

How to Cite:

Malhan, S., Bansal, C., & Johar, S. (2021). Root canal irrigants: A review. *International Journal of Health Sciences*, 5(S1), 134–142. <https://doi.org/10.53730/ijhs.v5nS1.5406>

Root canal irrigants: A review

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Abstract---Root canal irrigation is not much emphasised in endodontic therapy. The primary objective of root canal therapy is the retention of the pulpless or pulpally involved tooth with its associated periapical tissues in a healthy state. Achievement of this objective requires that the pulpal spaces and contents be eliminated as sources of infection. As the *Enterococcus faecalis* is also found to be the most important cause for endodontic failures, the action and efficacy of fewer irrigants against *E. faecalis* should also be given prime importance as of others. Therefore, the introduction of an antimicrobial endodontic irrigant during root canal therapy should be given priority in the hierarchy of root canal treatment. The purpose of this article is to analyse root canal irrigants, irrigation techniques and irrigation protocol.

Keywords---disinfection, EDTA, smear layer, sodium hypochlorite, root canal irrigants, enter-ococcus faecalis, endodontic irrigants.

Introduction

Mechanical debridement of the root canal system is done with the use of either hand instruments or rotary nickel-titanium instruments which helps in removal of vital and necrotic remnants of pulp tissue, microorganisms, and microbial toxins. The root canal system has been found to be very complex with anastomoses, cul-de-sacs, and deltas which are difficult if not impossible to clean completely.¹ This region may accumulate necrotic tissues, microorganisms, and their byproducts resulting in persistent periradicular inflammation.¹ Therefore,

International Journal of Health Sciences ISSN 2550-6978 E-ISSN 2550-696X © 2021.

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Manuscript submitted: 18 April 2021, Manuscript revised: 9 June 2021, Accepted for publication: 5 July 2021

root canal irrigation by using various chemical agents is an essential part of debridement as it allows for cleaning more than what might be achieved by root canal instrumentation alone.

Ideal requirements of root canal irrigants ²:

- Broad antimicrobial spectrum.
- High efficacy against anaerobic and facultative microorganisms organized in biofilms.
- Ability to dissolve necrotic pulp tissue remnants.
- Ability to inactivate endotoxin.
- Ability to prevent the formation of a smear layer during instrumentation or to dissolve the latter once it has formed.
- Systemically nontoxic when they come in contact with vital tissues, non-caustic to periodontal tissues, and with little potential to cause an anaphylactic reaction.

Classification ³:

- A) No bactericidal irrigants: Saline, local anesthetics and distilled water.
- B) Bactericidal irrigants:
1. Sodium hypochlorite (0.5%, 1%, 1.5%, 2.5%, 5.25%, and 6% concentrations)
 2. Chlorhexidine (CHX) (2%)
 3. Iodine
 4. Hydrogen peroxide (H₂O₂) (3%).
- C) Chelator solutions:
1. Ethylene diamine tetra acetic acid (EDTA, 17%)
 2. Citric acid (10-50%)
 3. Mixture of tetracycline, acid and detergent (MTAD, Tween 80)
 4. Tetraclean
 5. Maleic acid.
- D) Herbal irrigants:
1. Electronically activated water (EAW)
 2. Bis-dequalinium acetate (BDA)
 3. Photo-activated disinfection (PAD)
 4. Ozone
 5. Laser

Bactericidal irrigants

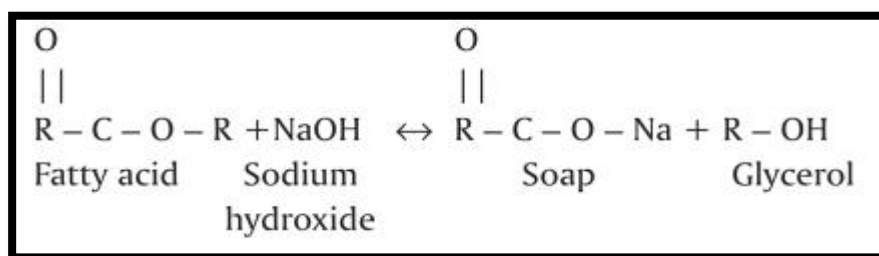
Sodium Hypochlorite (NaOCl)

NaOCl is the most widely used irrigation solution. It is ideal compared with other irrigation solutions because it is the only solution that possesses most required properties. The first chemically produced liquid chlorine solution was potassium hypochlorite, discovered in France by Berthollet (1748-1822). The chemist Labarraque (1777-1850) proposed the use of NaOCl for the prevention of puerperium and other infectious diseases ².

