

Endodontic Irrigating Solutions, Disinfection Devices and Techniques: A Review

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Abstract: Pulp and periapical pathosis and the role of microbes has been investigated and documented. Persistent bacteria in biofilms have a wide range of characteristics including The role of microorganisms within the root canal system in causing pulp and periapical pathosis has been investigated and well documented. Bacteria that persist in biofilms show a wide range of characteristics such as, increased protection from host defence, increased antimicrobial resistance and the ability to survive and adapt despite ecological changes such as nutrient deprivation. Endodontic instruments alone have been shown to touch only 30–50 % of canal walls regardless of the instrument selected. When considering the complex anatomical irregularities (such as fins, isthmuses and recesses) within the root canal system, the emphasis on chemical disinfection and correct irrigation protocols are of paramount importance. A clinical protocol is proposed at the end of the article

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I. Introduction

The goal of endodontic treatment is to prevent or cure apical periodontitis. Apical periodontitis is an inflammatory process in the periradicular tissues caused by microorganisms in the infected root canal. It is well known that shaping, cleaning, and obturating the root canal system provide the strategy for successful treatment. In endodontic disinfection, there are two main challenges which are important to be recognized the anatomical challenge and the microbiological challenge. Root canal is an enclosed complex space with intricate configurations and apical constriction it is important to mention here that more than 35 % of the root canal surface is left untouched by conventional instrumentation. Also, common instrumentation techniques accumulate debris in isthmus areas.

Endodontic irrigants have three major objectives: chemical, biological, and mechanical. Mechanical objectives include to rinse out debris and lubricate the canal; chemical objectives include to soften and dissolve organic and inorganic tissues, prevent the formation of a smear layer during instrumentation, and dissolve smear layer once it has formed; and biological objectives are related to their antiseptic and nontoxic. The ideal irrigating solution to disinfect the root canal system should be a biocompatible bactericidal agent, tissue solvent, lubricant, and smear layer remover capable of physically flushing debris, with sustained effect but without affecting the physical properties of the dentin.

II. Irrigating solutions

The irrigating solutions in endodontics can be classified as antimicrobial solutions, chelating solutions, combinations (antibacterial and chelating solutions combined), and solutions with detergent. Antimicrobial effects: antiseptic solutions, topical antibiotics, bacteriostatic solutions, and bactericidal solutions. Given below are the list of irrigants used in endodontics

Local anaesthetic, saline and/or water

Practitioners using water, saline or local anaesthetic are profoundly misguided in their understanding of endodontics and place themselves at risk of litigation should treatment fail: these irrigants have no antimicrobial properties

Sodium Hypochlorite

NaOCl is an antiseptic solution. Surveys from around the world reported that sodium hypochlorite is the most common irrigating solution used in endodontics. It is an effective antimicrobial and proteolytic agent, excellent organic tissue solvent, and lubricant with fairly quick effects. NaOCl is both an oxidizing agent and a hydrolyzing agent. Commercial sodium hypochlorite solutions are strongly alkaline and hypertonic and typically have nominal concentrations of 10–14 % available chlorine.

Mode of action

1: Saponification reaction: Sodium hypochlorite acts as an organic and fat solvent that degrades fatty acids and transforms them into fatty acid salts (soap) and glycerol (alcohol), reducing the surface tension of the remaining solution.

2: Neutralization reaction: Sodium hypochlorite neutralizes amino acids by forming water and salt. With the exit of hydroxyl ions, the pH is reduced.

3: Hypochlorous acid formation: When chlorine dissolves in water and it is in contact with organic matter, it forms hypochlorous acid. It is a weak acid with the chemical formula HClO that acts as an oxidizer. Hypochlorous acid (HOCl) and hypochlorite ions (OCl⁻) lead to amino acid degradation and hydrolysis.

4: Solvent action: Sodium hypochlorite also acts as a solvent, releasing chlorine that combines with protein amino groups (NH) to form chloramines (chloramination reaction). Chloramines impede cell metabolism; chlorine is a strong oxidant and inhibits essential bacterial enzymes by irreversible oxidation of SH groups (sulfhydryl group).

5: High pH: Sodium hypochlorite is a strong base (pH > 11). The antimicrobial effectiveness of sodium hypochlorite, based on its high pH (hydroxyl ion action), is similar to the mechanism of action of calcium hydroxide. The high pH interferes in cytoplasmic membrane integrity due to irreversible enzymatic inhibition, biosynthetic alterations in cellular metabolism, and phospholipid degradation observed in lipidic peroxidation.

