Antimicrobial Irrigants in the Endodontic Therapy

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Abstract:

This paper highlights the importance of root canal disinfection. It discusses the different endodontic irrigants available and comments on how these can be used most effectively. Eliminating bacteria from the root canal system is an essential stage in endodontic therapy. An objective of endodontic treatment is removal of diseased tissue, elimination of bacteria from the root canal system and prevention of recontamination.(1) Disinfection of the root canal system, as part of endodontic therapy, by preparation and irrigation is a key in reducing the number of bacteria within the root canal and helping to control periapical disease.

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Introduction

Eliminating bacteria from the root canal system is an essential stage in endodontic therapy. Practitioners should be adequately informed and skilled in this vital aspect of endodontics. It is desirable for endodontics to be straightforward, cost-effective and predictable. An objective of endodontic treatment is removal of diseased tissue, elimination of bacteria from the canal system and prevention of recontamination.[1] Disinfection of the root canal system, as part of endodontic therapy, by preparation and irrigation is key in reducing the number of bacteria within the root canal and helping to control periapical disease.[2] Recent guidelines,[3] suggest single-use for all endodontic instruments. This further enforces the need for effective irrigation, as potentially most root canal therapy is likely to be carried out over a single appointment. Additionally, greater than ever patient expectation of success makes it essential to optimize the disinfection process during endodontic treatment. There is no evidence that directly correlates endodontic outcome with type of irrigant used. Consequently, there is no agreement on which irrigant is best and whether they should be used alone or with others; however, it is agreed that the irrigant needs to have a bactericidal action. It seems logical to expect best results from an irrigant with good disinfection power, in relation to the causative organisms, when it is in contact with the bacteria for an adequate time period within the root canal system. This means the safe delivery of an appropriate volume of irrigant fluid throughout the endodontic treatment to complement the preparation process prior to obturation. This paper will therefore deal with the types and mode of action of modern endodontic irrigants.

Endodontic Microbes

Although around 500 species of bacteria have been identified in the oral environment, only a limited number have been found to colonize the root canal system.[4] This might suggest that the root canal system is a hostile and difficult environment for microbes to survive, and those that do survive may be difficult to eliminate. The majority of infective microbes within the root canal system are bacteria; however, fungi have also been isolated.[5] The microbial flora within necrotic root canals depends on the stage of the infection.[6] Initially, the bacterial load may be facultative (i.e those that can use dissolved oxygen or chemically derived oxygen for respiration and can live under aerobic or anaerobic conditions, as time progresses (over 3 months) and the consumption of oxygen within the root canal increases, about 90% of the microbial flora is obligate anaerobic bacteria (those that do not require oxygen to live.[6] Micro-organisms can exist within the root canals, dentinal tubules, accessory canals, canal's ramifications,apical deltas, fins and transverse anastomoses.[7] They are found within biofilms (structured communities encapsulated within a self-developed polymeric matrix and adherent to the root surface) or in planktonic form (drifting in a body of fluid). Microbes are difficult to culture and it is known that those within a biofilm are 1000 times more resistant to biocides than the same organisms in planktonic forms.[8] There is disagreement on the importance of removing the smear layer.

Endodontic Irrigants

Non-bactericidal Irrigants

Some general dental practitioners either use saline, local anaesthetics and/or distilled water.[9] These have no antibacterial action and will not reduce bacterial load significantly.[10] These irrigants may be used frequently as they are easy to use and readily available. In the case of local anaesthetic solutions, they also come in sterile packaging and can be dispensed easily through very small gauge needles. Additional contributing factors for their use may be safety. These irrigants should have no role in managing infected root canals. There are a number of better irrigating solutions available which are more appropriate for managing infected root canals.

Bacteriostatic/bactericidal Irrigants

These include an array of solutions which either kill bacteria or facilitate their death by allowing other irrigants to come into contact with the bacteria.

