International Journal of

Innovative Drug Discovery

e ISSN 2249 - 7609
Print ISSN 2249 - 7617

www.ijidd.com

TRADITIONAL & NEWER ROOT CANAL IRRIGANTS IN ENDODONTICS: AN OVERVIEW

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ABSTRACT

Root canal irrigants play an indispensable role for the complete disinfection of the root canal system, in particular those areas of the root canal that are not accessible for instrumentation**.** Modern, biologic root canal therapy should be performed with suitable irrigating solutions and intracanal medicaments. The goal of endodontic treatment is to free the treated tooth from infection and prevent re infection as thoroughly as possible by means which do not put the organism at risk. Sodium hypochlorite, ethylene diamine tetra acetic acid, hydrogen peroxide and chlorhexidine are the most commonly used root canal irrigants in endodontic practice, but they do not satisfy all the properties of an ideal root canal irrigant. Newer irrigants such as MTAD, tetraclean, ozonated water, photon activated disinfection have arrived in the market & are commercially available. In this review article, the specifics of the pulpal microenvironment and the resulting requirements for irrigating solutions are spelled out. In this review of the literature, an evidence-based concept for irrigation and medication of root canal systems is presented. Irrigants and medicaments are discussed with respect to their antimicrobial, tissue-dissolving and endotoxin-decontaminating capacity in relation to their systemic toxicity.

KEY WORDS: Irrigants, Chelators, Chlorhexidine, EDTA, Sodium hypochlorite, MTAD etc.

INTRODUCTION

Instrumentation has a key role in the cascade of treatment procedures to eradicate microbes in the root canal system. Instrumentation removes a great number of microbes from the accessible parts of the main root canal by direct mechanical cleaning action. Moreover, instrumentation shapes the root canal in such a way that effective irrigation becomes possible. In addition, it supports and facilitates mechanical removal and chemical eradication of the infection by irrigation during and following instrumentation. The effectiveness of endodontic files, rotary instrumentation, irrigating solutions and chelating agents to clean, shape, and disinfect root canals underpins the success, longevity and reliability of modern endodontic treatments [1]. The use of chemical agents during instrumentation to completely clean all aspects of the root canal system is central to successful endodontic treatment. Irrigation is complementary to instrumentation in facilitating the removal of pulp tissue and/or microorganisms. Irrigation dynamics plays an important role; the effectiveness of irrigation depends on the working mechanism(s) of the irrigant and the ability to bring the irrigant in contact with the microorganisms and tissue debris in the root canal [2].

Desired Functions of Irrigating Solutions [3]

- Washing action (helps remove debris).
- Reduce instrument friction during preparation (lubricant).
- Facilitate dentin removal (lubricant).
- Dissolve inorganic tissue (dentin).
- Penetrate to canal periphery.
- Dissolve organic matter (dentin collagen, pulp tissue, biofilm).
- Kill bacteria and yeasts (also in biofilm).

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- Do not irritate or damage vital periapical tissue, no caustic or cytotoxic effects.
- Do not weaken tooth structure.

Benefits of Irrigation during Endodontic Work

Making a wet environment during preparation. The dentin shaving floating to the chamber Files and reamers are less likely to break when the canal is wet. The irrigant that are typically used have the function of necrotic tissue solvent. The irrigants loosen debris & pulp tissue. Most irrigants are germicidal. Also have a bleaching action to lighten teeth discoloured by trauma post-operative darkness [4].

Ideal Requirement of Root Canal Irrigants [5]

It appears evident that root canal irrigants ideally should

- Have a broad antimicrobial spectrum and high efficacy against anaerobic and facultative microorganisms organized in biofilms.
- Dissolve necrotic pulp tissue remnants.
- Inactivate endotoxin.
- Prevent the formation of a smear layer during instrumentation or dissolve the latter once it has formed.
- Be systemically non-toxic.
- Be non-caustic to periodontal tissues.
- Be little potential to cause an anaphylactic reaction.
- It must aid in the root canal debridement.
- Act as a good lubricant.
- Low surface tension to flow easily into the inaccessible areas.