Allergic Reactions to Sodium Hypochlorite

Although few reports have been published on allergic reactions to NaOCl, real allergies to NaOCl are unlikely to occur, as both Na and Cl are essential elements in the physiology of the human body. It must be remembered that the hypochlorous acid (active component of the sodium hypochlorite) is a chemical substance that is elaborated by neutrophils in the process of phagocytosis; it may create local tissue damage when it is produced in excess (liquefaction necrosis: purulent exudate) but does not cause allergic responses. Nevertheless, hypersensitivity and contact dermatitis may occur in rare situations. When hypersensitivity to NaOCl is suspected or confirmed, chlorhexidine should not be used either because of its chlorine content.

Concentration

In the literature, it can be found that NaOCl can be used in a concentration that ranges from 0.5 to 6 %. It was proven that the lower and higher concentrations are equally efficient in reducing the number of bacteria in infected root canal system but the tissue-dissolving effect is directly related to the concentration.

Volume

Volume is more critical for disinfection than its concentration. Frequent exchange with fresh NaOCl is important and the use of large amount of irrigant compensates for the low concentration. The chlorine ion, which is responsible for the dissolving and antibacterial capacity of NaOCl, is unstable and consumed rapidly during the first phase of tissue dissolution, probably within 2 min, which provides another reason for continuous replenishment. It should be kept in mind that the NaOCl will inactivate its components very fast, so fresh irrigating solution should be added to the canal system constantly.

Time

How long does NaOCl need to kill bacteria? This question can be misinterpreted in the literature. Some articles will show bacterial killing in 30 min when 0.5 % NaOCl is used, while higher concentrations will need only 30 s to do the same job.

Effect on the Dentin

The dentin is composed of 22 % organic material by weight. Most of this consists of type I collagen, which contributes considerably to the mechanical properties of the dentin. NaOCl solutions may affect mechanical dentin properties via the degradation of organic dentin components.

Depth of Penetration

The depth of NaOCl penetration varied between 77 and 300 µm, and it depends on concentration, time, and temperature.

Effect on Biofilms

Clegg et al. demonstrated that 6 % NaOCl was the only agent capable of both physically removing artificial biofilm and killing bacteria. There was a dose-dependent effect of NaOCl against bacteria, as higher concentrations were more antibacterial. In summary, 3 % and 6% NaOCl showed absence of biofilm, 1 % NaOCl showed disruption of biofilm, and 2 % CHX showed intact biofilm.

Toxicity

If inadvertently NaOCl is extruded through the apex, severe accidents may occur. It is important to recognize the symptoms and act accordingly. After an accident with NaOCl, the following can be expected: severe pain, edema of neighboring soft tissues, possible extension of edema over the injured half of face and upper lip, profuse bleeding from root canal, profuse interstitial bleeding with hemorrhage of skin and mucosa (ecchymosis), chlorine taste and irritation of throat after injection into maxillary sinus, secondary infection possible, and reversible anesthesia or paresthesia is possible. Treatment of NaOCl accidents is palliative and consists of observation of the patient as well as prescribing antibiotics and analgesics. Prompt referral may be necessary in cases of bone necrosis or swelling which can compromise the airway.

Limitations

Unfortunately, even though NaOCl has many ideal properties, it has some limitations such as being toxic, nonsubstantive, ineffective in smear layer removal and corrosive. It may cause discoloration and has unpleasant odour. When NaOCl is used as a final rinse, bonding of the sealer to the dentin may be altered.

Clinical Recommendation

NaOCl in concentrations between 2.5 and 6 % should be used during the whole cleaning and shaping procedure. Pulp chamber should be used as a reservoir of fresh irrigant. Once the mechanical preparation is finished and a master apical file is determined, the protocol of irrigation should start with the activation of fresh NaOCl in each canal.

Chlorhexidine Gluconate (CHX)

Molecular Structure CHX is a strongly basic molecule with a pH between 5.5 and 7 that belongs to the polybiguanide group. CHX digluconate salt is easily soluble in water and is very stable.

Mode of Action

Chlorhexidine, because of its cationic charges, is capable of electrostatically binding to the negatively charged surfaces of bacteria, damaging the outer layers of the cell wall and rendering it permeable. CHX is a wide-spectrum antimicrobial agent, active against gram-positive and gram-negative bacteria and yeasts. Depending on its concentration, CHX can have both bacteriostatic and bactericidal effects. At high concentrations, CHX acts as a detergent and exerts its bactericidal effect by damaging the cell membrane and causes precipitation of the cytoplasm. At low concentrations, CHX is bacteriostatic, causing low-molecular-weight substances (i.e., potassium and phosphorous) to leak out from the cell membrane without the cell being permanently damaged.

