Recent Advances in Root Canal Disinfection - A review

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ABSTRACT

Chemical and mechanical root canal debridement are the primary methods used in conjuction with conventional endodontic therapy to remove all dead tissue, bacteria, and microbial byproducts from the root canal. Commonly used root canal disinfection with sodium hypochlorite, a powerful organic tissue dissolver with a broad spectrum of antibacterial properties is an excellent choice opted for dentists for disinfecting root canals. On the other hand, chelating agents such as EDTA is routinely used to remove the inorganic tissue components of the smear layer. The use of chelating agents in endodontic therapy is less effective in the apical third. While performing endodontic therapy, the dentist must ensure the direct contacts of irrigants with the whole root canal wall surfaces, especially in the narrower apical portions of the root canals. In the current article, the authors has presented a detailed review in context to the various irrigating solutions used during the biomechanical preparation, their actions and advantages and disadvantages.

Keywords: Bio-film, Debridement, Root Canal Disinfection, Sodium Hypochlorite, Smear Layer

INTRODUCTION

Endodontics is a specialty within dentistry that deals with the anatomy and function of the pulp and periradicular tissues surrounding a root canals. The ultimate goal of root canal therapy is to clean the infected pulp and periradicular tissues while also preventing infection (European Society of Endodontology, 2006), thus providing a sterile environment within the root canal. Before the start of endodontic therapy, the microorganisms are commonly presented as a bio-film in the root canal, are the most common cause of pulpal and periradicular pathologies.[1]

An successful endodontic treatment will cause an ecological disturbance in the microbial biofilm sparing the most resistant microorganisms that had adapted themselves to the stress generated by instrumentation, irrigation and intracanal medications [2]

Ecological Disturbances in the root canal system

Disinfection procedures in endodontic therapy consists of root canal shaping, frequent irrigation and placements of intracanal medicaments.[2]

Since instrumentation mainly eliminates bacteria in the main root canal, in the problematic areas the ecological disturbances on biofilm are mostly caused by irrigation and intracanal medication. Several factors will influence the effectiveness of these disinfection procedures such as the type, concentration and frequency of application of the irrigant. [3] The present article has explained a detailed review in the history of root canal irrigants, their mechanism of action and their advantages and disadvantages.

Brief history of root canal irrigants

Taft recommended the use of irrigants for root canal irrigation regularly. He suggested using a 'deodorizer' such as sodium chloride. Using a range of flushing chemicals and medicaments, the early literature outlines several procedures for getting a clean canal. To eliminate necrotic pulp tissue, potassium salt were introduced into the canals. The sulphuric acid solution was put on a cotton pellet and sealed into the root canal for 24-48 hours. Callahan was the first to use this method in 1894. After that, a bicarbonate soda solution was injected into the root, causing effervescence and bringing debris to the surface for removal. As a result of research conducted by Grossman and Meiman, in the late twentieth century, double-strength sodium hypochlorite was used to remove pulp tissue pieces and dentin shavings after mechanical instrumentation in 1941, which led to the development of the usage of hydrogen peroxide as an irrigant. In 1943, Grossman published a book as a follow-up to his research. Hydrogen peroxide is now being used in clinical practice and has been deemed safe and effective.[4]

Functions of root canal disinfectants

Irrigation is an important part of root canal treatment because it removes dentin shavings from canals. As a result, they do not become compacted near the root canal's apex. The effectivness of instruments is more in a wet and clean root canal. Instuments are less likely to break in a properly cleaned canal. They operate as a necrotic tissue solvent, releasing debris, pulp tissue, and microbes, especially in the apical portions of the root canal. They assist in the clearance of debris from auxiliary and lateral channels where instruments are unable to reach. Although they may be antibacterial, the majority of them are germicidal, having a whitening impact on teeth discoloured by trauma or hefty silver restorations. The use of lubricating agents such as RC Prep (EDTA and urea peroxide) together with copious amount of irrigant solution in the canal makes instrumentation simpler and smoother. [5]

