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REVIEW ARTICLE

Unusual Root Canal Irrigation Solutions

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ABSTRACT

Microorganisms and their by-products play a critical role in pulp and periradicular pathosis. Therefore, one of the main purposes of root canal treatment is disinfection of the entire system of the canal. This aim may be obtained using mechanical preparation, chemical irrigation, and temporary medication of the canal. For this purpose, various irrigation solutions have been advocated. Common root canal irrigants, such as sodium hypochlorite, chlorhexidine, and a mixture of tetracycline, acid, and detergent have been extensively reviewed. The aim of this review was to address the less common newer root canal irrigation solutions, such as citric acid, maleic acid, electrochemically activated water, green tea, ozonated water, and SmearClear.

Keywords: Citric acid, Electrochemically activated solutions, Green tea, Maleic acid, Ozonated water, Root canal irrigants, SmearClear.

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INTRODUCTION

The important role of microorganisms in the pathogenesis of pulpoperiapical lesions has been proved.[1-3] Decrease in amount of microorganisms inside the infected canal needs usage of the various instrumentation techniques, irrigation solutions, and intracanal temporary medicaments. Mechanical preparation of the canal alone cannot induce a bacteria-free canal, especially in cases with complex anatomy.[4] On the contrary, *ex vivo* and clinical documents have indicated that mechanical preparation of the canal leaves large portions of the canal walls undebrided[5] and complete removal of the bacteria by this mechanical procedure alone is unlikely to be seen.[6] Therefore, some form of disinfection/irrigation is mandatory to kill the microorganisms and to remove the residual tissues. Common root canal irrigants, such as sodium hypochlorite (NaOCl),[7] chlorhexidine (CHX),[8] and mixture of tetracycline, acid, and detergent[9] have been extensively reviewed. The aim of this review was to address less common newer root canal irrigation solutions.

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CITRIC ACID

Structure and Characteristics

Citric acid is a weak organic acid with the appearance of white crystalline powder at room temperature. It can exist either in water-free form (anhydrous) or monohydrate form. The water-free form crystallizes from the hot water, whereas the monohydrate forms from the cold water. The latter may be converted to anhydrous form by heating more than 78°C.[10]

Antimicrobial Activity

Yamaguchi et al[11] showed that citric acid solution had antibacterial effects on all 12 root canal bacteria tested. Arias-Moliz et al[12] evaluated the minimal bactericidal concentration (MBC) for *Enterococcus faecalis*. They showed that MBCs of citric acid and phosphoric acid were 20 and 2.5% respectively. They also showed that ethylenediaminetetraacetic acid (EDTA) has no bactericidal activity, even after 1 hour contact.

Smear Layer Removal

This acid has the ability of root canal irrigation and also smear layer removal.[13] Different concentrations (1–50%) have been proposed.[14] Gutmann et al[15] concluded that 10% citric acid is better than ultrasound for smear layer removal from the root end cavities. Yamaguchi et al[11] also assessed the chelating property of citric acid and EDTA and showed that powdered resin-dentin combination is more soluble in 0.5 to 2 M citric acid than in 0.5 M EDTA. Liolios et al[16] showed that commercial EDTA is better than 50% citric acid for smear layer removal. In other studies, Di Lenarda et al[17] and Scelza et al[18] showed minor difference in the ability of smear layer removal with 15% EDTA and citric acid. In a recent study, Machado-Silveiro et al[19] showed that 10% citric acid is more effective than 1% citric acid, which is more effective than EDTA in dentine demineralization. Takeda et al[20] also concluded that irrigation with 6% phosphoric acid, 6% citric acid, and 17% EDTA cannot remove the whole smear layer from the canal walls. According to Reis et al,[21] citric acid solutions removed the smear layer after 60 seconds of application.

Toxicity

Using the 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide assay (MTA), Prado et al[22] revealed that 10% citric acid showed higher cell viability compared with other tested irrigation solutions. Marins et al[23] assessed the capacity of some root canal irrigants to induce genetic damage and/or cellular death in marine fibroblasts *in vitro*. According to their findings, NaOCl, citric acid, and EDTA show dose-dependent cytotoxicity with no genotoxicity. Kang et al[24] studied the biocompatibility property of MTA mixed with hydration accelerators, such as citric acid, calcium chloride, and calcium lactate gluconate. They showed that MTA mixed with 0.1 wt% citric acid shows the best results.

Effect on Fracture Resistance

Arslan et al[25] evaluated the effect of citric acid on root fracture. According to their findings, using 50% citric acid for 10 minutes and 10% citric acid for 1 minute demonstrated highest and lowest fracture resistance respectively.