Various Irrigants Used In Endodontics

Sodium Hypochlorite: Chlorine is one of the most widely distributed elements on earth. It is not found in a free state in nature, but it exists in combination with sodium, potassium, calcium and magnesium. In the human body, chlorine compounds are part of the nonspecific immune defence. They are generated by neutrophils via the myeloperoxidase-mediated chlorination of a nitrogenous compound or set of compounds. Hypochlorite preparations are sporicidal and virucidal and show far greater tissue dissolving effects on necrotic than on vital tissues. These features prompted the use of aqueous sodium hypochlorite in endodontics as the main irrigant as early as 1920. There has been much controversy over the concentration of hypochlorite solutions to be used in endodontics. The antibacterial effectiveness and tissue dissolution capacity of aqueous hypochlorite is a function of its concentration, and so is its toxicity [6]. It appears that the majority of practitioners use “full strength” 5.25% sodium hypochlorite as it is sold in the form of household bleach leading to several adverse reactions like irritation and decrease in flexural strength of dentin. Also decrease in microbiota was also not significantly altered with this high concentration. It must be realized that during irrigation, fresh hypochlorite consistently reaches the canal system, and concentration of the solution may thus not play a decisive role.

Unclean areas may be a result of the inability of solutions to physically reach these areas rather than their concentration. Hence, based on the currently available evidence, there is no rationale for using hypochlorite solutions at concentrations over 1% wt/vol. One of the methods to improve the efficacy of sodium hypochlorite was to use heated solution. This improves their immediate tissue-dissolution capacity. Furthermore, heated hypochlorite solutions remove organic debris from dentin shavings more efficiently than unheated counter parts. However, there are no clinical studies available at this point to support the use of heated sodium hypochlorite [7]. Ultrasonic activation of sodium hypochlorite has also been advocated, as this would “accelerate chemical reactions, create cavitational effects, and achieve a superior cleansing action”. However, results obtained with ultrasonically activated hypochlorite versus irrigation alone are contradictory, in terms of both root canal cleanliness and remaining microbiota in the infected root canal system after the cleaning and shaping procedure. It should also be noted that time is a factor that has gained little attention in endodontic studies. Even fast-acting biocides such as sodium hypochlorite require an adequate working time to reach their potential. This should especially be considered in view of the fact that rotary root canal preparation techniques have expedited the shaping process. The optimal time that a hypochlorite irrigant at a given concentration needs to remain in the canal system is an issue yet to be resolved [8].

EDTA: Although sodium hypochlorite appears to be the most desirable single endodontic irrigant, it cannot dissolve inorganic dentin particles and thus prevent the formation of a smear layer during instrumentation. Demineralizing agents such as ethylenediamine tetraacetic acid (EDTA) and citric acid have therefore been recommended as adjuvants in root canal therapy.

These are highly biocompatible and are commonly used in personal care products. Although citric acid appears to be slightly more potent at similar concentration than EDTA, both agents show high efficiency in removing the smear layer. In addition to their cleaning ability, chelators may detach biofilms adhering to root canal walls. An alternating irrigating regimen of NaOCl and EDTA may be more efficient in reducing bacterial loads in root canal systems than NaOCl alone. Antiseptics such as quaternary ammonium compounds (EDTAC) or tetracycline antibiotics (MTAD) have been added to EDTA and citric acid irrigants, respectively, to increase their antimicrobial capacity. The clinical value of this, however, is questionable. Both citric acid and EDTA immediately reduce the available chlorine in solution, rendering the sodium hypochlorite irrigant ineffective on bacteria and necrotic tissue. Hence, citric acid or EDTA should never be mixed with sodium hypochlorite [9]. Calt and Serper demonstrated that 10 mL irrigation with

17% EDTA for 1 minute was effective in removal of smear layer, but a 10-minute application caused excessive peritubular and intertubular dentinal erosion. Citric acid which is recommended as a root canal irrigant/cleaner and conditioner – a mild chelating agent that can also be used to dissolve calcium hydroxide from canals; EDTA which facilitates the removal of the smear layer and dentine 'mud', enhancing disinfection and preparing the dentine walls for advanced adhesion of filling materials; eucalyptus oil plus many other very useful products [10].

Chlorhexidine digluconate (CHX)*:* It is widely used in disinfection in dentistry because of its good antimicrobial activity. It has a considerable popularity in endodontics as an irrigating solution and as an intracanal medicament. It 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. 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. It was developed in the late 1940s in the research laboratories of Imperial Chemical Industries Ltd. (Macclesfield, England) [11]. The original salts were chlorhexidine acetate and hydrochloride, both of which are relatively poorly soluble in water. Hence, they have been replaced by chlorhexidine digluconate. It is a potent antiseptic, which is widely used for chemical plaque control in the oral cavity. Aqueous solutions of 0.1 to 0.2% are recommended for that purpose, while 2% is the concentration of root canal irrigating solutions usually found in the endodontic literature. Heating a chlorhexidine irrigant of lesser concentration could increase its local efficacy in the root canal system while keeping the systemic toxicity low. Despite its usefulness as a final irrigant, chlorhexidine cannot be advocated as the main irrigant in standard endodontic cases, because (a) chlorhexidine is unable to dissolve necrotic tissue remnants, and (b) chlorhexidine is less effective on Gram-negative than on Gram-positive bacteria [12].