Substantivity

Due to the cationic nature of the CHX molecule, it can be absorbed by anionic substrates such as the oral mucosa and tooth structure. CHX is readily adsorbed onto hydroxyapatite and teeth. Studies have shown that the uptake of CHX onto the teeth is reversible. This reversible reaction of uptake and release of CHX leads to substantive antimicrobial activity and is referred to as substantivity. This effect depends on the concentration of CHX. At low concentrations of 0.005–0.01 %, only a constant monolayer of CHX is adsorbed on the tooth surface, but at higher concentrations, a multilayer of CHX is formed on the surface, providing a reservoir of CHX which can rapidly release the excess into the environment as the concentration of CHX in the surrounding environment decreases. Time and concentration of CHX can influence the antibacterial substantivity and the conclusions are inconsistent. When comparing its effectiveness with NaOCl, controversial results can be found. Unlike NaOCl, CHX lacks a tissue-dissolving property. Therefore, NaOCl is still considered the primary irrigating solution in endodontics.

Chlorhexidine and Dentin Bonding

Researchers evaluated the effect of CHX on resin-dentin bond stability *ex vivo*. They concluded that auto degradation of collagen matrices can occur in resin-infiltrated dentin, but this may be prevented by the application of a synthetic protease inhibitor such as CHX. Because of its broad-spectrum matrix metalloproteinase (MMP)-inhibitory effect, CHX may significantly improve resin-dentin bond stability.

Allergic Reactions to Chlorhexidine

Allergic responses to CHX are rare, and there are no reports of reactions following root canal irrigation with CHX. The sensitization rate has been reported in several studies to be approximately 2%. However, some allergic reactions such as anaphylaxis, contact dermatitis, and urticaria have been reported following direct contact to mucosal tissue or open wounds.

Limitations

The limitations of using CHX as a primary and sole endodontic irrigant are the following: the inability to dissolve organic matter, no action on smear layer, and minor effect on biofilm disruption. The clinical recommendation to use CHX during endodontic treatment include, teeth with open apices or perforation where there is a risk to extrude NaOCl, When maximal antimicrobial effect is desirable as a final rinse after EDTA to further facilitate disinfection and to improve dentin bonding (where relevant).

Decalcifying Agents

Debris is defined as dentin chips or residual vital or necrotic pulp tissue attached to the root canal wall. Smear layer was defined by the American Association of Endodontists in 2003 as a surface film of debris retained on the dentin or other surfaces after instrumentation with either rotary instruments or endodontic files; it consists of dentin particles, remnants of vital or necrotic pulp tissue, bacterial components, and retained irrigants. Some researchers emphasize the importance of removing the smear layer to allow irrigants, medications, and sealers to penetrate into the dentinal tubules and improve disinfection. On the other hand, other researchers focused on keeping the smear layer as a protection for bacterial invasion, apical and coronal microleakage, bacterial penetration of the tubules, and the adaptation of root canal materials. The chelating agents can be classified as strong or weak. Strong chelating agents are EDTA, citric acid, and chitosan nanoparticles, while weak chelating agent is HEBP or etidronate.

Citric Acid

Citric acid can also be used for irrigation of the root canal and for removal of the smear layer. Similar to EDTA, complete removal of smear layer requires also irrigation with NaOCl before or after citric acid irrigation. Concentrations ranging from 1 to 50% have been used. In comparison with ultrasound, 10% citric acid has been shown to remove the smear layer more effectively from apical root-end cavities than ultrasound. It has been recommended as an irrigant in techniques such as photoactivated disinfection,

Ethylenediaminetetraacetic Acid (EDTA)

Ethylenediaminetetraacetic acid, widely abbreviated as EDTA, is an aminopolycarboxylic acid, and a colorless, water-soluble solid. EDTA is often suggested as an irrigant because it can chelate and remove the mineralized portion of the smear layer. Its prominence as a chelating agent arises from its ability to sequester di- and tricationic metal ions such as Ca²⁺ and Fe³⁺. After being bound by EDTA, metal ions remain in solution but exhibit diminished reactivity.

Mode of Action

On direct exposure for extended time, EDTA extracts bacterial surface proteins by combining with metal ions from the cell membrane which can eventually lead to bacterial death. Chelators such as EDTA form a stable complex with calcium. When all available ions have been bound, equilibrium is formed and no further dissolution takes place; therefore, EDTA is self-limiting.

Applications in Endodontics

EDTA alone normally cannot remove the smear layer effectively; a proteolytic component, such as NaOCl, must be added to remove the organic components of the smear layer. For root canal preparation, EDTA has limited value alone as an irrigation fluid. EDTA is normally used in a concentration of 17% and can remove the smear layer when in direct contact with the root canal wall for less than 1 min. In addition to their cleaning ability, chelators may detach biofilms adhering to root canal walls. This may explain why an EDTA irrigant proved to be highly superior to saline in reducing intracanal microbiota despite the fact that its antiseptic capacity is relatively limited. It exerts its strongest effect when used synergistically with NaOCl.