In the body, it is formed in neutrophils through the myeloperoxidase-mediated chlorination of a nitrogenous compound.⁴ Buffered 0.5% sodium hypochlorite was initially used for the irrigation of the infected wounds.⁴ Sodium hypochlorite is sporicidal, virucidal and shows tissue dissolving effect on tissues. Furthermore, sodium hypochlorite solutions have minimum cost and easily available and demonstrated good shelf life. There are other derivatives of chlorine like chloramine-T and sodium dichloroisocyanurate.^{4,5} These, however, are less effective than sodium hypochlorite at similar concentrations.^{4,5}

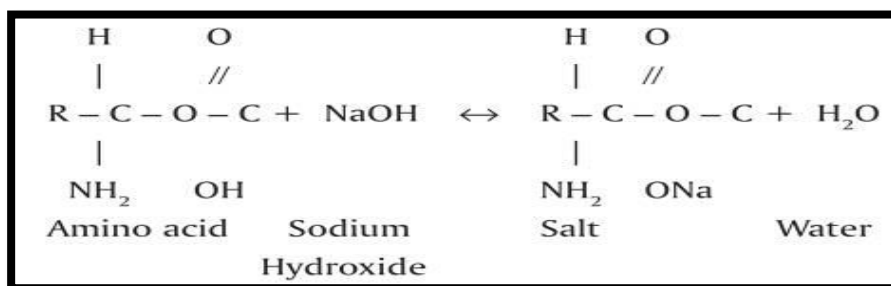
Mechanism of action

NaOCl has two important properties, namely, antimicrobial activity, and organic tissue dissolution. This can be shown by reactions that take place when NaOCl comes in contact with the organic tissues or microorganisms.⁴



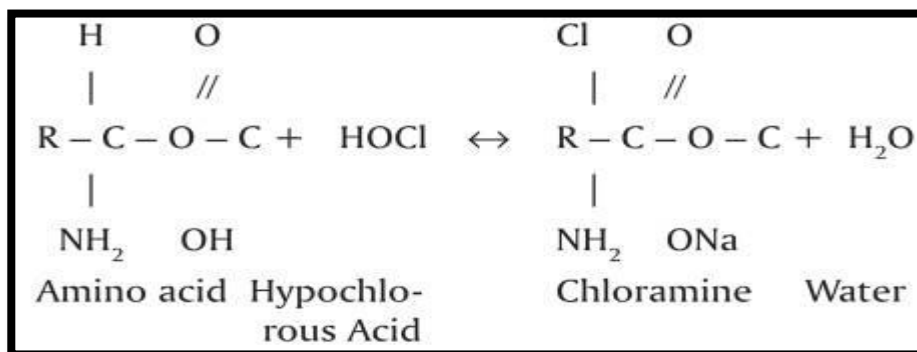
Scheme 1: Saponification reaction

NaOCl has organic tissue dissolving properties which will help in degrading fatty acids and transforming them into fatty acid salts (soap) and glycerol (alcohol) which will help to reduce the surface tension of the remaining solution.⁴



Scheme 2: Amino acid neutralization reaction

NaOCl buffers the amino acids forming water and salt. Formation of hydroxyl ions takes place which leads to the reduction of pH.⁴



Scheme 3: Chloramination reaction

In the next step, hypochlorous acid combines with protein amino groups to form chloramines. This reaction between chlorine and the amino group (NH) leads to the formation of chloramines that interfere with the cell metabolism. Antimicrobial action of chlorine occurs by inhibiting bacterial enzymes and leading to an oxidation of SH groups (sulphydryl groups) of bacterial enzymes.⁴