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Irrigants in endodontics

1. Sodium hypochlorite - Sodium hypochlorite (NaOCl) is the most commonly used irrigating solution in the clinical practice due to its effective antimicrobial activity and organic tissue dissolution ability, which allows organic matters dissolution including pulp tissue and biofilm.[3] Its action depends on its volume, concentration, exposure time, temperature, pH and its contact with the root canal surfaces. Furthermore, NaOCl has a low surface tension. Considering this, penetration in areas untouched by instrumentation remains challenging.[3]

It seems to be logical that increasing NaOCl concentration would increase bacterial elimination, biofilm removal and tissue dissolution. However, especially in higher concentrations, NaOCl has toxical effects for the periapical tissues, and an extrusion of this irrigant during endodontic treatment can cause marked facial edema and pain extending for hours to days. [6]

A study was conducted to evaluate the debridement capability of 0.5, 1, 2.5 and 5.25% NaOCl in instrumented and uninstrumented root canal surfaces. The authors found that 1; 2.5 and 5.25% NaOCl were able to completely remove pulpal remnants and pre-dentin from uninstrumented surfaces, whereas after using at 0.5% some fibrils were left on the surface.[7]

The antimicrobial action performed by NaOCl is suggested to be due to the active chlorine present in the hypochlorous acid formed when NaOCl reacts with water. The active chlorine is an oxidizing agent able to disrupt the metabolic functions of the bacterial cells by an irreversible oxidation of sulfhydryl groups of essential enzymes.[8]

Sodium hypochlorite has several advantages. It is an antibacterial and proteolytic agent that works effectively as a organic tissue solvent with a quick onset of action. It is widely used both as an oxidizing and a hydrolysing agent. Unfortunately, despite its many positive characteristics, NaOCl has significant drawbacks as well, including the fact that it is poisonous, ineffective in removing smear layers, corrosive, it may result in discolouration, and pungent odour. The sealer's connection to the dentin will be compromised if NaOCl is used as a final rinse. The percentage of NaOCl to be used during the entire cleaning and shaping treatment is recommended to be between 2.5 and 6%. [9]

2. Chlorhexidine (CHX) is a strong antiseptic that is often used to chemically control plaque in the mouth. Mouthwash is made up of 0.1-0.2% aqueous solutions, while root canal irrigation in endodontic treatment is done with a 2% concentration. The antibacterial action of CHX is dependent on achieving an ideal pH (5.5-7). At lower quantities, CHX is bacteriostatic; at larger quantities, it is bactericidal. CHX is effective against Gram-positive and -negative bacteria, spores of bacteria, lipophilic viruses, yeast, and fungi. But since CHX is pH-dependent, these effects are much reduced when organic matter is present.

One of the reasons for the extensive use of CHX is it attaches to hard tissues and retains its antibacterial action. This is because of the interaction of a large number of CHX molecules with dentin at any point in time. The anti-bacterial action of 2% CHX solution lasts from 72 hours to 12 weeks. The main drawback of CHX is its inability to dissolve in tissue. CHX is a matrix metalloproteinase (MMP) inhibitor with a wide range of action (anti-collagenolytic effect). [10]

3. EDTA - Tissue-dissolving irrigation solutions, both organic and inorganic, are essential for a comprehensive root canal cleanup. A supplementary solution of EDTA and other demineralizing agents should be administered during root canal therapy aids in removal of smear layer within the root canal. In 1957, Nygaart-Ostby recommended the use of chlorinating chemicals for the production of hardened root canals. In the beginning, it was advised to use the 15% EDTA solution with a pH value of 7.3. The most common kind of EDTA solution is a neutralized solution with a concentration of 17%. Dentin calcium ions react with fluid to generate calcium chelates. When the chelator is missing, the process of decalcification halts. Calt and Serper used 10 mL of the EDTA solution for 1 min to remove the smear layer of the canal wall. Demineralization of dentin was shown to increase with the amount of time spent in contact with it. In the apical third of the root, a minute-long ultrasonic application of 17% EDTA is highly helpful, and the use of liquid EDTA during root canal therapy is also advised.[11]