HEBP (Etidronic acid)

Etidronic acid, HEBPT also known as 1-hydroxyethylidene-1, 1-bisphosphonate (HEBP) or etidronate, a substance that prevents bone resorption, has been used in medicine for patients suffering from osteoporosis or Paget's disease and was suggested as a substitute for traditional chelators due to fewer effects observed on dentin structure. It is considered the unique chelator that can be mixed with NaOCl without interfering with its

antimicrobial property. This irrigant has the ability to remove the smear layer similar to that of EDTA or citric acid, and it can be mixed with NaOCl without any loss of the NaOCl antimicrobial activity. The NaOCl/HEBPsolution could be used as a single irrigant during and after instrumentation, replacing the final rinse with a chelating agent.

Combinations and Solutions with Detergents

The irrigant flow can be affected by density, viscosity, contact angle, and wetting behavior of the irrigant. Even though density and viscosity always affect the flow, surface tension only affects the flow when 2 immiscible (incapable of mixing) fluids are present. Because the dentin is hydrophilic and dentinal tubules always contain water, there is no need in endodontic irrigants to add detergents. Some added detergents in the market are: SmearClear: (EDTA + detergents), Chlor-XTRA: (NaOCl + detergents), CHX-Plus: (CHX + detergents), Tetraclean: (50 mg/mL doxycycline + polypropylene glycol + citric acid), MTAD: (3 % doxycycline hyclate + 4.25 % citric acid + Tween 80), QMiX: (CHX + EDTA + detergent).

BioPure MTAD and Tetraclean

Two new irrigants based on a mixture of antibiotics, citric acid, and a detergent have been developed. These irrigants are capable of removing both the smear layer and organic tissue from the infected root canal system. MTAD, introduced by Torabinejad and Johnson at Loma Linda University in 2003, is an aqueous solution of 3 % doxycycline, a broad-spectrum antibiotic; 4.25 % citric acid, a demineralizing agent; and 0.5 % polysorbate 80 detergent. It is mixed as a liquid and powder prior to use. MTAD has been recommended in clinical practice as a final rinse after completion of conventional chemomechanical preparation. Tetraclean (Ogna Laboratori Farmaceutici, Muggio, Italy) is a combination product similar to MTAD. The two irrigants differ in the concentration of antibiotics (doxycycline 150 mg/5 ml for MTAD and 50 mg/5 ml for Tetraclean) and the kind of detergent (Tween 80 for MTAD, polypropylene glycol for Tetraclean).

Mode of Action .

Tetracyclines inhibit protein synthesis by reversibly binding to the 30S subunit of bacterial ribosome in susceptible bacteria. It is effective against *A. capnocytophaga*, *P. gingivalis*, and *P. intermedia* and affects both gram-positive and gram-negative (more gram-negative effect). Tetracycline is a bacteriostatic antibiotic, but in high concentrations, tetracycline may also have a bactericidal effect. Doxycycline, citric acid, and Tween 80 together may have a synergistic effect on the disruption of the bacterial cell wall and on the cytoplasmic membrane. Protocol for Use 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 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 min and rinsing it with an additional 4 ml of MTAD as the final rinse.

QMiX

QMiX was introduced in 2011; it is one of the new combination products introduced for root canal irrigation. It is recommended to be used at the end of instrumentation, after NaOCl irrigation. According to the patent, QMiX contains a CHX analog, triclosan, (N-cetyl N, N, N-trimethylammonium bromide), and EDTA as a decalcifying agent; it is intended as an antimicrobial irrigant as well as to be used in the removal of canal wall smear layers and debris. Protocol Q MiX is suggested as a final rinse. If sodium hypochlorite was used throughout the cleaning and shaping, saline can rinse out NaOCl to prevent the formation of PCA.

Iodine Potassium

Iodide Iodine potassium iodide (IKI) is a root canal disinfectant that is used in concentrations ranging from 2% to 5%. IKI kills a wide spectrum of microorganisms found in root canals but shows relatively low toxicity in experiments using tissue cultures. Iodine acts as an oxidizing agent by reacting with free sulfhydryl groups of bacterial enzymes, cleaving disulfide bonds. *E. faecalis* often is associated with therapy-resistant periapical infections, and combinations of IKI and CHX may be able to kill Ca(OH)₂-resistant bacteria more efficiently. An obvious disadvantage of iodine is a possible allergic reaction in some patients. Although iodine is not generally considered an allergen, some patients are hypersensitive to this compound and may be considered to have an iodine “allergy.”

