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Review ARTICLE

Root canal irrigants: A comprehensive review

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ABSTRACT
Of three essential steps of root canal therapy, irrigation of the root canal is the most important determinant in the healing of the periapical tissues. The primary endodontic treatment goal must thus be to optimize root canal disinfection and to prevent reinfection. The irrigants that are currently used during cleaning and shaping can be divided into antibacterial and decalcifying agents or their combinations. They include sodium hypochlorite (NaOCl), chlorhexidine, ethylenediaminetetraacetic acid (EDTA), and a mixture of tetracycline, an acid and a detergent (MTAD). Hence; the present review was planned for highlighting important aspects of root canal irrigation solutions.
Key words: Root canal, Irrigants

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INTRODUCTION

Diagnosis, instrumentation, obturation and restoration are the main steps involved in the treatment of teeth with pulpal and periapical diseases. Elimination or significant reduction of irritants and prevention of recontamination of the root canal after treatment are the essential elements for successful outcomes. Although many advances have been made in different aspects of endodontics within the last few years to preserve natural dentition, the main objective of this field remains elimination of microorganisms from the root canal systems and prevention of recontamination after treatment. The common belief that inadequate obturation is the major cause of endodontic failures has been proven to be fallacious as obturation reflects the adequacy of cleaning and shaping. In other words, what you take out of a root canal may be more important than what you put in it.[1-3]

The success of endodontic treatment depends on the eradication of microbes (if present) from the root-canal system and prevention of reinfection. The root canal is shaped with hand and rotary instruments under constant irrigation to remove the inflamed and necrotic tissue, microbes/biofilms, and other debris from the root-canal space. The main goal of instrumentation is to facilitate effective irrigation, disinfection, and filling. Several studies using advanced techniques such as microcomputed tomography (CT) scanning have demonstrated that proportionally large areas of the main root-canal wall remain untouched by the instruments, emphasizing the importance of chemical means of cleaning and disinfecting all areas of the root canal. There is no single irrigating solution that alone sufficiently covers all of the functions required from an irrigant. Optimal irrigation is based on the combined use of 2 or several irrigating solutions, in a specific sequence, to predictably obtain the goals of safe and effective irrigation. Irrigants have traditionally been delivered into the root-canal space using syringes and metal needles of different size and tip design. Clinical experience and research have shown, however, that this classic approach typically results in ineffective irrigation, particularly in peripheral areas such as anastomoses between canals, fins, and the most apical part of the main root canal.[4, 5]

Goals of root canal irrigation

Irrigation is often regarded as the most important part of endodontic treatment in particular for the eradication of root canal microbes. During and following instrumentation, irrigating solutions facilitate the killing and removal of microorganisms, necrotic and inflamed tissue and dentine debris. Irrigation reduces friction between the instrument and dentine, improves the cutting effectiveness of the files, dissolves tissue, and cools the file and tooth especially during the use of ultrasonic energy. Irrigation may prevent packing of the hard and soft tissue into the apical root canal and extrusion of planktonic and biofilm bacteria out into the periapical tissues. The most important irrigating solutions have tissue-dissolving activity either on organic or inorganic tissue. In addition, several irrigating solutions have antimicrobial activity and actively kill bacteria and yeasts in direct contact with them. However, irrigating solutions show varying degrees of cytotoxicity and sodium hypochlorite may cause severe, immediate and long lasting pain if it is expressed under pressure and then escapes through the apical foramen. Clearly, none of the presently available irrigating solutions can be regarded as optimal, or even close to that. In clinical practice, use of a combination of solutions in a specific sequence is necessary in order to maximally contribute to the success of root canal treatment.[6, 7]

Chlorhexidine Digluconate

Chlorhexidine digluconate (CHX) is widely used in disinfection in dentistry because of its good antimicrobial activity. It has gained considerable popularity in endodontics as an irrigating solution and as an intracanal medicament. CHX does not possess some of the undesired characteristics of sodium hypochlorite (ie, bad smell and strong irritation to periapical tissues). However, CHX has no tissue-dissolving capability and therefore it cannot replace sodium hypochlorite. CHX permeates the microbial cell wall or outer membrane and attacks the bacterial cytoplasmic or inner membrane or the yeast plasma membrane. In high concentrations, CHX causes coagulation of intracellular components. One of the reasons for the popularity of CHX is its substantivity (ie, continued antimicrobial effect), because CHX binds to hard tissue and remains antimicrobial. However, similar to other endodontic disinfecting agents, the activity of CHX depends on the pH and is also greatly reduced in the presence of organic matter.[8, 9]

Most of the research on the use of CHX in endodontics is carried out using in vitro and ex vivo models and gram-positive test organisms, mostly E faecalis. It is therefore possible that the studies have given an overpositive picture of the usefulness of CHX as an antimicrobial agent in endodontics. More research is needed to identify the optimal irrigation regimen for various types of endodontic treatments. CHX is marketed as a water-based solution and as a gel (with Natrosol). Some studies have indicated that the CHX gel has a slightly better performance than the CHX liquid but the reasons for possible differences are not known.[10]

Sodium Hypochlorite (NaOCl)

Sodium hypochlorite (NaOCl) is the main endodontic irrigant used, due to its antibacterial properties and its ability to dissolve organic tissues. NaOCl is used during the instrumentation phase to increase as much as possible its time of action within the canal without being chemically altered by the presence of other substances. Its effectiveness has been shown to depend on its concentration, temperature, pH solution and storage conditions. Heated solutions (45-60 °C) and higher concentrations (5-6%) have greater tissue-dissolving properties. However, the greater the concentration the more severe is the potential reaction that may happen if some of the irrigant is inadvertently forced into the periapical tissues. To reduce this risk, use of specially designed endodontic needles and a technique of injection without pressure are recommended. [11, 12]

