Review Article

Irrigating Solutions in Pediatric Dentistry: Literature Review and Update

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Abstract:

Successful root canal treatment is dependent on the removal of microorganisms from the pulp and other anatomical irregularities of the root canal system through chemo-mechanical instrumentation with the use of instruments and irrigating solutions. Irrigants can augment mechanical debridement by flushing out debris, dissolving tissue, and disinfecting the root canal system. Chemical debridement is especially needed for primary teeth with complex internal anatomy and zones inaccessible to debridement, such as accessory canals, ramifications, and dentinal tubules that might be missed by instrumentation. The choice of a cleanser in the pulpal therapy of primary teeth should take into account the differences among the dentin substrata, and not be irritating to the periapical tissues. The aim of this review article here is to discuss the efficacy and other correlates of various root canal irrigants used in pediatric dentistry and provide an update with regard to recent advancements for the sterilization of infected root canals.

Key words: Irrigating Solutions, Sodium Hypochlorite

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Introduction

Preservation of primary teeth is integral for the harmonious development of occlusion, maintenance of arch length, optimum function of chewing and speech and preservation of healthy oral environment. Considering the fast development of caries in primary teeth, and consequently the pulp damage due to the pulpal tissue contamination by bacteria and their derived toxins, the endodontic treatment can be necessary.[1]Root canal preparation is a fundamental step in endodontic treatment. A clean root canal system along with a three-dimensional seal is the clinician's path to success. The contents of the root canal system are removed during the biomechanical preparation. However, primary teeth have zones inaccessible to debridement, such as accessory canals, ramifications, and dentinal tubules. Therefore, it is imperative to use auxiliary solutions that promote disinfection of these areas, mainly because infected primary teeth can

harbor micro-organisms inside the dentinal tubules,[2] in the same way permanent teeth do.[3] Irrigation is presently the best method for lubrication, destruction of microbes, the removal of tissue remnants, and dentin debris during instrumentation. The simple act of irrigation allows the flushes away loose, necrotic, contaminated materials before that they are inadvertently pushed deeper into the canal and apical tissues, compromising the periapical tissue and permanent bud. In this context, the use of cleansers in the irrigation process is essential.[4] The choice of a cleanser in the pulpal therapy of primary teeth should take into account the differences among the dentin substrata, and not be irritating to the periapical tissues. It is important to avoid harming the germ of the permanent successor tooth because the physiologic root resorption allows the apical extrusion of the cleanser.[5] To achieve these properties various root canal irrigants are used either singly or with combination.

The aim of this review article here is to discuss the efficacy and other correlates of various root canal irrigants used in pediatric dentistry and provide an update with regard to recent advancements for the sterilization of infected root canals.

Rationale for Using Root Canal Irrigants

While various chemical and physical irritants can cause irritation and even necrosis of the pulp, the most common causes for pulpal inflammation (pulpitis) are bacteria and/or their products entering the pulp through a deep caries lesion or a leaking filling, e.g. an inflammatory reaction in the pulp starts long before bacteria invade the pulp tissue. The inflammatory reaction is first initiated by bacterial antigens interacting with the local immune system[6,7] Although no exact data are available, it is likely that the majority of bacteria in most primary root canal infections are located in the main root canal, while a minority of the cells would have invaded further into the dentinal tubules and lateral canals.[8] In root canal treatment, cleaning is the removal of all contents of root canal system before and during shaping. Irrigation is presently the best method for lubrication, destruction of microbes, the removal of tissue remnants, and dentin debris during instrumentation. The simple act of irrigation allows the flushes away loose, necrotic, contaminated materials before that they are inadvertently pushed deeper into the canal and apical tissues, compromising the periapical tissue and permanent bud. In this context, the use of cleansers in the irrigation process is essential.[4]

Ideal Requirements of Root Canal Irrigants[9]

1. Broad antimicrobial spectrum
2. High efficacy against anaerobic and facultative microorganisms organized in biofilms.
3. Ability to dissolve necrotic pulp tissue remnants
4. Ability to inactivate endotoxin
5. Ability to prevent the formation of a smear layer during instrumentation or to dissolve the latter once it has formed.
6. Systemically nontoxic when they come in contact with vital tissues, noncaustic to periodontal tissues, and with little potential to cause an anaphylactic reaction.