MTAD: Bio Pure MTAD is a mixture of a tetracycline isomer, an acetic acid and Tween 80 detergent (MTAD)—was designed to be used as a final root canal rinse before obturation. Tetracycline has many unique properties of low pH and thus can act as a calcium chelator and cause enamel and root surface demineralization. Its surface demineralization of dentin is comparable to that seen using citric acid. In addition, it has been shown that it is a substantive medication that is it gets absorbed and gradually released from tooth structures such as dentin and cementum. In particular, MTAD mixture is effective against E. faecalis, and it is also less cytotoxic than a range of endodontic medicaments, including eugenol, hydrogen peroxide (3%), EDTA, and calcium hydroxide paste [13].

*Advantages***:** MTAD is a most biocompatible material with least cytotoxicity and strongest antimicrobial activity. It was found to be highly effective against E. faecalis in refractory root canal infections. It does not cause any irritation to the periapical tissues even if it is extruded into periapical area. It is the most effective in the removal of endodontic smear layer with minimal erosion of dentinal tubules. It helps in the simultaneous removal of endodontic smear layers and disinfection of root canals and clinically effective.

Disadvantages: MTAD a tetracycline derivative has the ability to intrinsically stain teeth during odontogenesis, can chelate calcium ions and can get incorporated into teeth, resulting in discolouration of both primary and permanent dentitions. It is contraindicated in pregnancy. It is expensive than other commonly used root canal irrigants. MTAD (once the liquid component is mixed with powder) has a short shelf life and has to be used within 48 h even if refrigerated. It demonstrates lesser compatibility to dental pulp cells for revascularization procedures. Torabinejad et al. showed that the effectiveness of the MTAD was enhanced when low concentration of NaOCl is used as an intracanal irrigant before the use of MTAD as a final rinse [14].

Tetraclean: It is like MTAD is a mixture of an antibiotic, an acid and a detergent. However, the concentration of the antibiotic, doxycycline (50 mg/mL), and the type of detergent (polypropylene glycol) differ from those of MTAD. Giardino et al. compared the surface tension of 17% EDTA, Cetrexidin, Smear Clear, 5.25% NaOCl, MTAD and Tetraclean. The NaOCl and EDTA had the highest surface tension, whereas Cetrexedin and Tetraclean had the lowest values. In another study, they compared the antimicrobial efficacy of 5.25% NaOCl, MTAD and Tetraclean against an E. faecalis bio film generated on cellulose nitrate membrane filters. Only the NaOCl could disaggregate and remove the biofilm at every time interval tested although treatment with Tetraclean caused a high degree of biofilm disaggregation at each time interval when compared with MTAD [15].

Electrochemically Activated Solutions (ECA): It is produced from tap water and low-concentrated salt solutions. The ECA technology represents a new scientific paradigm developed by Russian scientists at the All-Russian Institute for Medical Engineering (Moscow, Russia, CIS). Principle of ECA is transferring liquids into a metastable state via an electrochemical unipolar (anode or cathode) action through the use of an element/reactor ("Flow-through Electrolytic Module" or FEM). The FEM consists of an anode, a solid titanium cylinder with a special coating that fits coaxially inside the cathode, a hollow cylinder also made from titanium with another special coating. A ceramic membrane separates the electrodes. The FEM is capable of producing types of solutions that have bactericidal and

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sporicidal activity; yet they are odourless, safe to human tissue and essentially noncorrosive for most metal surfaces.

Electrochemical treatment in the anode and cathode chambers results in the synthesis of two types of solutions: that produced in the anode chamber is termed an Anolyte, and that produced in the cathode chamber is Catholyte. Anolyte solutions containing a mixture of oxidizing substances demonstrate pronounced microbiocidal effectiveness against bacteria, viruses, fungi and protozoa. Anolyte solution has been termed Superoxidized Water or Oxidative Potential Water. Depending on the type ECA device that incorporated the FEM elements the pH of anolyte varies; it may be acidic (anolyte), neutral (anolyte neutral), or alkaline (anolyte neutral cathodic); acidic anolyte was used initially but in recent years the neutral and alkaline solutions have been recommended for clinical application. Under clean conditions, freshly generated superoxidized solution was found to be highly active against all these microorganisms giving a 99.999% or greater reduction in two minutes or less. That allowed investigators to treat it as a potent microbiocidal agent. It is nontoxic when being in contact with vital biological tissues .Clinical applications of anolyte and catholyte were reported to be effective. ECA solutions demonstrated more pronounced clinical effect and were associated with fewer incidences of allergic reactions compared to other antibacterial irrigants tested. Cleaning efficiency and safety for surfaces of dental instruments and equipment has been demonstrated in a number of studies. The experience of oxidative potential water application for irrigation of root canals has been reported. However, Haga and coworkers studied the effect of acidic anolyte solutions. The anolyte neutral cathodic solution (ANC) provides an increased antiseptic effect and an enhanced cleaning ability at lower concentrations of active chlorine compared to the acidic anolyte and anolyte neutral solutions because of its higher concentration of peroxides.