Lubricants

Lubricants facilitate manipulation of hand files during cleaning and shaping. They are an aid in initial canal negotiation, especially in small and constricted canals without taper. Glycerin is a mild alcohol that is inexpensive, nontoxic, aseptic, and somewhat soluble. Paste lubricants can incorporate chelators. One advantage to paste lubricants is that they can suspend dentinal debris and prevent apical compaction. One proprietary

product consists of glycol, urea peroxide, and EDTA in a special water-soluble base. It has been demonstrated to exert antimicrobial action. Another type is composed of 19% EDTA in a water-soluble, viscous solution. A disadvantage of these EDTA compounds appears to be the deactivation of NaOCl by reducing the available chlorine and potential toxicity. When nickel-titanium rotary techniques are used, aqueous solutions (e.g., NaOCl), rather than paste lubricants, should always be present in the root canal to reduce torque.

Alcohol

The use of 95 % ethyl alcohol has been recommended as a pre-irrigation step or final irrigation step prior to intra-canal medicament placement or obturation of the canal. This is based on anecdotal practice with the assumption that the alcohol reduces the surface tension of either the irrigant fluid to be used thereafter or sealer during obturation. The evaporation of the alcohol is thought to aid either irrigant or sealer penetration. A final rinse of approximately 3–5 ml of 95 % Ethyl alcohol can be recommended in order to improve the sealing ability of the root canal filling.

Hydrogen peroxide

From a historical perspective, hydrogen peroxide has been used in concentrations ranging from 3 to 5 % alternating with sodium hypochlorite as part of the irrigation protocol. The release of nascent oxygen, which produces effervescence, was thought to help dislodge debris, which could drain out of the canal with the irrigant [56]. Accidental extrusion of hydrogen peroxide beyond the confines of the canal has resulted in sudden, severe pain, swelling, emphysema and crepitus, as reported in the literature. Its use as an endodontic irrigant can therefore no longer be recommended.

Superoxidized Water

Superoxidized water, also called electrochemically activated water or oxidative potential water, is effectively saline that has been electrolyzed to form superoxidized water, hypochlorous acid, and free chlorine radicals. It is commercially available as Sterilox (Sterilox Technologies, Radnor, PA). This solution is nontoxic to biologic tissues yet able to kill microorganisms. The use of superoxidized water is sparsely described in the endodontic literature but shows early promise. Clinicians may prefer to wait for more studies to demonstrate safety and efficacy under ordinary clinical setting conditions before adopting newer, less tested irrigating solutions.

Ozonated Water

Ozone is a chemical compound consisting of three oxygen atoms (O₃—triatomic oxygen), a higher energetic form than normal atmospheric oxygen (O₂). Thus, the molecules of these two forms are different in structure. Ozone is produced naturally by natural methods. Ozone is a very powerful bactericide that can kill microorganisms effectively. It is an unstable gas, capable of oxidizing any biological entity. It was reported that ozone at low concentration, 0.1 ppm, is sufficient to inactivate bacterial cells including their spores. It is present naturally in air and can be easily produced by ozone generator. When introduced in water, ozone dissolves rapidly and dissociates rather quickly. The concentration of ozone in ozonated water can be measured using a dissolved ozone meter. Although ozonated water is a powerful antimicrobial agent against bacteria, fungi, protozoa, and viruses, less attention has been paid to the antibacterial activity of ozonated water in bacterial biofilm and hence in root canal infection

Antibacterial Nanoparticles

Nanoparticles are microscopic particles with one or more dimensions in the range of 1 to 100 nm. Nanoparticles are recognized to have properties that are unique from their bulk or powder counterparts. Antibacterial nanoparticles have been found to have a broad spectrum of antimicrobial activity and a far lower propensity to induce microbial resistance than antibiotics. Such nanoparticles in endodontics are being studied in different ways, such as mixed with irrigants, photosensitizer, and sealers.

Herbal

Murray et al. evaluated *Morinda citrifolia* juice in conjunction with EDTA as a possible alternative to NaOCl. Triphala (IMPCOPS Ltd, Chennai, India) is an Indian ayurvedic herbal formulation consisting of dried and powdered fruits of three medicinal plants, *Terminalia bellerica*, *Terminalia chebula*, and *Emblca officinalis*, and green tea polyphenols (GTPs; Essence and Flavours, Mysore, India). Dimethyl sulfoxide (DMSO) is used as a solvent for Triphala and GTP, although they are readily soluble in water. DMSO is a clean, safe, highly polar, aprotic solvent that helps in bringing out the pure properties of all the components of the herb being dissolved. Herbal alternatives showed promising antibacterial efficacy on 3- and 6-week biofilm along with MTAD and 5% sodium hypochlorite. Triphala and GTPs are proven to be safe, containing active constituents that have

beneficial physiologic effect apart from its curative property such as antioxidant, antiinflammatory, and radical scavenging activity and may have an added advantage over the traditional root canal irrigants

Interaction between CHX, NaOCl, and EDTA

Interaction Between CHX and NaOCl

The combination of NaOCl and CHX produces a change of color and a precipitate. The reaction is dependent of the concentration of NaOCl. The higher the concentration of NaOCl, the larger the precipitate is if 2 % CHX is used. Furthermore, concerns have been raised that the color change may have some clinical relevance causing staining of the tooth. Also the resulting precipitate might interfere with the seal of the root canal obturation. Basrani et al. evaluated the chemical nature of this precipitate and reported the formation of 4-chloroaniline (PCA). PCA has been shown to be toxic in humans with short-term exposure, resulting in cyanosis, which is a manifestation of methemoglobin formation. The interaction should be avoided by using EDTA or other irrigants after NaOCl and before CHX or alternatively, the canals can be dried using paper points before the final rinse.