Sodium Hypochlorite

Sodium Hypochlorite (NaOCl) have been used separately or associated with other medicines. NaOCl is a weak alkaline/ base that acts on the albumin (remains of pulpal tissue, foods and microorganisms), denaturing them and turning them soluble in water. Like soap, it facilitates the removal of debris from the root canals and, in spite of being a necrosis agent (to act on organic matter) it is little poisonous or irritating to the live tissues.[10] When hypochlorous acid, a substance present in NaOCl solution, comes in contact with organic tissue it acts as a solvent and

releases chlorine, which combines with the protein amino group to form chloramines. Hypochlorous acid (HOCl−) and hypochlorite ions (OCl−) lead to amino acid degradation and hydrolysis.[11] The chloramination reaction between chlorine and the amino group (NH) forms chloramines that interfere in cell metabolism. Chlorine (a strong oxidant) has an antimicrobial action, inhibiting bacterial enzymes and leading to an irreversible oxidation of SH groups (sulphydryl group) of essential bacterial enzymes.[11] Thus, the saponification, amino acid neutralization, and chloramination reactions that occur in the presence of microorganisms and organic tissue lead to the antimicrobial effect and tissue dissolution process.[11] NaOCl is used in concentrations varying from 0.5% to 5.25%; it is a potent antimicrobial agent, and effectively dissolves pulpal remnants and organic components of dentine. It is used both as an unbuffered solution at pH 11 in concentration 0.5– 5.25%, and buffered with bicarbonate buffer (pH 9.0) usually as a 0.5% solution (Dakin's solution).[12] Contradicting earlier statements, Zehnder et al.[13] reported that buffering had little effect on tissue dissolution, and Dakin's solution was equally effective on decayed (necrotic) and fresh tissues. In addition, no differences were recorded for the antibacterial properties of Dakin's solution and an equivalent unbuffered hypochlorite solution. NaOCl is best known for its strong antibacterial activity; it kills bacteria very rapidly even at low concentrations. Waltimo et al[14] showed that the resistant microorganism, Candida albicans, was killed in vitro in 30 s by both 5% and 0.5% NaOCl, whereas concentrations 0.05% and 0.005% were too weak to kill the yeast even after 24 h of incubation. Recent laboratory experiments using three Gramnegative anaerobic rods typically isolated from primary apical periodontitis, Porphyromonas gingivalis, P. endodontalis, and Prevotella intermedia demonstrated high susceptibility to NaOCl, and all three species were killed within 15s with all concentrations tested (0.5– 5%)[15] The efficacy of NaOCl can be increased by altering the pH, temperature and method of irrigation. The antibacterial properties and tissue-dissolving properties of 5.25% NaOCl decrease when it is diluted.[16,17] A rise in temperature by 25°C increased NaOCl efficacy by a factor of 100.[18] The capacity of a 1% NaOCl at 45°C to dissolve human dental pulps was found to be equal to that of a 5.25% solution at 20°C.[19] The use of ultrasonic agitation increased the effectiveness of 5% NaOCl in the apical third of the canal wall. NaOCl has been criticized for its unpleasant taste, relative toxicity, and its inability to remove smear layer.[20,21] Pashley et al compared the biological effects of mild and strong NaOCl solutions and demonstrated greater cytotoxicity and caustic effects on healthy tissue with 5.25% NaOCl than with 0.5% and 1% solutions.[22] Chang et al also showed the relationship between the concentration and cytotoxicity of NaOCl.[23] Therefore, it might be recommended to use 0.5–1% NaOCl for canal irrigation instead of the 5.25% solution.

Chlorhexidine Gluconate

CHX gluconate has been in use for a long time in dentistry because of its antimicrobial properties, its substantivity, and its relatively low toxicity. It has a wide antimicrobial spectrum and is effective against both Gram-positive and Gram-negative bacteria as well as yeasts, while mycobacteria and bacterial spores are resistant to CHX.[24, 25] Chlorhexidine Gluconate, currently used in endodontic therapy, seems to act by adsorbing onto the cell wall of the microorganisms and causing leakage of the intracellular components. At low concentrations, small molecular weight substances will leak out, especially potassium and phosphorus, resulting in a bacteriostatic effect. At high