Ethylene-diamine-tetra-acetic Acid (EDTA)

The main disadvantage of NaOCl is its inability to remove the inorganic portion of smear layer. For this reason, it is advised the combination of NaOCl with EDTA. EDTA has the ability to decompose the inorganic component of intracanal debris and is generally used at 17% concentration. EDTA seems to reduce the antibacterial and solvent activity of hypochlorite and so these two liquids should not be in the canal at same time. For this reason, during mechanical preparation abundant and frequent washing with sodium hypochlorite is used, while EDTA is used at the end of the preparation phase to completely remove the inorganic debris and smear layer from the canal walls.[13- 15]

Antimicrobial photodynamic therapy (APDT)

APDT is a two-step procedure that involves the application of a photosensitizer, followed by light illumination of the sensitized tissues, which would generate a toxic photochemistry on target cells, leading to killing of microorganisms. Nowadays, APDT is considered as a supplement to traditional protocols for canal disinfection. In an approach to adapt and improve the antimicrobial efficacy of APDT in endodontics, recent research has developed novel formulations of photosensitizers that displayed effective penetration into dentinal tubules, anatomical complexities, and antibiofilm properties. Well-designed clinical studies are currently warranted to examine the prospects for APDT in root canal disinfection.[15- 17]

Photon-induced photoacoustic streaming (PIPS)

PIPS is based on the radial firing stripped tip with laser impulses of subablative energies of 20 mJ at 15 Hz for an average power of 0.3W at 50 µs impulses. These impulses induce interaction of water molecules with peak powers of 400W. This creates successive shock waves leading to formation of a powerful streaming of the antibacterial fluid located inside the canal, with no temperature rising.[16]

Unlike the conventional laser applications, the unique tapered PIPS tip is not mandatory to be placed inside the canal itself but rather in the pulp chamber only. This can reduce the need for using larger instruments to create larger canals so that irrigation solutions used during treatment can effectively reach to the apical part of the canal and also canal ramifications. This procedure can effectively remove both vital and nonvital tissues, kill bacteria, and disinfect dentin tubules.[17- 19]

Gentlewave irrigation

Gentlewave (GW) (Sonendo, Laguna Hills, CA, USA) system aims to clean the root canal through generation of different physiochemical mechanisms including a broad spectrum of sound waves. Multisonic waves are initiated at the tip of GentleWave™ handpiece, which is positioned inside the pulp chamber. It delivers a stream of treatment solution from the handpiece tip into the pulp chamber while excess fluid is simultaneously removed by the built-in vented suction through the handpiece. Upon initiation of flow through the treatment tip of the handpiece, the stream of the treatment fluid interacts with the stationary fluid inside the chamber creating a force which causes hydrodynamic cavitation. The continuous formation of microbubbles inside cavitation cloud generates acoustic field with broadband frequency spectrum that travels through the fluid into the entire canal.[20- 22]

Chlorine dioxide

Chlorine dioxide (ClO_2) is chemically similar to chlorine or hypochlorite, the familiar household bleach. An In vitro study compared organic tissue dissolution capacity of NaOCl and ClO_2. It was concluded that ClO_2 and NaOCl are equally efficient for dissolving organic tissue. ClO_2 produces little or no trihalomethanes. A study showed that trihalomethane is an animal carcinogen and a suspected human carcinogen. ClO_2 might therefore be a better dental irrigant than NaOCl. [22-24]

Silver diamine fluoride

A 3.8% w/v silver diamine fluoride (Ag[NH3]2F) solution has been developed for intracanal irrigation. This represents a 1:10 dilution of the original 38% $Ag(NH_3)_2F$ solution used for root canal infection. The study on the antibacterial effect of 3.8% $Ag(NH_3)_2F$ against a E faecalis biofilm model concluded that $Ag(NH_3)_2F$ has potential for use as an antimicrobial root canal irrigant or interappointment medicament to reduce bacterial loads. E faecalis was completely killed by $Ag(NH_3)_2F$ after exposure to these agents for 60 min. The silver deposits were found to occlude tubular orifices after removal of the smear layer. [24-26]

Tetraclean®

Tetraclean is a mixture of doxycycline hyclate (at a lower concentration than in MTAD), an acid, and a detergent. 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. [25-27]

Triclosan and Gantrez®

Triclosan is a broad spectrum antimicrobial agent, active against gram-positive and gram-negative bacteria as well as some fungi and viruses. Previous authors have evaluated 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. The MBC of triclosan ranged from 12-94 μg/ml. The MBC of triclosan with Gantrez® ranged from <0.3-10.4 μg/ml. The addition of Gantrez® enhanced the bactericidal activity of triclosan. Both triclosan and triclosan with Gantrez® demonstrated bactericidal activity against the five specific endodontic pathogens. [27-29]

CONCLUSION

The need for retreatment may be attributed to either reinfection by oral bacteria or, more often, to the persistence and regrowth of microorganisms that were not eliminated during the previous treatment. Elimination of microbes from the pulpal tissue as well as in root canals is the main goal when aiming to prevent and treat pulpal and periapical lesions. Successful root canal therapy relies on the combination of proper instrumentation, disinfection and obturation of root canal. Therefore, the current focus of interest has been the use of irrigating solutions with strong antibacterial activity as the necessary supplement to mechanical preparation.

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