Methods to increase the efficacy of NaOCl

1. Temperature:

Warming of low concentration NaOCl solution increases the efficacy of tissue dissolution and its antibacterial properties. Recent studies showed that a temperature rise of 25°C increased NaOCl efficacy by 100 times.[8] The temperature and concentration effect suggest that the capacity of 1% of NaOCl at 45°C to dissolve pulp tissue is found to be equal to that of a 5.25% of the solution at 20°C.⁴

2. Ultrasonic agitation:

The ultrasonic agitation with a small file (mostly ISO no. 15) in canals filled with NaOCl lead to the development of ultrasonic energy which warms the solution in the canal. The vibrations cause movement of aqueous NaOCl into the ramifications in the canal, this effect being called as “acoustic streaming.”⁴

3. Use of fresh solution

Freshly prepared NaOCl solutions have better antimicrobial and tissue dissolving effects. Since NaOCl decomposes quickly, it is stored in opaque containers.

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CHX (Chlorhexidine digluconate)

CHX is antimicrobial, and this effect is due to its positive charge, which is attracted to the negatively charged bacterial cell wall and increases the permeability of bacterial contents. It is bacteriostatic at low concentrations and at higher concentrations, it bactericidal and thus is effective against Gram-positive

microbes and due to this reason it can be used in retreatment cases. Various in vivo and invitro studies have shown that it can be used against *C. albicans* and *E. faecalis*. In higher concentrations it causes extensive bacterial cell damage, coagulation of cytoplasm, and precipitation of proteins and nucleic acids. It shows increased antimicrobial activity against various pathogens like *Staphylococcus aureus*, *Porphyromonas endodontalis*, *Prevotellaintermedia*, *E. faecalis*, *C. albicans*, and *Streptococcus mutants*. It can be used either in liquid or gel forms. Its gel formulation makes the instrumentation easier which in turn reduces the smear layer formation better than the liquid formulation. As a result of cationic nature of the CHX molecule, it can be adsorbed by the hydroxyapatite and the teeth. At concentrations $>0.02\%$, a layer of CHX is formed on the tooth surface which may reduce or prevent bacterial colonization. According to Rosenthal et al. substantivity of 2% CHX solution within the root canal is present after 10 min of application.^{12,13}

Iodine

Iodine, used in endodontics in 1979, was found to be an antiseptic against a large number of microbes.¹⁴ Iodine is bactericidal, fungicidal, virucidal, sporicidal, degrades proteins, nucleotides, and fatty acids, leading to bacterial cell death.³ The advantages of iodine over the other irrigants is that 2% of preparations are shown to be less irritating, poisonous, and rapidly reduces the bacterial load.¹⁴ Two percent IKI needs 1-2 h to inhibit the development of *E. faecalis* and *C. albicans*.¹⁴ Iodine has the capability to penetrate all the way through dentinal tubules and destroy bacteria, though the period of its antimicrobial action is less.¹⁵ It has the disadvantage of staining dentin tissue.¹⁴

H₂O₂ (Hydrogen peroxide)

H₂O₂ is available in 3% to 5% of concentrations.¹⁶ It is effective against bacteria, spores, viruses, and yeasts by the formation of free radicals which causes degradation of cell components such as proteins and DNA.¹⁷ The antibacterial action and tissue dissolving capability of H₂O₂ are less than that of NaOCl. Combined action of H₂O₂ and CHX has better antibacterial action.¹⁷

Chelator solutions

Ethylenediaminetetraacetic Acid (EDTA)

Complete cleaning of the root canal system requires the combined use of organic and inorganic tissue-dissolving irrigation solutions. As NaOCl effectively dissolves only organic tissue, other solutions should be used to remove the smear layer and debris from the root canal system. The use of demineralizing agents, such as EDTA and CA, as auxiliary solutions during root canal treatment is recommended. In 1957, Nygaard-Ostby proposed the use of chelating agents to aid in the preparation of narrow and calcified root canals. The first recommended EDTA solution had a concentration of 15% and a pH of 7.3.^{6,7}

EDTA is used most commonly as a 17% neutralized solution. The solution reacts with the calcium ions in the dentin and forms soluble calcium chelates.