concentrations, chlorhexidine gluconate has a bactericidal effect due to the precipitation and/or coagulation of the cellular cytoplasm, probably caused by cross-linking proteins[26]. Although studies comparing the antibacterial effect of NaOCl and CHX have produced somewhat conflicting results, it seems that when used in identical concentrations, their antibacterial effect in the root canal and in infected dentine is similar.[27-29] Vahdaty et al evaluated in vitro the antibacterial efficiency of 2% and 0.2% chlorhexidine, comparing them with NaOCl in the same concentrations.[30] These cleansers were used in the infected dentin tubules. The results indicated that both substances reduced the number of bacteria in the superficial layers of the dentin tubules. Oncag et al[31] evaluated the antibacterial properties against *Enterococcus faecalis* of 5.25% NaOCl, 2% CHX, and 0.2% CHX plus 0.2% cetrimide after 5 min and 48 h. The 2% CHX and Cetrexidin® were significantly more effective against *E faecalis*. Gomes et al[32] evaluated the antimicrobial activity of the two formulations of Chlorhexidine Gluconate (liquid and gel) in three concentrations (0.2%, 1.0% and 2%), and of NaOCl (0.5%, 1.0%, 2.5%, 4.0%). The results showed that chlorhexidine in liquid form eliminated bacterial cells more quickly than the chlorhexidine gel. Even though all tested cleansers possessed antimicrobial activity, the time required to eliminate the studied microorganisms depended on the concentration and of the type of cleansers used. CHX lacks the tissue-dissolving ability, which is one of the obvious benefits of NaOCl. While the in vitro studies have demonstrated the antibacterial effect of CHX against E. faecalis to be superior to that of NaOCl, there are no in vivo studies yet available that would confirm the better activity of CHX against this resistant species also in the infected root canal. Nevertheless, there is no doubt that CHX gluconate, in concentrations between 0.2% and 2%, offers a good alternative for root canal irrigation with potent antimicrobial activity. Future studies of CHX combinations are needed to establish whether these could give additional advantage in the fight against resistant root canal microbes.

Ethylenediamine tetraacetic acid (EDTA)

EDTA is a chelating agent used for the removal of the inorganic portion of the smear layer. 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.[33] Longer exposures can cause excessive removal of both peritubular and intratubular dentin.[34] EDTA (17%, disodium salt, pH 7) has little if any antibacterial activity. On direct exposure for extended time, EDTA extracts bacterial surface proteins by combining with metal ions from the cell envelope, which can eventually lead to bacterial death. EDTA is an effective chelating agent, which is widely used in endodontic preparation.[35] EDTA reacts with the calcium ions in dentine and forms soluble calcium chelates. It has been reported that EDTA decalcified dentin to a depth of 20–30 μm in 5 min.[36] It effectively removes smear layer by chelating the inorganic component of the dentine. Therefore, by facilitating cleaning and removal of infected tissue, EDTA contributes to the elimination of bacteria in the root canal. Niu et al[37] studied the ultrastructure on canal walls after EDTA and combined EDTA plus NaOCl irrigation by scanning electron microscopy: more debris was removed by irrigation with EDTA followed by NaOCl than with EDTA alone. According to Saito *et al.* greater smear layer removal was found in the 1-min EDTA irrigation group than the 30-sec or 15-sec groups.[38,39] Hariharan et al[40] showed that EDTA when used as a root canal irrigant in primary teeth, it removed

the smear layer but adversely affected the dentinal tubules. The similar type of damage was also noted in permanent teeth studies but with 17% EDTA.[34] The work by Marshall showed that there was a substantial difference in the microstructure of primary dentin as compared to permanent dentin, substantial differences with location, and the relatively common occurrence of microcanals.[41] These may be the reasons for the occurrence of erosion in primary teeth. Pitoni et al[42] compared EDTA and Citric acid solution for smear layer removal in primary tooth root canals. The authors concluded that there is no statistically significant difference between 17% EDTA solution and the 6% citric solution regarding smear layer removal efficiency.