Sodium hypochlorite

Sodium hypochlorite (NaOCl) is the most frequently recommended and a commonly used endodontic irrigant. Its advantages are two-fold; pulpal dissolution and antimicrobial effect. NaOCl is a strong base (pH>11) and acts as an organic solvent, causing amino acid degradation and hydrolysis through the production of chloramine molecules.(11) There is evidence to show that a decrease in microbial numbers is achievable when using NaOCl for endodontic treatment of teeth with apical periodontitis.(12) The smear layer is not removed by NaOCl.(2) NaOCl is available from a variety of sources from supermarkets to dental supply companies and in a variety of concentrations. When NaOCl is chosen, it must be remembered that the concentration and temperature of the solution has a bearing on its effectiveness. A concentration of over 0.5% is required to reduce bacterial load significantly.(13) *In vitro* evidence has implied that using NaOCl at a concentration of 0.5% for 10 seconds can reduce the bacterial load of *A. naeslundi* (found in untreated necrotic root canals) and *C. albicans* (found in endodontic failure cases) to below the limit of detection. It was seen that a contact period of 30 minutes was required to reduce the bacterial load of *E. faecalis* below the limit of detection. At a concentration of 5.25%, 2 minutes of contact was required to reduce the bacterial load.(14) Other studies have shown that a concentration of 5.25% NaOCl can kill *E. faecalis* and *C. albicans* within 15–30 seconds.(2) NaOCl, at a concentration of 1% heated to 20°C, is less effective than that at 45°C, which in turn is less effective than that at 60°C, as more chlorine is released at higher temperatures. NaOCl at a concentration of 5.25% heated to 20°C is as effective as NaOCl at a concentration of 1% heated to 45°C. NaOCl at a concentration of 1% heated to 60°C is significantly more effective than 5.25% at 20°C.(15) The same study showed that aqueous solutions of 1%, 2.62% and 5.25% NaOCl heated to 21°C, 45°C and 60°C maintained 100% availability of chlorine for at least 60 minutes. Stock solutions should be stored at low temperatures and heated chair-side when required. To achieve pulpal dissolution a concentration of 1% or above is required.(15) There is a limited evidence for NaOCl at a concentration of 6% being significantly better than 5.25%. However, common sense dictates that higher concentrations will achieve reduction in bacterial load faster owing to the presence of a higher concentration of chloramine molecules. It should also be kept in mind that the more concentrated solutions of NaOCl are thicker and subsequently there is less wetting of the canal walls.(16) It has been observed that NaOCl solutions at concentrations of 0.5%, 3% and 5% degrade the organic phase (collagen) of dentine with no loss of mineral, possibly leading to brittleness of endodontically treated teeth.(14) There are significant biological toxicity risks if NaOCl is expressed under pressure into the periodontal ligament space. The outcomes are significantly worse the higher the concentration. The advantage of lower concentrations of NaOCl heated to higher temperatures is that, once they reach body temperature, the systemic toxicity should be lower than that of nonheated, high concentrations of NaOCl.

Iodine

Iodine was introduced into endodontics in 1979 advocating the use of povidone iodine, as it was seen to be an antiseptic against a broad range of micro-organisms, hypoallergenic, with low toxicity and has a decreased tendency to stain dentine.(17) Since then iodine has been shown to be bactericidal, fungicidal, tuberculocidal, virucidal and sporicidal.(6)The collagen matrix in dentine can inhibit iodine.(17) It is thought that iodine attacks key group proteins, nucleotides and fatty acids, leading to cell death.(2) The advantage of iodine over the other irrigants is that 2% preparations of Iodine Potassium Iodide (IPI) used in endodontics are shown to be less irritating and toxic than Formocresol, Camphorated Monochlorophenol (FMCP), and Cresatin.(2,17) It is also suggested that iodine at a concentration of 2% is faster at reducing the bacterial load than a calcium hydroxide inter-appointment dressing. 2%IPI needs 1–2 hours to prevent growth of *E. faecalis*.(17)