4. ***Citric Acid -*** The citric acid (CA) is available on the market in quantities ranging from 1% to 50%. Using 10% CA as a final irrigation solution offered good results for removing smear layers. Although EDTA and CA are equally effective in removing the smear layer from root canal walls, CA has shown some advantages over EDTA when used at comparable doses. The cytotoxicity of chelators has been studied *in vitro*. The biocompatibility of a 10% CA solution against a 17% EDTA solution has been shown. On three separate occasions (1, 5, and 10 min), a 25% CA solution was shown to be ineffective in the removal of *Enterococcus faecalis* biofilms.[12]

5. MTA-D (Mineral tri-oxide aggregate) -BioPure™ MTAD™, a combination of a tetracycline isomer, an acid (citric acid), and a detergent, is an alternative to EDTA for eliminating the smear coat. MTAD was created to clean the root canal system and clear the smear coating as a final rinse. When a low concentration of NaOCl (1.3 %) is used as an intracanal irrigant before inserting 1 ml of MTAD in a canal for 5 minutes and rinsing it with an additional 4 ml of MTAD as the final rinse, the effectiveness of MTAD to fully dissolve the smear layer is increased. In terms of antimicrobial activity, it tends to be superior to CHX. It also has antibacterial action that lasts, is biocompatible, and improves bond strength.[13]

6. Tetraclean - Triclosan is an antimicrobial agent that works against both gram-positive and gram-negative bacteria, as well as fungi and viruses. The minimum inhibitory concentrations (MIC) and minimum bactericidal concentrations (MBC) of triclosan and triclosan with Gantrez® against P intermedia, F nucleatum, A naeslundii,

P gingivalis, and E faecalis were determined by Nudera et al. The MBC of triclosan was found to be between 12 and 94 g/ml. For Gantrez®, the MBC of triclosan ranged from 0.3 to 10.4 g/ml. The addition of Gantrez® increased the triclosan's bactericidal function. Both triclosan and triclosan combined with Gantrez® had bactericidal efficacy against the five endodontic pathogens studied.[14]

7. *Superoxide Water-* Superoxidized water is obtained by the electrochemical treatment of a saline solution. It can be obtained from regular tap water and low-concentration salt solutions by electrochemically activating (ECA) them. Oxidizing compounds having microbicidal action against bacteria, viruses, fungi, and protozoa make up anolyte solutions. The names 'superoxidized water' and 'oxidative potential water' are both used to describe this kind of water. They are non-toxic and do not harm key biological tissues ECA has promising results for effective root canal irrigation.[15]

8. *Ozonated Water* - Even at low quantities, ozone (O_3) can kill pathogens, including spores (0.01 ppm). It is simply prepared using an ozone generator. Ozone dissolves quickly and easily in water. Lipopolysaccharides in root canals were discovered to have biological consequences, including the induction of apical periodontitis and could not be neutralized by ozonated water, despite the fact that ozonated water kills bacteria. Before ozonated water is used as a frequent therapeutic technique for root canals, more research is needed.[16]

9. Nano-particles - Magnesium oxide, calcium oxide, and zinc oxide nanoparticles are microscopic particles with antibacterial properties. The electrostatic interaction between positively charged nanoparticles and negatively charged bacterial cells is responsible for the antibacterial impact. Nanoparticles can also alter the chemical and physical properties of dentin, reducing the bacterial adhesion strength to the dentin.[17]

10. Castor oil detergent - Castor oil detergent has shown antimicrobial activity and biocompatibility, as well as non-toxic effects and detergent properties, both of which are essential characteristics for an irrigant solution. Endodontic irrigation with castor oil extract can remove debris in the same way as 1 percent NaOCl can. During biomechanical preparation, root canal irrigation with castor oil reduces the number of Escherichia coli and E. faecalis.[18]

11. Photon-Activated Disinfection - The use of photodynamic therapy (PDT) for the inactivation of microorganisms was first shown by Oscar Raab who reported the lethal effect of acridine hydrochloride on Paramecia caudatum.[19] PDT is based on the concept that nontoxic photosensitizers can be preferentially localized in certain tissues and subsequently activated by light of the appropriate wavelength to generate singlet oxygen and free radicals that are cytotoxic to cells of the target tissue.[20] Methylene blue (MB) is a well-established photosensitizer that has been used in PDT for targeting various gram-positive and gram-negative oral bacteria and was previously used to study the effect of PDT on endodontic disinfection.[21]