Citric acid

Citric acid can also be used for irrigation of the root canal to remove the smear layer.[35,43,44] Concentrations ranging from 1% to 50% have been used.[43] The use of 10% citric acid as final irrigation has shown good results in smear layer removal[45] and proven to be more biocompatible than 17% EDTA-T and 17% EDTA.[46,47] Gutmann et al[48] showed that 10% citric acid was more effective in removing the smear layer from apical root-end cavities than ultrasound. Yamaguchi et al[49] compared the chelating and antibacterial properties of citric acid and EDTA. Powdered dentine–resin mixture was found to be more soluble in a 0.5, 1, and 2M citric acid solutions than in a 0.5M EDTA solution. Citric acid solution showed antibacterial effects on all 12 root canal bacteria tested. Di Lenarda et al and Scelza et al[50] reported a minor or no difference in smear layer removal with citric acid and 15% EDTA. The use of 25% citric acid was found to be ineffective in eradication of biofilms of *E faecalis* after 1, 5, and 10 mins of exposure.[51] In a recent study, Machado-Silveiro et al[52] measured the demineralization capability of 1% and 10% citric acid, 10% sodium citrate, and 17% EDTA during immersions of 5, 10, and 15 min on root canal dentine. Ten percent citric acid was more effective than 1% citric acid, which was more effective than EDTA. Hariharan et al[40] conducted an in vitro study to determine the efficacy of 5.25% NaOCl, 5.25 NaOCl + 10% EDTA, 6% citric acid and 2% chlorhexidine and saline (control) in removing the smear layer in primary teeth root canals after hand instrumentation. They showed the superior efficacy of 6% citric acid than the other tested irrigants on removing the smear layer in primary teeth. Both EDTA and citric acid can effectively remove the smear layer created during canal instrumentation. Although citric acid may also have an antibacterial effect, this has not been compared with other root canal disinfecting agents in in vitro or in vivo studies.[8]

MTAD

BioPure MTAD has been introduced to dentistry as a final irrigant for smear layer removal.[53] MTAD has been proved to be effective in eliminating resistant microorganisms and providing sustained antimicrobial activity.[54,54] Minimal erosion of intra-radicular dentin has been reported after final canal irrigation with MTAD.[56] Torabinejad *et al*. developed a irrigant with combined chelating and antibacterial properties.[53] MTAD (a mixture of tetracycline isomer, acid, and detergent, Biopure, Tulsa Dentsply, Tulsa OK, USA) is a new product in the quest for a better root canal irrigant, with a pH as low as 2.15.[53] In their study, the above authors used this new irrigant, focusing on the removal of smear layer, 48 extracted single-rooted teeth were prepared by using passive stepback and rotary 0.04 taper NiTi files. Distilled water or 5.25% NaOCl was used for irrigation followed by a 5mL irrigation with one of the following: sterile distilled water, 5.25% NaOCl, 17% EDTA, or MTAD. The results indicated that MTAD is an effective solution for the removal of the

smear layer and does not significantly change the structure of the dentinal tubules, when canals are first irrigated with NaOCl, followed by a final rinse of MTAD.[53] MTAD is an irrigant solution with ingredients capable of disinfecting the dentin, removing the smear layer, opening the dentinal tubules and allowing the antibacterial agents to penetrate the entire root canal system.[53]

In another study, the same group investigated the effect of various concentrations of sodium NaOCl as an intracanal irrigant before irrigation with MTAD as a final rinse on the smear layer. The results showed that MTAD removed most of the smear layer when used alone; however, remnants of the organic component of the smear layer could be detected on the root canal walls. There were no significant differences between the ability of 1.3%, 2.6%, and 5.25% NaOCl as root canal irrigants and MTAD as a final rinse to remove the smear layer. All combinations removed both the smear layer as well as the organic remnants. Therefore, it seems to be reasonable to use 1.3% NaOCl during instrumentation, followed by MTAD to remove the smear layer.[56] Beltz et al.[57] compared the tissue-solubilizing action of MTAD, NaOCl, and EDTA. MTAD solubilised dentine well, whereas organic pulp tissue was clearly more unaffected by it. Nara et al[58] compared the antimicrobial efficacy of 3% NaOCl, Biopure MTAD and Brazilian ethanolic extract of propolis (EEP) against Enterococcus faecalis. Their study concluded that MTAD was more effective than 3% NaOCl and propolis against E. Faecalis. Venkataram et al[59] compare the effectiveness of chamomile hydroalcoholic extract, Biopure MTAD and 2.5 % sodium hypochlorite (NaOCl) on removal of the smear layer in the root canals of primary teeth. They concluded that the efficacy of chamomile to remove the smear layer was superior to 2.5 % NaOCl alone, but less effective than MTAD mixture In the MTAD preparation, the citric acid may serve to remove the smear layer, allowing doxycycline to enter the dentinal tubules and exert an antibacterial effect.[56] The recently revised protocol for clinical use of MTAD advises an initial irrigation for 20 min with 1.3% NaOCl, followed by a 5-min final rinse with MTAD.[56]