Effect on Calcium Hydroxide ($Ca(OH)_2$) Removal

Arslan et al[26] showed that 10% citric acid is more effective for removal of $Ca(OH)_2$ combined with 2% CHX from the root canal than those of 17% EDTA and 1% NaOCl.

MALEIC ACID

Structure

Maleic acid (MA; $C_4H_4O_4$) is an organic composition; its nature is a dicarboxylic acid.[27]

Smear Layer-removing Ability

The MA has been found to possess the smear layer-removing ability.[28] When MA is used at a higher concentration than 7%, it caused damage to the intertubular dentin.[28] Ballal et al[29] showed that final rinse with 7% MA may be more effective than 17% EDTA in smear layer removal from the apical area. Ballal et al[30] demonstrated that microhardness of dentin may be decreased by MA (similar to EDTA). Furthermore, MA may eradicate *E. faecalis* at 0.88% concentration after 30 seconds and at 0.11% concentration after 120 seconds of contact time.[31]

Furthermore, 7% MA has minimal tissue dissolution capacity compared with NaOCl.[32] The MA demineralized the root dentin, with most calcium and phosphorus extracted during the first 5 minutes, compared with EDTA.[33] It has been indicated that there was no significant difference between MA and EDTA.[34]

Ballal et al[34] showed that MA produced the highest surface roughness compared with other irrigation solutions *in vitro*. According to Kuruvilla et al,[35] final rinse with 7% MA may be more effective than 17% EDTA and 18% etidronic acid in smear layer removal from apical area.

Antimicrobial Activity

Ferrer-Luque et al[31] demonstrated that final irrigation with 7% MA combined with 2% CHX or 2% CHX + 0.2% cetrimide (CTR) can improve disinfection of the canal. Ferrer-Luque et al[36] showed the antimicrobial activity of MA against *E. faecalis* alone or in association with CTR from 30 seconds onward.

Baca et al[37] showed that 2% CHX and 0.2% CTR solution showed complete inhibition of *E. faecalis* biofilm, whereas 2.5% NaOCl has the lowest residual activity. Killing percentage of 0.2% CTR and 2.5% NaOCl was 100% followed by 7% MA, 2% CHX, and finally 17% EDTA.

Toxicity

The cytotoxic effect of EDTA and MA on Chinese hamster fibroblasts cells has been shown by Ballal et al.[38]

Effect on Apical Seal

Ballal et al[39] evaluated the postobturation apical seal following irrigation with 7% MA or 17% EDTA using dye leakage under vacuum method. Findings revealed that final irrigation with 7% MA improves the postobturation apical seal compared with 17% EDTA.

Effect on Dentin

Ballal et al[40] evaluated the effect of 7% MA and 17% EDTA on microhardness and roughness of dentin and showed that there is no significant difference between EDTA and MA regarding the reduction of microhardness. The increase in roughness was greater with MA comparing EDTA. Kara Tuncer et al[41] revealed that MA produced the greatest reduction in dentin microhardness.

Tissue Solubility

Ballal et al[32] showed that 2.5% NaOCl dissolved the pulp tissue significantly more than 17% EDTA and 7% MA; however, there was no significant difference between 17% EDTA and 7% MA.

ELECTROCHEMICALLY ACTIVATED SOLUTIONS

Electrochemically activated (ECA) water is produced from tap water and low-concentrated salt solutions. Two kinds of ECA can be produced from the tap water and a saline solution by using a flow-through electrolytic module. The first is an antimicrobial anolyte with pH ranging between 2 and 9, and the latter is a catholyte can act as an alkaline detergent.[42,43]

The ECA water is presented in a metastable state and contains some kinds of free radicals and also biocidal agents, such as sodium hydroxide and hydrogen peroxide.[44]

Forty-eight hours after activation, the solution will return to a stable inactive state. Using ECA in dental unit water lines can effectively eliminate microbial biofilms.[45] Solovyeva and Dummer[46] showed that elimination of debris is equal for anolyte neutral cathodic solution and NaOCl. Gulabivala et al[47] assessed the effectiveness of ECA aqueous solutions in the debridement of *E. faecalis* biofilms in root canals of extracted teeth and found that these solutions were much weaker than NaOCl. Cloete et al[43] showed the effectiveness of ECA water on *Porphyromonas gingivalis* and *Escherichia coli*, while Helme et al[48] showed that ECA anolyte solution was more effective than NaOCl for disinfection and biological decontamination of drinking water. Yang et al[49] and Russell[44] confirmed the ability of ECA water to kill microorganisms.