Decalcification is a self-limiting process that eventually stops due to the lack of a chelator that will react quickly enough.⁸

Citric Acid

CA is also available on the market and is used at concentrations ranging from 1% to 50%. The use of 10% CA as a final irrigation solution yielded very good results in terms of smear layer removal.¹⁷ CA has shown slightly better performance than EDTA at similar concentrations, although both solutions are highly effective in removing the smear layer from root canal walls.¹⁸

Mixture of tetracycline, acid, and detergent

It is a mixture of an antibiotic (3% doxycycline), a chelating agent (citric acid), and a detergent (Tween 80). Citric acid eliminates the smear layer, allowing the doxycycline to pass into the dentinal tubules and cause an antibacterial effect. The protocol for clinical use of MTAD is 1.3% NaOCl for 20 min followed by 5 min application of MTAD. There may be a risk of development of bacterial resistance, intrinsic staining of dentine, and sensitivity of tooth.¹⁹

Tetraclean

It is similar to MTAD, the difference is due to the addition of doxycycline-50 mg/ml and a detergent (polypropylene glycol). It is effective against both facultative and anaerobic bacteria. And removes the smear layer and opens up the dentinal tubule orifices. It shows low surface tension that allows the better penetration of the solution into the dentinal tubule. Various in-vitro studies have proved that Tetraclean is more efficient than MTAD against *E. Faecalis*.^{19,20}

Maleic Acid

MA is a mild organic acid used to roughen enamel and dentin surfaces in adhesive dentistry. It removes the smear layer effectively at concentrations of 5% and 7%. In addition, when used at concentrations of 10% or higher, it causes demineralization and erosion of the root canal wall. Ballal et al. reported that final irrigation with 7% maleic acid for 1 min was more efficient than 17% EDTA in the removal of smear layer from the apical third of the root canal system.²¹

Herbal Irrigants

Electronically Activated Water

EAW is also recognized as oxidative potential water. It is an electrolyzed saline solution and usually utilized to remove the microbial contamination and biofilm from the dental unit piping and tubing. It is able to disturb biofilms by reducing the adhering capability of bacteria to the canal walls by generating a negative isotonic pressure.²²

Bis-Dequalinium Acetate

BDA, a dequalinium compound and an oxine derivative with the trade name Salvizol has been shown to remove the smear layer throughout the canal, even in the apical third. BDA is well-tolerated by periodontal tissues and has a low surface tension allowing good penetration. It is considered less toxic than NaOCl and can be used as a root canal dressing.²³

Photo-Activated Disinfection

Oscar Raab introduced the photo-activated therapy for the inactivation of microorganisms in the endodontic management.²³ PAD is the placement of a dye (toluidine blue or methylene blue) into the root canals which is then activated by the laser radiation emitted from a low power (100 mW) laser device, causing interference with the microbial cell walls and bacterial death. After normal irrigation, the canals are washed with sterile water, and they are dried by sterilized paper points before the application of the PAD solution into the canals. The photosensitizer molecules will attach to the membrane of the microorganisms and the irradiation with a precise wavelength coordinated to the absorption of the photosensitizer will form singlet oxygen which causes cell wall rupture and death of the microbes. The benefit of PAD is that the dye is only poisonous to bacteria, and there are no side effects to adjacent tissues.^{23,24}

Ozonated Water

Even at a low concentration (0.01 ppm), ozone (O₃) can effectively kill bacteria, including spores. It can be produced easily with an ozone generator. Ozone dissolves easily and rapidly in water.²⁵ In one study, the researchers compared the microbicidal activities of ozonated water and 2.5% NaOCl under sonic activation. They reported that ozonated water did not neutralize *Escherichia coli* or lipopolysaccharides in root canals and that the amount of remaining lipopolysaccharides may have biological effects, such as the induction of apical periodontitis.^{25,26}

Lasers

Neodymium: Yttrium aluminum garnet lasers have been recently introduced for the disinfection in endodontic therapy. However, it was established that when there was direct contact to the laser, all root canal systems were not entirely eliminated of bacteria and lasers were not superior to irrigation with NaOCl.¹⁹

Conclusion

Selection and use of the correct irrigant for the different clinical situations will help to achieve predictable endodontic success. Future studies of irrigants should focus on the production of a single solution that is biocompatible, has tissue-solubilizing properties, removes the smear layer, and has antibacterial effects.

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