Other Irrigants

H_2O_2

Hydrogen peroxide was used for many years as an endodontic irrigant. H2O2 is a widely used biocide for disinfection and sterilization.[60] It is a clear, colorless liquid that is used in a variety of concentrations in dentistry, ranging from 1% to 30%. When combined with sodium hypochlorite it creates effervescence, which was thought to facilitate debris removal. H2O2 is active against viruses, bacteria, yeasts, and even bacterial spores. It has greater activity against Gram positive than Gram-negative bacteria. H2O2 produces hydroxyl free radicals (-OH), which attack several cell components such as proteins and DNA.[60] In addition, the idea that peroxide acts as an oxidizing agent was extremely attractive to many dental professionals. Unfortunately, at high concentrations, hydrogen peroxide is not well tolerated in the body and might play a role in the development of cervical resorption. There is not a great deal of evidence supporting the use of hydrogen peroxide as an endodontic irrigant.

Maleic acid

Maleic acid is a mild organic acid used as an acid conditioner in adhesive dentistry.[62] Ballal *et al*. reported that final irrigation with 7% maleic acid for 1 min was more efficient than 17% EDTA in the removal of smear layer from the apical third of the root canal system.[62]

Chlorine dioxide

Chlorine dioxide has recently come under consideration as a possible root canal irrigant. It is reported to be tuberculocidal, bactericidal, virucidal, and fungicidal. Chlorine dioxide can be more effective as

a disinfectant when compared to sodium hypochlorite because $HOCl^-$ (Hypochlorous acid) or OCl^- (hypochlorite ions), two effective components of sodium hypochlorite, when come in contact with negatively charged bacterial cell wall might be repelled as both are negatively charged, thus causing less penetration and absorption of the disinfectant into the membranes, whereas chlorine dioxide irrigant, exists as gas in water, which enables it to permeate through bacterial cell membranes and bring about its destruction at a wide range of pH from 3 to 9.[63] Brian D et al concluded that chlorine dioxide is less cytotoxic as compared to Sodium hypochlorite.[64] Sodium hypochlorite reacts with natural organic matter to produce trihalomethanes and haloacetic acids both of which are animal carcinogens and suspected human carcinogens. Chlorine dioxide produces little or no trihalomethanes, and may be a better dental disinfectant than NaOCl.[65] Singh et al compared the dissolution efficacy of chlorine dioxide and sodium hypochlorite on human pulp tissue. They concluded that 5% Chlorine dioxide is capable of dissolving human pulp tissue but sodium hypochlorite was more effective.[66]

Tetraclean

Tetraclean is a mixture of doxycycline hyclate (at a lower concentration than in MTAD), an acid, and a detergent.[53,67] It is recommended to be used as a final rinse after root canal preparation.[67] It is similar to MTAD but with a reduced amount of doxycycline (50mg/5ml instead of 150mg/5ml for MTAD), with polypropylene glycol (a surfactant), citric acid, and cetrimide. This substance is supposedly capable of eliminating all bacteria and smear layer from the root canal system when used as a final irrigation. It is able to eliminate microorganisms and smear layer in dentinal tubules of infected root canals with a final 5-min rinse. Comparison of antimicrobial efficacy of 5.25% NaOCl, MTAD, and Tetraclean® against *E faecalis* biofilm showed that only 5.25% NaOCl could consistently disgregate and remove the biofilm at every time interval. However, treatment with Tetraclean® caused a high degree of biofilm disgregation in every considered time interval (5, 30, and 60 min at 20°C) as compared with MTAD.[68]

Smear clear

Designed to remove the smear layer, SmearClear contains 17% EDTA solution along with centrimide and additional proprietary surfactants. These components aid in the removal of inorganic matter left in the canal during instrumentation. By removing the smearlayer and leaving the dentinal tubules clear of inorganic matter, a more effective seal may be facilitated. SmearClear has been recently launched as a 17% EDTA-based endodontic irrigant containing cetrimide and additional proprietary surfactants. This product is known to have been evaluated in only one in vitro study with permanent teeth,[69] which compared the efficacy of different root canal irrigants against *Enterococcus faecalis* biofilms. These authors found that SmearClear had greater efficacy than almost of them. These results may be attributed to the fact that SmearClear contains cetrimide, which is a quaternary ammonium compound and a cationic detergent that is effective against gram-positive and gram-negative micro-organisms.[70]