Interaction Between CHX and EDTA

The combination of CHX and EDTA produces a white precipitate, so a group of investigators did a study to determine whether the precipitate involves the chemical degradation of CHX. The precipitate was produced and redissolved in a known amount of dilute trifluoroacetic acid. Based on the results, CHX was found to form a salt with EDTA rather than undergoing a chemical reaction.

Interaction Between EDTA and NaOCl

Investigators studied the interactions between EDTA and NaOCl. They concluded that EDTA retained its calcium-complex ability when mixed with NaOCl, but EDTA caused NaOCl to lose its tissue-dissolving capacity, with virtually no free chlorine detected in the combinations. Clinically, this suggests that EDTA and NaOCl should be used separately. In an alternating irrigating regimen. In modern endodontics, EDTA is used once the cleaning and shaping is completed for around 1 min. It can be ultrasonically activated for better penetration in dentinal tubules. After NaOCl was used throughout the cleaning and shaping procedure, irrigation with EDTA for 1 min should be used to remove smear layer. EDTA can be activated for a couple of seconds to improve penetration. EDTA will leave a layer of collagen on the surface of the root canal lumen, and collagen can be important for the binding of bacteria; therefore, a final rinse with a low concentration of NaOCl can be applied at this time. Note that larger concentration may produce dentin erosion. Any collagen and/or other proteins left exposed by EDTA would be removed by a short exposure to sodium hypochlorite.

Effect of Temperature on CHX, NaOCl, and EDTA.

NaOCl + Heat

Increasing the temperature of low-concentration NaOCl solutions improves their immediate tissue dissolution capacity. Furthermore, heated hypochlorite solutions remove organic debris from dentin shavings more efficiently. There are various devices to preheat NaOCl syringes; however, it was demonstrated that as soon as the irrigant touches the root canal system, the temperature reaches the body temperature. Therefore, in situ heating of NaOCl is recommended by some authors. This can be done by activating ultrasonic or sonic tips to the NaOCl inside the root canal for a couple of minutes. Cavitation is the formation of vapor cavities in a liquid that are the consequence of forces acting upon the liquid. It usually occurs when a liquid is subjected to rapid changes that cause the formation of cavities where the pressure is relatively low. When subjected to higher pressure, the voids implode and can generate an intense shockwave

EDTA + Heat

The ultrasonic activation and heat production of chelating agents with an ultrasonic tip are also of questionable value. While the streaming of the solution will be enhanced, the generation of heat and the possibility of cavitation may not be beneficial. Chelators have a clear temperature range at which they work best. Heating from 20 to 90 °C will decrease the calcium binding capacity of EDTA and citric acid from 219 to 154 and from 195 to 30 mg CaO/g, respectively.

CHX + Heat

The use of ultrasonic energy to enhance the efficacy of irrigants is a new trend in clinical endodontics. Cameron et al reported that an increase in the intracanal temperature from 37 to 45 °C occurred close to the tip of the instrument when the NaOCl solution was ultrasonically activated for 30 s without replenishment. In 2009, Basrani et al published a paper showing that CHX at room temperature and at 37 °C did not result in a yellow end product when diazotized, therefore indicating that there is no aromatic amine present. However, when CHX that was heated to 45 °C was diazotized, the result was a yellow end product, indicating the presence of PCA or

another aromatic amine. These findings might be clinically relevant because PCA has been shown to be toxic. Considering that CHX can break down to form PCA by exposure to heat, it is not recommended to elevate the temperature of the CHX.

III. Disinfection Devices and Techniques

Just as several irrigant solutions are available to practitioners, so are adjunctive irrigation techniques, including passive ultrasonic activation, sonic activation, photodynamic therapy, and the EndoVac [Kerr] irrigation system. All techniques appear to offer improvements in disinfection, debridement, or both. The EndoVac system and photodynamic therapy offer improvements in debridement or bacterial reduction, but not both.