Chlorhexidine

Chlorhexidine (CHX) is a cationic bis-biguanide antiseptic. Its advantages are based on a broad spectrum of activity. CHX attacks multiple sites at a cellular level, making resistance less likely.(3) CHX is a positively charged hydrophilic and lipophilic molecule which interacts with phospholipids and lipopolysaccharides in cell membranes. Consequently, there is disruption of the cell membranes which allows CHX molecules to enter the cell to cause intracellular toxic effects, such as coagulation of the cytoplasm.[15] CHX is bacteriostatic at low concentrations and at higher concentrations is bactericidal to both gram positive and gram negative microbes, with greater activity against gram positive bacteria. CHX at a concentration of 0.2% (*Corsodyl*, GlaxoSmithKline Consumer Healthcare, UK) is not very bacteriocidal. CHX at a concentration of 2% (Chlorhexidine Gluconate Solution, Essential Dental Systems Inc, USA) is better, although if used directly following NaOCl can cause a dark precipitate, which is difficult to remove. *Hibiscrub* (Regent Medical, Bedfordshire, UK) contains 4% CHX and is a useful lubricant during endodontic procedures. It is thought that the precipitate is, as a result of the acidbase reaction between NaOCl and CHX. The precipitate formed is neutral but insoluble.[12] There is a question mark regarding the potential health risks associated with this precipitate. The authors recommend saline as an intermediate irrigant, when using both NaOCl and CHX as irrigants in the same tooth. It has been suggested that CHX is sporostatic but not sporocidal[13] and has been shown to inhibit adherence of *P. gingivalis* to host cells.[3] A disadvantage is that CHX does not dissolve organic tissue. On the other hand, this contributes to the fact that it is of low toxicity to periapical tissues.[11] Chlorhexidine has a unique property in that it has substantivity, i.e has a persistent residual antimicrobial action.[3] It can theoretically prevent microbial colonization for a period of time after the actual medication period. However, while the dentine is absorbing CHX in the first hour, it is not yet active[13] and the dentine must reach a saturation point for there to be a persistent antimicrobial effect. Some have stated that CHX needs to be in contact with the dentine for at least 7 days for saturation of the dentine rather than be used as an irrigant.[10] CHX is unsuitable as an interappointment dressing, as there are issues of leakage which may increase the space available for recolonization of microbes. Like many of the other irrigants, CHX is self limiting and antimicrobial substantivity depends upon the number of CHX molecules available for interaction with the dentine, and hence must be replenished frequently.

EDTA

Ethylene diamine tetra acetic acid (EDTA) is a synthetic amino acid and the sodium salts of EDTA (Na2EDTA) are used in dentistry. It is often used as a chelating agent. EDTA is not bactericidal nor bacteriostatic but inhibits the growth of, and eventually kills, bacteria by starvation as metallic ions needed for growth are chelated thus are not available for use by micro-organisms.[12, 13] EDTA is relatively non toxic but is slightly irritating in weak solution. EDTA at concentrations of 15–17% removes calcium from dentine leaving a softened matrix of dentine. It also emulsifies soft tissue and removes the smear layer with no deleterious effect to pulpal or periapical tissues.[5] The application of EDTA at a concentration of 17% for over 10 minutes has been shown to cause excessive erosion of peritubular and intertubular dentine.[4] The suggestion for EDTA is to be in the root canal system 1–5 minutes to achieve the desired effect.[3,4] EDTA, like many other irrigants, is self limiting. Frequent changing of the solution is more effective than one continuous application. EDTA is available in a liquid form for irrigation and a gel form for lubrication (*Glyde File Prep*, Dentsply-Maillefer, Ballaigues, Switzerland). A well known alternative is *Citric Acid*, however, EDTA has been shown to be a faster chelating agent.[6]

Hydrogen peroxide

Hydrogen peroxide (H2O2) is a colourless liquid and has been used in dentistry in concentrations varying from 1% to 30%. H2O2 degrades to form water and oxygen. It is active against viruses, bacteria, bacterial spores and yeasts[16] via the production of hydroxyl free radicals which attack proteins and DNA.[7] It has been shown that NaOCl, combined with H2O2, is no more effective against *E. faecalis* than NaOCl alone [8] however, CHX combined with H2O2 was a better antimicrobial agent than either one on their own.[9] The current evidence does not support the use of H2O2 over other irrigants and it has not been shown to reduce bacterial load in canals significantly.[2] There is the rare but potential danger of effervescence with H2O2 and seepage into the tissues may lead to air emphysema.[10]

Other products
Antibiotics

MTAD (Mixture of Tetracycline, Acid and Detergent) is a product with a pH of 2.15, consisting of doxycycline, citric acid and the detergent Tween-80.[2] MTAD has been seen to remove the smear layer without significantly changing the structure of the dentinal tubules, and the canals were seen to be cleaner when compared with EDTA.[11] MTAD was seen to be less toxic than eugenol, 3% H2O2, Ca(OH)2 paste, 5.25% NaOCl, *Peridex* (a CHX mouthwash with additives) and EDTA,[12] however, was more toxic than NaOCl in concentrations of 2.63%, 1.33% and 0.66%. [13] The protocol for clinical use of MTAD is 20 minutes with 1.3% NaOCl followed by 5 minutes of MTAD and is available from Dentsply as *BioPure* MTAD. Good antibacterial activity with MTAD is reported.[14, 15] As this irrigant is based on a tetracycline isomer, there may be problems with staining, resistance and sensitivity. Limited evidence is available for the use of these compared with conventional irrigants, such as NaOCl.