Herbal Irrigants

Triphala and Green tea polyphenols (GTP)

Triphala is one of the well known Indian Ayurvedic herbal formulation consisting of dried and powdered fruits of three medicinal plants namely Terminalia Bellerica, Terminalia Chebula and Emblica Officinalis.[71] *Triphala* achieved 100% killing of *E faecalis* at 6 min. This may be attributed to its formulation, which contains three different medicinal plants in

equal proportions; in such formulations, different compounds may help enhance the potency of the active compounds, producing an additive or synergistic effect.[71] *Triphala* contains fruits that are rich in citric acid, which may aid in removal of the smear layer. The polyphenols found in Green tea are more commonly known as flavanols or catechins. Green tea polyphenols have significant antioxidant, anticariogenic, an anti-inflammatory, thermogenic, probiotic and antimicrobial properties in numerous human, animal and in vitro studies.[72] It can be used as an effective antiplaque angent because of its antioxidant properties and it can effectively inhibit the biofilm formation.[73] An in vitro study conducted to evaluate the antimicrobial efficacy of Triphala, GTPs, MTAD, and 5% Sodium Hypochlorite against E faecalis biofilm formed on tooth substrate showed maximum antibacterial activity with NaOCl and statistically significant antibacterial activity with Triphala, GTPs and MTAD.[71]

Morinda Citrifolia (NONI)

Morinda Citrifolia commercially known as Noni, is indigenous to tropical countries and is considered as and is indigenous to tropical countries and is considered as an important folk medicine. Its juice has a broad range of therapeutic effects including antibacterial, anti-inflammatory, antiviral, antitumor, antihelmenthic, analgesic, hypotensive, anti-inflammatory and immune enhancing effects. An invitro study compared the effectiveness of MCJ with NaOCl and CHX to remove the smear layer from the root canal walls of instrumented teeth. It was concluded that the efficacy of Morinda Citrifolia was similar to NaOCl in conjunction with EDTA as an intracanal irrigant. The antimicrobial activity of 2% CHX gel propolis, Morinda Citrifolia juice and Ca(OH)2 has been compared on E.faecalis infected root canal dentin at two different depths and three intervals. It was concluded that Propolis and Morinda Citrifolia were effective against E. faecalis in dentin on extracted teeth.[74] Morinda Citrifolia appears to be the first juice to be identified as a possible alternative to the use of NaOCl as an intracanal irrigant.

German chamomile and tea tree oil

The German chamomile (Marticaria recutitia L.) has been used for centuries as a medicinal plant mostly for its anti-inflammatory, analgesic, anti-microbial, antispasmic and sedative properties. German chamomile, in particular, is the most commonly used variety. Tea tree oil (Melaleuca alternifolia) as it is more commonly known, is a native Australian plant with many properties such as being an antiseptic, an antifungal agent and a mild solvent. Tea tree oil's major active component is terpinen-4-ol(typically 30-40%). This compound is responsible for its antibacterial and antifungal properties.[75]

In order to avoid the undesirable effects of NaOCl, an SEM study was conducted using two medicinal plants i.e german chamomile extract and tea tree oil which might disinfect the root canal system with less toxicity when used as irrigants. It was concluded that the efficacy of chamomile to remove smear layer was superior to NaOCl alone but less than NaOCl combined with EDTA.[76]

Conclusion

During instrumentation canals should be irrigated using copious amounts of the NaOCl solution. Once the shaping procedure is completed, canals can be thoroughly rinsed using aqueous EDTA or citric acid. Generally each canal is rinsed for at least 1 min using 5 to 10 ml of the chelator irrigant. After the smear layer removal procedure, a final rinse with an antiseptic solution appears beneficial. Chlorhexidine appears to be the most promising agent for use as a final irrigant in this situation. It has an affinity for dental hard tissues and, once bound to a surface, it has prolonged antimicrobial

activity, a phenomenon called substantivity. After the introduction of MTAD irrigant, newer irrigating regimen followed was initial rinse with 1.3 % NaOCl for 20 min and followed by final rinse with MTAD for 5 min. Future research on irrigants needs to focus on finding a single irrigant that has tissue dissolving capacity, smear layer removal property, and antibacterial efficacy.

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