Manual Passive Irrigation

Conventional Syringe and Needles Plastic syringes of different sizes are available with 1 and 5 mL typically sufficient for endodontic irrigation purposes. Larger syringes (10 and 20 mL) although time saving due to their greater capacity for solution storage are more difficult to control when exerting pressure increasing the risks of inadvertent accidents. All endodontic syringes should have a Luer-Lok hub design, which avoids potential needle disengagement and irrigant spray, which can be harmful on skin/mucosal/eye contact and damage to clothing. Smaller needles (greater than 30G) although easier to deliver irrigant to the apex are a risk of potential apical extrusion. Needle tip designs have been modified with this view in mind with side venting to minimize extrusion.

Manual Dynamic Irrigation

Manual dynamic irrigation can be performed with hand files, brushes, or a well-fitting tapered gutta-percha point. The use of an apically well-fitting master gutta-percha cone moved in an up and down motion at the working length in short amplitude motions repeatedly will facilitate irrigant exchange in the apical 1/3rd. Replenishment of fresh NaOCl solution is necessary to ensure optimal antibacterial activity. This technique has been shown to produce favourable results with minimal risk of apical extrusion.

Rotary brushes

Machine assisted agitation systems have been developed to facilitate debris and smear layer removal. Rotary brushes such as CanalBrush (Coltene Whaledent, Langenau, Germany) has introduced a rotary handpiece-attached micro brush constructed from polypropylene. The micro brush is intended to rotate at 600rpm allowing and has been shown to effectively remove debris from simulated canal extensions and irregularities

Sonic Irrigation

EndoActivator

Sonic activation has been shown to be an effective method to enhance disinfection of the root canal. The use of a battery-operated portable handpiece offers three-speed sonic motor options (high, medium and low) with the choice of three disposable medical grade polymer tips (small #15/02, medium #25/04 and large #35/04) for single use application. Manufacturers claim the device is capable of sonic vibration up to 10,000 cycles per minute creating fluid hydrodynamics that improve both debridement and disruption of the smear layer and biofilm.

Micromega® Sonic Air®1500 handpiece with an attached Rispi-Sonic® file (Medidenta International Inc.)

The Sonic Air® 1500 unit is an air-driven device that produces vibrations ranging from 1,500 to 3,000 Hz (manufacturer data). The Rispi-Sonic® files are stainless steel and have barbs along the length of the file in a spiral design (Fig. 10.17b). This file is designed to cut dentin as well as agitate the irrigant solution with the canal. Irrigant is delivered and refreshed intermittently via needle delivery and not by the handpiece.

Vibringe

Vibringe (Vibringe BV, Amsterdam, The Netherlands) is a new sonic irrigation system that combines battery-driven vibrations (9000 cpm) with manually operated irrigation of the root canal. Vibringe uses the traditional type of syringe/needle delivery but adds sonic vibration.

Ultrasonic Irrigation

Passive Ultrasonic Irrigation

Ultrasonic Irrigation Cleaning of the root canal system and enhancing disinfection can be achieved by the use of ultrasonics. Passive ultrasonic irrigation refers to the file being used passively with the ability to move

freely within the canal without making contact that can result in ultrasonic preparation and inadvertent ledging. Cavitation and acoustic streaming of the irrigant contribute to the chemomechanical effectiveness of this procedure. The hydrodynamic response of the oscillating file with cavitation micro-streaming contributes to the cleaning of the canal.

Continuous Ultrasonic Irrigation (CUI)

As PUI/UAI was reported to improve the cleanliness of root canals and canal isthmuses, the issue of time for the technique and irrigant replenishment became an issue. Another problem that was previously noted was the potential for straightening of curved canals and file breakage. These issues lead to the development of an ultrasonically activated irrigating needle which could simultaneously activate and replenish irrigant deep within the canals. This system was designated continuous ultrasonic irrigation (CUI).

Currently there are two products commercially available for clinical use to provide CUI: Dentsply Tulsa Dental Specialties ProUltra® Piezoflow™ Ultrasonic tip) and Vista Dental Products StreamClean™ Flo-thru tip. The Piezoflow tip is a 25-gauge, blunt-ended stainless steel needle, while the StreamClean™ tip is a 30-gauge blunt-ended NiTi tube with external serrations. Research utilizing the commercial tips has been rather limited and has looked at the efficacy

Pressure Alternation Devices

EndoVac

EndoVac (Discus Dental, Culver City, CA, USA) is a proprietary product that uses negative pressure to draw irrigant within a canal and then removes it. The device is attached to a suction unit and utilizes a micro-cannula, which can be placed deep within canal. The cannula acts as a micro-suction drawing irrigant into a canal as far as its tip reaches. This imparts a degree of fluid movement although not as much as what might be achieved with ultrasonic irrigation. It does however ensure the apical extent of a canal is continuously flooded with fresh irrigant for an optimum effect. It also has the key advantage that it is not possible to extrude irrigant using this device and thus it is a very safe, almost making a hypochlorite accident impossible.