Both electrolyzed neutral water and oxidative potential water are claimed to be harmless to humans and are probably similar to ECA water. The quality of debridement was better in the coronal and middle parts of canal walls where only scattered debris was noted in contrast to the apical part that contained huge amount of debris. This observation confirms the previously published results. According to Solovyeva and Dummer NaOCl and ECA solutions left a thinner smear layer with a smoother and more even surface. The texture of the canal surfaces treated with ECA solutions was relatively uniform in the various regions of the root canal and did not seem to be influenced by the method of instrumentation, that is, manually or mechanical. Irrigation with NaOCl or ECA solutions enhanced the opening of dentine tubules. It is important to note that irrigation with NaOCL resulted in open tubules predominantly in the coronal and middle thirds of root canals with no signs of tubule orifices were revealed in the apical third of canals. Irrigating with anolyte neutral cathodic as well as with alternate ANC and catholyte resulted in more numerous open dentine tubules in the apical as well as in the coronal regions. Solovyeva and Dummer studied the cleaning effectiveness of root canal irrigation with ECA solution and found that it was similar to NaOCl in debris removal but was more effective than NaOCl in smear layer removal. ECA is showing promising results due to ease of removal of debris and smear layer, nontoxic and efficient in apical one third of canal. It has a potential to be an efficient root canal irrigant [17].

Ozonated Water: Ozone is a chemical compound consisting of three oxygen atoms (O3–triatomic oxygen), a higher energetic form than normal atmospheric oxygen (O2). Thus, the molecules of these two forms are different in structure. Ozone is produced naturally by the following natural methods:

(i) The first is from electrical discharges following thunderstorms. Ozone is created when an oxygen molecule receives an electrical discharge breaking it into two oxygen atoms. The individual atoms combine with another oxygen molecule to form an O_3 molecule.

(ii) The second from ultraviolet rays emitted from the sun which plays the role of electrical discharge over oxygen present in the stratosphere, thus, creating the ozone layer which absorbs most of the ultraviolet radiation emitted by the sun [18].

Ozone is a very powerful bactericide that can kill microorganisms effectively. It is an unstable gas, capable of oxidizing any biological entity. It was reported that ozone at low concentration, 0.1 ppm, is sufficient to inactivate bacterial cells including their spores. It is present naturally in air and can be easily produced by ozone generator. When introduced in water, ozone dissolves rapidly and dissociates rather quickly. The concentration of ozone in ozonated water can be measured using a dissolved ozone meter. Although ozonated water is a powerful antimicrobial agent against bacteria, fungi, protozoa, and viruses, less attention has been paid to the antibacterial activity of ozonated water in bacterial biofilm and hence in root canal infection. Cavitation is the formation of vapor-containing bubbles inside a fluid causing formation of pressure waves/shockwaves characterized by rapid changes in pressure and high amplitude. A forced collapse of bubbles causes implosions that impact on surfaces, causing shear forces, surface deformation and removal of surface material. In the root canal environment, such shockwaves could potentially disrupt bacterial biofilms, rupture bacterial cell walls, and remove smear layer and debris. Shockwave generation can also enhance the breakdown of agents such as hydrogen peroxide and ozone dissolved in water and thereby enhances their disinfecting and debriding actions [19]. Nagayoshi et al. found that killing ability of ozonated water and 2.5% of sodium hypochlorite was almost comparable when the specimen was irrigated with sonication [20]. Study by Hems et al. however found that

NaOCI was superior to ozonated water in killing E. faecalis in broth culture and in biofilm [21]. Ibrahim and Abdullah studied that 1.31% NaOCl might allow passage of oxidation of ozonated water, thus increasing their antibacterial effect compared to 1.31% NaOCl or ozonated water alone [22]. Cardoso evaluated the efficiency of ozonated water as an irrigating agent during endodontic treatment in an attempt to eliminate Candida albicans and Enterococcus faecalis and to neutralize lipopolysacharides (LPSs) inoculated in root canals. It was possible to see effective antimicrobial action after ten minutes of water ozonization on the microbial suspension. There was no residue found when a second sample was collected seven days later. However, ozonated water was not able to neutralize E. coli and LPS inside root canals and the remaining amount of LPS may have biological consequences such as apical periodontitis [23]. Estrela et al. assessed the antimicrobial efficiency of aqueous ozone, gaseous ozone, 2.5% sodium hypoclorite, and 2% chlorexidine in human root canals infected with Enterococcus faecalis. None of the solutions tested were found to be effective against the bacterial suspension .There is need for further studies and modifications in ozonated water before it could be used as a root canal irrigant [24].