Photo-activated disinfection (PAD)

PAD is the application of a dye (often Toluidine blue) into the root canal system, followed by a laser radiation emitted from a low power (100 mW) laser device which activates the dye. Following normal irrigation, sterile water is used to wash the canals and the canals are dried using sterile paper points prior to introduction of the PAD solution into the canals. The principle behind the system is that the photosensitizer molecules will attach to the membrane of the bacteria, and then the irradiation with a specific wavelength matched to the absorption of the photosensitizer will lead to the production of singlet oxygen, causing rupture of the cell wall and death of the bacteria.[16] The effectiveness against endodontic pathogens depends on the power, length of exposure, absorption of light into the tissues, and tip-to-target tissue distance. A recent *in vivo* study concluded that PAD offers a mean of destroying bacteria that may remain after using conventional irrigants in endodontic therapy.[17] The advantage is that the dye is lethal to bacteria with no toxicity to the patient and there are no thermal side-effects to tissues surrounding the root.[11]

There is no robust evidence for this technique.Neodymium:yttrium-aluminumgarnet (Nd:YAG) lasers have also been used for photothermal disinfection and it was found that, even when there was direct exposure to the laser, all systems were not left bacteria free and these were therefore no better than irrigation with NaOCl.[6] The use of a photosensitizing agent and laser was not able to achieve total reduction in bacterial load *in vitro*, however, 3% NaOCl was seen to achieve this.[8] It must be remembered that it may be difficult to access small and curved canal spaces with lasers. These systems may also be expensive items to purchase.

Electronically Activated Water

Electronically Activated Water (EAW) is also known as Oxidative Potential Water. It is essentially electrolysing saline solution and is used commonly to remove biofilms from dental piping and tubing. The thought is that EAW is able to disrupt biofilms as well as removing the adhering ability of microbes to canal walls by creating a negative isotonic pressure which draws molecules into it. Research suggests that EAW with the use of ultrasound gave a large reduction in bacterial load; however, it was not as effective as 3% NaOCl.[9]

Summary

Sodium hypochlorite is still the most effective “gold standard irrigant”. Unlike with sodium hypochlorite, the extrusion of iodine and chlorhexidine is thought to be more forgiving to the soft tissues as they do not dissolve organic tissue. Chelators in liquid form are not a replacement for antimicrobial irrigants like NaOCl. The antimicrobial properties of chelators are low yet they can be used to remove the smear layer, increasing the penetration of other irrigants such as NaOCl and hence increasing their antimicrobial effects.[14] The inorganic portion of smear layer can be removed by the use of 15–17% concentrations of EDTA and the organic portion can be removed by NaOCl in concentrations exceeding 1%. Chelators in paste form can act as lubricants and may reduce the risk of instrument separation. Local anaesthetic agents and saline have no antimicrobial properties. These are useful only as a flushing agent in non-infected teeth i.e irreversible pulpitis cases and elective endodontic treatment. They cannot be expected to remove and kill microbes within the root canal system. They are also more expensive to purchase than sodium hypochlorite. Dentine has a buffering capacity and is able to neutralize acids and alkalines. The organic part of dentine is able to reduce the antimicrobial effect of chlorhexidine, iodine potassium iodide, and sodium hypochlorite. As yet there is limited evidence of methods to overcome this problem.

Conclusion

It must be kept in mind that the effectiveness of all irrigants has mostly been measured *in vitro* environments. More research that relates to endodontic success with irrigant types and methods used is required. This paper has described the irrigants available for endodontic therapy, highlighted their method of action and explained where they can be obtained. NaOCl is probably still the best available irrigant owing to its wide antibacterial spectrum.

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