to make root canal irrigants more effective in removing debris and bacteria from the root canal system. These techniques can be classified into two broad categories: manual and rotary agitation.³⁴ The manual irrigation techniques include irrigation with needles, agitation with brushes, and manual dynamic agitation with files or gutta-percha points. The rotary irrigation techniques include rotary brushes, continuous irrigation during instrumentation, sonic and ultrasonic vibrations, and application of negative pressure during irrigation of the root canal system. The use of these methods results in better canal cleanliness when compared with that of conventional syringe needle irrigation. However, there is no high level of evidence that correlates the clinical efficacy of these devices with better treatment outcomes. Clinical data are needed to support the use of these devices in endodontics.

Lasers

Some investigators have reported that lasers can be used to vaporize tissues in the main canal, remove the smear layer and eliminate the residual tissue in the apical portion of the root canals.⁷ Several investigators have reported that the efficacy of lasers depends on many factors including the power level, the duration of exposure, the absorption of light in the tissue, the geometry of the root canal and the tip-to-target distance.³⁵⁻³⁷ The efficacy of the lasers to completely clean the root canals remains to be seen. The main difficulty continues to be access to small canal spaces with the relatively large probes that deliver the laser beams and the expense of these units.

Table 1

Advantages and Disadvantages of Currently Used Intracanal Irrigants				
Characteristics	MTAD	NaOCl	CHX	EDTA
Shelf life stability	+	-	+	+
Antimicrobial activity	+	+	+	-
Ability to remove smear layer	+	-	-	+
Biocompatibility	+	-	+	+
Ability to dissolve pulp tissue	+	+	-	+/-
Dentin conditioning properties	+	-	-	+
Positive effect on root canal seal	+	-	-	+/-
Negative effect on dentin structure	-	+	-	+
Upregulation of regional immune response	+	-	-	-
Application time (minutes)	5 ¹⁸	40 ²²	?	1 ³¹

Because current solutions and techniques cannot completely remove all irritants, dissolve all organic tissue or remove the smear layer, various methods have been employed to deliver irrigants more efficiently to the working length. These include sonic and ultrasonic vibrations as well as application of negative pressure to flush out the debris present in instrumented canals.

EndoVac® System

The EndoVac® system (Discus Dental, Culver City, Calif.) is a new irrigation system that consists of a delivery/evacuation tip attached to a syringe of irrigant and the high-speed suction source of the dental unit. As the cannulas are placed in the canal, negative pressure pulls irrigant from a fresh supply in the chamber down into the canal to the tip of the cannula, then into the cannula and finally out through the suction hose.³⁸ Investigators compared the efficacy of the EndoVac® irrigation system with that of a needle irrigation system to clean root canals at 1 and 3mm from working length and found no significant difference between the two groups at the 3mm level. However, their results show significantly better debridement at 1mm from working length using the EndoVac® compared with needle irrigation.³⁸

A recent *in vitro* study compared three agitation and two irrigation devices with ultrasonic agitation for mechanically removing bacteria from a plastic-simulated canal that was instrumented to a size 35 with a .06 taper.³⁹ The irrigation and agitation techniques evaluated were ultrasonic agitation, needle irrigation, EndoVac® irrigation, EndoActivator® (DENTSPLY Tulsa Dental Specialties, Tulsa, Okla.), F® File (Plastic Endo, Lincolnshire, Ill) and sonic agitation. Based on the results of this investigation, the authors conclude that ultrasonic agitation is significantly more effective than needle irrigation and EndoVac® irrigation at removing intracanal bacteria. Ultrasonic, EndoActivator®, F® File and sonic agitation are similar in their ability to remove bacteria in a plastic-simulated canal. These findings point to the importance of the use of antiseptic irrigants in addition to mechanical vibrations and application of negative pressure during cleaning and shaping of root canals. The results of a recent *in vitro* study using a combination of mechanical and chemical means to disinfect root canals showed that activation of MTAD with the EndoActivator® system for 1.5 minutes was an effective method to completely inhibit the growth of *E. faecali*.⁴⁰

Intracanal Medicaments

Intracanal medicaments have been used to disinfect root canals between appointments and reduce interappointment pain.⁷ The disinfectants can be divided into phenolic compounds such as camphorated monochlorophenol, cresatin, aldehydes such as formocresol and glutaraldehyde, and halides, as well as other materials like calcium hydroxide [Ca(OH)₂] and some antibiotics.¹⁴ These compounds are potent antibacterial agents under laboratory test conditions, but their efficacy in clinical use is unpredictable.⁷ Some of the aldehyde derivatives have been proposed to neutralize canal tissue remnants and to render them inert. These can be used to fix fresh tissues for histological examination, but they may not effectively fix necrotic or decomposed tissues. According to one report,⁴¹ fixed tissues are not inert and may become more toxic and antigenic after fixation. Intracanal medications have also been used clinically to prevent post-treatment pain. Studies have shown, however, that routine use of these materials as intracanal medications has no significant effect on prevention of pain.⁷