RinsEndo system

RinsEndo system (Dürr Dental, Bietigheim-Bissingen, Germany). Another device that makes use of pressure-suction technology is the It aspirates the delivered rinsing solution into an irrigation needle that is placed close to working length and at the same time activates the needle with oscillations of 1.6 Hz amplitude.

Safety-Irrigator

The Safety-Irrigator (Vista Dental Products) is an irrigation/ evacuation system that apically delivers the irrigant under positive pressure through a thin needle containing a lateral opening and evacuates the solution through a large needle at the root canal orifice. The Safety-Irrigator features a large coronal evacuation tube, enabling the user to safely irrigate and evacuate simultaneously. It fits any standard Luerlock syringe. Designed to limit risk of NaOCl accidents, this “negative-pressure” irrigation device comes fully assembled and fitted with a side-vented irrigating needle for added safety.

Gentle Wave System

Sonendo Inc. develops a so-called multisonic cleaning technology (Gentle Wave) that only requires pulp chamber access. This system is noninstrumentational and being tested clinically with, according to the company, promising results. It appears to have the potential to reach inaccessible canal areas with significantly more cleaned surface than other systems.

Photoactivation Disinfection

Photodynamic therapy (PDT) or light-activated therapy (LAT) may have endodontic applications because of its antimicrobial effectiveness. In principle, antimicrobial photodynamic therapy (APDT) is a two-step procedure that involves the introduction of a photosensitizer (step 1: photosensitization of the infected tissue) followed by light illumination (step 2: irradiation of the photosensitized tissue) of the sensitized tissue, which would generate a toxic photochemistry on the target cell, leading to cell lysis. Each of these elements used independently will not have any action, but together they have a synergism effect to produce antibacterial action. Along with methylene blue, tolonium chloride has been also used as a photosensitizing agent.

Laser-Activated Irrigation (LAI)

Activation or agitation of root canal irrigants via the use of lasers is a relatively new concept in endodontics. However, issues have arisen in terms of potential damage to the root canal wall dentin, overheating of the root and periodontium, access around the canal curvatures, and the size of the laser tip. It produces

cavitation effects by stating that the fluid in the canal instantly vaporized next to the laser tip. The vaporized water expanded forming a void (bubble) as the irradiation continued and heated more water on the inner surface of the void. When the laser pulse ceased, the bubble began to shrink, but the pressure of the surrounding fluid caused a violent collapse resulting in acoustic waves which traveled through the fluid-acoustic streaming. It is these waves which result in cleaning of the canal by shearing debris off the walls. Therefore, the cleaning effect of LAI is very similar to that of PUI/UAI and CUI and hence the term laser-activated irrigation. Another term seen in the literature for a similar process is photon-induced photoacoustic streaming (PIPS). The difference in this technique over the LAI techniques is that the laser tip is not placed within the root canal but only placed at the canal orifice.

Self adjusting file (SAF)

In the SAF concept (ReDent Nova, Ra'anana, Israel), irrigant is delivered with the filing system to improve penetration and irrigant exchange.

IV. Disinfection Protocol Suggested

Recommended irrigation protocol for root canal treatment: Many protocols are suggested in the modern endodontic literature. The following steps are the most commonly used:

1. 2.5–5 % NaOCl throughout the instrumentation procedure until final shape of the canal is achieved (adequate size and taper).
2. Activation and heating of the fresh NaOCl (such as ultrasonic, sonic or laser activation) for approx. 30 sec with fresh solution per canal.
3. Apical negative pressure devices are optional to enhance apical irrigation without extrusion (ex. Endovac).
4. Smear layer removal (EDTA, Citric acid, etc.) for approx. 1min (activation and/or apical negative pressure optional).
5. Final rinse options include Fresh NaOCl for approx. 1 min or CHX, QMiX, or Alcohol after that dry with paper points and obturate

V. Conclusion

Irrigation is a key part of successful root canal treatment. It has several important functions including: reducing friction between the instrument and dentine, improving the cutting effectiveness of the files, dissolving organic tissue remnants, cooling both the file and tooth, and furthermore, it has a washing effect and an antimicrobial effect. Irrigation is also the only way to have a positive impact on areas of the root canal wall not touched by mechanical instrumentation. Different means of delivery are used for root canal irrigation, from traditional syringe needle delivery to various machine-driven systems, including automatic pumps and sonic or ultrasonic energy. In selecting any irrigant and delivery system, consideration must be given to both safety and efficacy. This article reviewed the potential new irrigants that could substitute the traditional endodontic irrigants. Available literature and studies demonstrate advantages and limitations of each irrigant under consideration and none of them satisfy the requirements of the ideal root canal irrigant completely. Presently these newer irrigants could be used as an adjunct to NaOCl, with the hunt for the elusive ideal root canal irrigant continues.

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