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. 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. 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. Several studies have shown incomplete destruction of oral biofilms using MB-mediated PDT due to reduced penetration of the photosensitizer [25]. Soukos et al. used the combined effect of MB and red light (665 nm) exhibited up to 97% reduction of bacterial viability. The results suggested the potential of PDT to be used as an adjunctive antimicrobial procedure after standard endodontic chemo mechanical debridement, but they also demonstrated the importance of further optimization of light dosimetry for bacterial photo destruction in root canals [26]. 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. 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. Lethal photosensitization of Streptococcus intermedius biofilms in root canals is unable to achieve a total kill rate when a combination of a helium-neon laser and tolonium chloride is used [27]. Leticia et al. investigated the antibacterial effects of photodynamic therapy (PDT) with methylene blue (MB) or toluidine blue (TB) (both at 15 mg/mL) as a supplement to instrumentation/irrigation of root canals experimentally contaminated with Enterococcus faecalis.

The study revealed that PDT with either MB or TB may not exert a significant supplemental effect to instrumentation /irrigation procedures with regard to intracanal disinfection, until further adjustments in the PDT protocol are modified before clinical use is recommended. In contrast, irrigation with sodium hypochlorite (3%) eliminated the entire bacterial population. The difference could be because the optical fiber was not properly introduced into the root canals, and so the light could not transmit through the tooth structure. Thus, PAD might not be able to achieve a 100% kill rate in infected root canals that have complex anatomic features and colonized by polymicrobial biofilms of varying properties [28]. Pagonis et al. studied the in vitro effects of poly(lacticco- glycolic acid) (PLGA) nanoparticles loaded with the photosensitizer methylene blue (MB) and light against Enterococcus faecalis . The study showed that utilization of PLGA nanoparticles encapsulated with photoactive drugs may be a promising adjunct in antimicrobial endodontic treatment [29].

Herbal: Murray et al. evaluated Morinda citrifolia juice in conjunction with EDTA as a possible alternative to NaOCl [30]. Triphala 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; the traditional drink of Japan and China is prepared from the young shoots of tea plant Camellia sinensis. Dimethyl sulfoxide (DMSO) is used as a solvent for Triphala and GTP, although they are readily soluble in water. DMSO is a clean, safe, highly polar, aprotic solvent that helps in bringing out the pure properties of all the components of the herb being dissolved. Herbal alternatives showed promising antibacterial efficacy on 3- and 6-week biofilm along with MTAD and 5% sodium hypochlorite. Although Triphala and green tea polyphenols exhibited similar antibacterial sensitivity on E. Faecalis planktonic cells, Triphala showed more potency on E. faecalis biofilm. This may be attributed to its formulation, which contains three different medicinal plants in equal proportions. In such formulations, different compounds may be of help in enhancing the potency of the active compounds resulting in an additive or synergistic positive effect. 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. 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 [31].

Other Irrigating Solutions: It includes sterile water, physiologic saline, hydrogen peroxide, urea peroxide and iodine compounds [32].

Newer Irrigation Devices and Techniques:

Endo Activator: It is a new type of irrigation facilitator. It is based on sonic vibration (up to 10,000 cpm) of a plastic tip in the root canal. The system has 3 different sizes of tips that are easily attached (snap-on) to the handpiece that creates the sonic vibrations. The use of Endo Activator facilitates irrigant penetration and mechanical cleansing compared with needle irrigation, with no increase in the risk of irrigant extrusion through the apex.

EndoVac System: It is based on a negative-pressure approach whereby the irrigant placed in the pulp chamber is sucked down the root canal and back up again through a thin needle with a special design [33].

CONCLUSION

The article reviewed the potential new irrigants that could substitute the traditional endodontic irrigants. Available literature and studies demonstrate advantages and limitations of each irrigant under consideration and none of them satisfy the requirements of the ideal root canal irrigant completely. Presently these newer irrigants could be used as an adjunct to traditional one, with the hunt for the elusive ideal root canal irrigant continues.

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