Calcium Hydroxide

Ca(OH)₂ is a substance that inhibits microbial growth in canals.⁴² The antibacterial effect of Ca(OH)₂ is due to its alkaline pH. It also dissolves necrotic tissue remnants and bacteria and their byproducts.⁴³ It can be placed as a dry powder, a powder mixed with a liquid such as water, saline, local anesthetic or glycerin, or a proprietary paste supplied in a syringe.¹⁴ Because of its toxicity⁴⁴, Ca(OH)₂ should be placed within the canal with the aid of a file or a needle. Extrusion of the material into the periapical tissues can cause tissue necrosis and pain for the patient. Ca(OH)₂ can be removed from the canal by using irrigants such as saline, NaOCl, EDTA or MTAD.

Corticosteroids

Corticosteroids are anti-inflammatory agents that have been advocated as intracanal medicaments to reduce postoperative pain.⁴⁵ An animal study has shown a reduction of inflammatory cells in periapical tissues following supraperiosteal infiltration of dexamethasone into the buccal vestibule of rats.⁴⁶ There is no significant clinical evidence that suggests that they are effective in patients with very high pain levels.⁴⁷ The use of corticosteroids in patients with irreversible pulpitis and symptomatic apical periodontitis may be beneficial.^{45,48}

Chlorhexidine Gel

A 2% CHX gel has recently been advocated as an intracanal medicament.⁴⁹ It can be used alone in gel form or mixed with $\text{Ca}(\text{OH})_2$. When used for seven days to medicate bovine teeth⁵⁰ or human teeth,⁵¹ CHX gel provides antimicrobial activity for up to 21 days after contamination. When it is used in combination with $\text{Ca}(\text{OH})_2$, the antimicrobial activity of this mixture is greater than the combination of $\text{Ca}(\text{OH})_2$ and saline.⁵²

Summary

Bacteria are the major cause of pulpal and periapical diseases. Complexity of the root canal system, invasion of the dentinal tubules by microorganisms, formation of smear layer during instrumentation and presence of dentin as a tissue are the major obstacles for complete elimination of bacteria during cleaning and shaping of root canal systems. The bacterial population of infected root canals can be significantly reduced by using saline irrigation; however, irrigants that have antibacterial effects have clearly superior effectiveness in bacterial elimination when compared with saline solution. The irrigants that are currently used during cleaning and shaping include NaOCl, CHX, EDTA and MTAD. None of these irrigants has all of the characteristics of an ideal irrigant. Sonic and ultrasonic vibrations alone or in combination with antibacterial irrigants as well as application of negative pressure have been used to increase the efficacy of these irrigants. Intracanal medicaments have been used to disinfect root canals between appointments and reduce interappointment pain. The major intracanal medications currently used in endodontics include $\text{Ca}(\text{OH})_2$ and CH. The search for an ideal material and/or technique to completely clean infected root canals continues.

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Dental Dam as Standard of Care

Presence of bacteria is the primary cause of pulpal and periapical diseases. Disinfection of the root canal system is accomplished mechanically and chemically. Isolation of a tooth using the dental dam during endodontic treatment provides a mechanical barrier against accidental mechanical and chemical mishaps. The use of the dental dam during endodontic treatment is mandatory in the United States and is considered the Standard of Care.¹

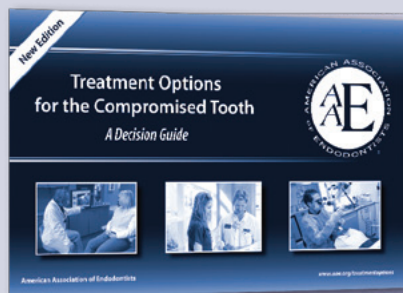
Application of a dental dam during endodontic treatment provides a physical barrier for the protection of the patient² from swallowing or aspirating instruments and materials³ and confines the irrigating solutions to the field of operation. In addition, it provides a clean environment that enhances vision, retracts tissues and makes treatment more efficient. Other advantages of the use of the dental dam during root canal treatment include: protection of the dentists and their auxiliary members,⁴ minimizing aerosols^{5,6} and decreasing the potential for transmission of systemic diseases such as HIV, hepatitis and tuberculosis.⁴

The dental dam is manufactured from latex. Nonlatex dental dam material is available for patients with a latex allergy. It can be obtained in a variety of colors and thicknesses (light, medium, heavy and extra heavy). Application of the dental dam takes a few minutes to provide a clean field of operation, protect the patient and prevent legal actions against the dentist. In the absence of a dental dam, an expert testimony is not required when patients swallow or aspirate instruments or materials during endodontic treatment.

For a copy of the AAE's position statement on the use of dental dams, visit www.aae.org/guidelines.

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- Summary: Irrigation Agitation Techniques and Devices

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