Several studies have shown incomplete destruction of oral biofilms using MB-mediated PDT due to reduced penetration of the photosensitizer. Study conducted by Soukos et al. used the combined effect of MB and red light (665 nm) exhibited up to 97% reduction of bacterial viability.[22] The results suggested the potential of PDT to be used as an adjunctive antimicrobial procedure after standard endodontic chemomechanical debridement, but they also demonstrated the importance of further optimization of light dosimetry for bacterial photodestruction in root canals.[22]

Along with methylene blue, tolonium chloride has been also used as a photosensitizing agent. It is applied to the infected area and left in situ for a short period. The agent binds to the cellular membrane of bacteria, which will then rupture when activated by a laser source emitting radiation at an appropriate wavelength (e.g., 635 nm radiation emitted by SaveDent; Denfotex Light Systems Ltd., Inverkeithing, United Kingdom). The light is transmitted into the root canals at the tip of a small flexible optical fiber that is attached to a disposable handpiece. The laser emits a maximum of only 100 mW and does not generate sufficient heat to harm adjacent tissues. Furthermore, tolonium chloride dye is biocompatible and does not stain dental tissue. The data quoted by the manufacturer suggest that this PAD system has antimicrobial efficacy.[23]

12. 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 Emblica officinalis, and green tea polyphenols (GTPs; Essence and Flavours, Mysore, India); the traditional drink of Japan and China is prepared from the young shoots of tea plant Camellia sinensis.[24]

Morinda citrifolia (MCJ) has antibacterial, antiviral, antifungal, antitumor, antihelmintic, analgesic, hypotensive, anti-inflammatory, and immune-enhancing properties. L-asperuloside and alizarin are antibacterial compounds found in MCJ. Murray et al. demonstrated that 6 percent MJC was as effective as 6 percent NaOCl in combination with EDTA as an intracanal irrigant for removing the smear layer. Since it is a biocompatible antioxidant, the use of MCJ as an irrigant can be beneficial because it is less likely to cause serious damage to patients than NaOCl accidents.

Although Triphala and green tea polyphenols (GTPs) exhibited similar antibacterial sensitivity on *E. faecalis* planktonic cells, Triphala showed more potency on *E. faecalis* biofilm. According to Prabhakar et al. 5% of sodium hypochlorite exhibited excellent antibacterial activity in both 3-week and 6-week biofilm, whereas Triphala and MTAD showed complete eradication only in 3-week biofilm.[24]

Triphala and GTPs are proven to be safe, containing active constituents that have beneficial physiologic effect apart from

its curative property such as antioxidant, anti-inflammatory, and radical scavenging activity and may have an added advantage over the traditional root canal irrigants.[26]

Factors influencing the maximal effects of irrigants in the root canal-

a) Concentration - The tissue dissolving power of NaOCl is higher at 5.2% than at 2.5% and 0.5%, and therefore, the higher the concentration, the greater the effectiveness.

b) Contact with substrate: To be effective, the irrigant must contact the substrate. The presence of organic tissue must be removed for irrigation to be successful.

c) Quantity of irrigant utilized: The more irrigant is used, the more effective it is. Irrigating needle gauze: 27 or 28 gauze is used for improved canal penetration.

d) Irrigant's surface tension: The lower the surface tension, the better the wettability.

e) Irrigant's temperature: Warming the sodium hypochlorite boosts its efficacy.

f) Irrigation frequency: The higher the frequency, the better the outcomes.

g) Canal diameter: The wider the canal, the better the irrigant's effect.

h) Irrigant's age: Newly produced solutions are more efficient than older solutions.

CONCLUSION

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 MTA-D. 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 pain between appointments. The major intracanal medications currently used in endodontics include Ca(OH)2 and CHX. The search for an ideal material and/or technique to completely clean infected root canals continues.

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