Electrolyzed neutral water and oxidative potential water have been shown to be harmless to human cells similar to ECA water.[50-52]

Ozonated Water

Ozone is considered as a naturally occurring compound consisting of three oxygen atoms. It can be found in the form of gas in the stratosphere being continually created from and destroyed into molecular oxygen.[53] Both of these reactions are catalyzed by ultraviolet light from the sunlight.[54] Ozone is also a powerful antibacterial agent.[55,56] The oxidant potential of this component results in destruction of cytoplasmic membranes and cell walls of the bacteria.[57] This may result in increases in membrane permeability and compromising the cell viability. Subsequently, ozone molecules can readily enter the cell and cause the microorganism to die.[58,59] By oxidizing the biomolecules, ozone may show a great disruptive effect on cariogenic bacteria, and so eliminate the acidogenic bacteria.[60-62]

Müller et al[63] compared the influence of ozone gas, photodynamic therapy, 2% CHX, and 0.5% and 5% NaOCl on a multispecies oral biofilm. They showed that only 5% NaOCl is able to eliminate all bacteria effectively. Baysan et al[64] evaluated the efficiency of ozone on *Streptococcus mutans* and *Streptococcus sobrinus*. Results indicated that exposing the mentioned bacteria to ozone for 10 to 20 seconds reduced the total levels of microorganisms in the primary root carious lesions to <1% of the control values. Ten seconds application of ozone can also decrease the number of *S. sobrinus* and *S. mutans in vitro*.[64]

Polydorou et al[65] showed that 80 seconds treatment by ozone is a suitable choice for decreasing the microorganisms in deep cavities. This result can prove the effect of ozone on increasing the success rate of restorative treatments.

Nagayoshi et al[59] concluded that ozonated water is very effective in killing of Gram-negative and Gram-positive bacteria. Gram-negative bacteria were more sensitive to ozonated water than Gram-positive bacteria.

Aqueous ozone fulfills optimal cell characteristics in terms of biocompatibility for oral application.[66] Hems et al[67] concluded that ozone in solution has antibacterial effect against planktonic *E. faecalis*; however, it was not effective in a biofilm environment unless displaced into surrounding medium by using agitation. It was also shown that gaseous ozone was not effective on biofilm of *E. faecalis*.

Estrela et al[68] also showed that gaseous ozone, ozonated water, 2.5% NaOCl, and 2% CHX had no antibacterial effect against *E. faecalis* over 20 minutes contact time.

Thanomsub et al[69] discovered that 0.167 mg/min/L ozone can sterilize water, which is contaminated with up to 105 cfu/mL bacteria within half an hour. This concentration had no effect on cell viability in bacterial cultures at higher concentrations.

Kronusová[70] proposed usage of ozone for prepared cavities, postextraction complications, chronic gingivitis, and purulent periodontitis.

SMEARCLEAR

SmearClear (Sybron Endo, Orange, CA) is a product that was introduced for removing the smear layer. It is a 17% EDTA solution including a cationic CTR and an anionic surfactant. It has been shown that there were no significant differences between SmearClear, 17% EDTA, and 10% citric acid regarding their smear layer-removing ability.[71] Da Silva et al[72] showed the ability of this material for removing the smear layer from canal. Nelson-Filho et al[73] showed that there was no significant difference between EDTA and SmearClear in removing the smear layer from the root canals of primary teeth. On the contrary, Wu et al[74] indicated that the efficacy of 17% EDTA was better than that of SmearClear, while Dunavant et al[75] demonstrated that the efficacy of SmearClear on *E. faecalis* biofilms was significantly weaker than 1 and 6% NaOCl.

GREEN TEA

Green tea contains epigallocatechin gallate (EGCG) and tocopherols, carotenoids, vitamin C, and some minerals. Regarding the antioxidant property, it is more potent than black tea.[76] It shows great antibacterial activity against *E. faecalis* biofilm and in 6 minutes, it can kill 100% of *E. faecalis*.[77] Antibacterial activity of this material has been confirmed in other studies, which showed the efficacy of green tea extract in maintaining the viability of periodontal ligament cells higher than that of milk.[78,79] Lee et al[80] concluded that EGCG can suppress the progression of apical periodontitis. Recently, Lee and Tan[81] showed that EGCG is an effective antimicrobial agent against both the planktonic and biofilm forms of *E. faecalis* and inhibiting bacterial growth. The antibacterial effect of EGCG on *E. faecalis* may occur during generation of hydroxyl radicals.

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