

A Review - Irrigation in Endodontics

Mukta Bansal, Asheesh Sawhny, Richa Singh, Pankaj Kumar Priyadarshi,

Saurav Paul, Saurabh Sharma,

Rama Dental College Hospital & Research Centre, Rama University, Mandhana, Kanpur,
Uttar Pradesh- India 209217

ABSTRACT: The goal of endodontic therapy is the removal of all vital or necrotic tissue, microorganisms, and microbial by-products from the root canal system. This may be achieved through chemomechanical debridement of root canal. In this review article, the specifics of the pulpal microenvironment and the resulting requirements for irrigating solutions are spelled out. Sodium hypochlorite solutions are recommended as the main irrigants. This is because of their broad antimicrobial spectrum as well as their unique capacity to dissolve necrotic tissue remnants. Chemical and toxicological concerns related to their use are discussed, including different approaches to enhance local efficacy without increasing the caustic potential. In addition, chelating solutions are recommended as adjunct irrigants to prevent the formation of a smear layer and/or remove it before filling the root canal system. Along with traditional irrigants, newer irrigants are also studied for potential replacement of sodium hypochloride. This article reviews the potential irrigants with their advantages and limitations with their future in endodontic irrigation. Based on the actions and interactions of currently available solutions, a clinical irrigating regimen is proposed. Furthermore, some technical aspects of irrigating the root canal system are discussed, and recent trends are critically inspected.

Keywords: Root canal irrigants; Sodium hypochlorite; Chelators; Chlorhexidine; Interactions; E.Faecali

INTRODUCTION: The goal of endodontic therapy is the removal of all vital or necrotic tissue, microorganisms, and microbial by-products from the root canal system. This may be achieved through chemomechanical debridement of root canal. The root canal system is highly complex and variable and has limited our ability to clean and disinfect it predictably. Shaping of root canals is performed almost entirely by using hand and rotary instrumentation techniques¹. Peters et al.² using micro computed tomography scans before and after mechanical instrumentation found that, regardless of the instrumentation technique, 35% or more of the root canal surfaces (including canal fins, isthmi and cul-de-sacs)remained uninstrumented. Therefore, irrigation is an essential part of root canal debridement because it allows for cleaning beyond what might be achieved by root canal instrumentation alone. In addition to disinfection, irrigants can also help remove the smear layer from the radicular wall. We used the keywords 'root canal irrigants' and 'endodontic irrigants' and mainly the META analysis and systemic review were included

Characteristics of an ideal endodontics irrigant³.

1. Effective germicide and fungicide.
2. Non-irritating to the periapical tissues.
3. Stable in solution.

4. Prolonged antimicrobial effect and a sustained antibacterial effect after use.
5. Active in the presence of blood, serum, and protein derivatives of tissue.
6. Able to completely remove the smear layer.
7. Low surface tension.
8. Able to disinfect the dentin/dentinal tubules.
9. Does not interfere with repair of periapical tissues.
10. Does not stain tooth structures.
11. Inactivation in a culture medium.
12. Does not induce a cell-mediated immune response. Is non antigenic, non-toxic, and non-carcinogenic to tissue cells surrounding the tooth.
13. Has no adverse effects on the physical properties of exposed dentin.
14. Has no adverse effect on the sealing ability of filling materials.
15. Easy to use/apply.
16. Inexpensive.

Classification of the commonly used irrigating solutions

- A) Instrumentation auxiliary substances (used during instrumentation, do not need the optimal physical properties, only the chemical one)-
- NaOCl (Sodium Hypochlorite)
 - CHX (Chlorhexidine)
 - EDTA (Ethylene Diamine Tetra Acetic Acid)
 - Qmix

B) Irrigating substances (Used during irrigation aspiration procedure, have optimal physical properties, such as lower surface tension and lower viscosity).

- NaOCl,
- Saline,
- Distilled Water
- MTAD (Mixture of Tetracycline, Acid and Detergent)
- Tetraclean
- Qmix
- Herbal Alternatives – Green Tea, Triphala.

However, there is currently no unique irrigant that meets all of the requirements for an optimal irrigating solution⁴⁻¹⁶. Using a combination of products in the correct irrigation sequence and technique contributes to a successful treatment outcome. This article summarizes the chemistry, biology, and procedures for safe and efficient irrigation and provides cutting-edge information on the most recent developments.

NaOCl

Of all the currently used substances, sodium hypochlorite appears to be the most ideal, as it covers more of the requirements for endodontic irrigant than any other known compound.

Natural Occurrence

Chlorine is one of the most widely distributed elements on earth. It is not found in a free state in nature, but exists in combination with sodium, potassium, calcium, and magnesium.

History

Potassium hypochlorite was the first chemically produced aqueous chlorine solution, invented in France by Berthollet (1748-1822). Starting in the late 18th century, this solution was industrially produced by Percy in Javel near Paris, hence the name "Eau de Javel". First, hypochlorite solutions were used as bleaching agents. Subsequently, sodium hypochlorite was recommended by Labarraque to prevent childbed fever and other infectious diseases. Based on the controlled laboratory studies by Koch and Pasteur, hypochlorite then gained wide acceptance as a disinfectant by the end of the 19th century. In World War I, the chemist Henry Drysdale Dakin and the surgeon Alexis Carrel extended the use of a buffered 0.5% sodium hypochlorite solution to the irrigation of infected wounds, based on Dakin's meticulous studies on the efficacy of different solutions on infected necrotic tissue⁵⁻¹⁷. Beside their wide-spectrum, nonspecific killing efficacy on all microbes, hypochlorite preparations are sporicidal, 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. Furthermore, sodium hypochlorite solutions are cheap, easily available, and demonstrate good shelf life. Other chlorine releasing compounds have been advocated in endodontics, such as chloramine-T and sodium dichloroisocyanurate. These, however, have never gained wide acceptance in endodontics, and appear to be less effective than hypochlorite at comparable concentration⁵.

Antimicrobial property –

Concentration and time 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. NaOCl was moderately effective against bacteria but less effective against endotoxins in root canal infection²¹. There has been much controversy over the concentration of hypochlorite solutions to be used in endodontics. The presence of organic matter (inflammatory exudate, tissue remnants, microbial biomass) weakens its effect. NaOCl in higher concentrations has a better tissue-dissolving ability, but even in lower concentrations when used in high volumes it can be equally effective²²⁻²³. Higher concentrations of NaOCl are more toxic than lower concentrations²⁴; however, due to the confined anatomy of the root canal system, higher concentrations have successfully been used during root. It must be realized that continuous irrigation to all areas of the root canal for optimum time is important factor (rather than concentration) for the effectiveness of hypochlorite. Based on the currently available evidence, there is no rationale for using hypochlorite solutions at concentrations over 1% wt/vol.

Tissue dissolution capacity

Hypochlorite has the unique capacity to dissolve necrotic tissue²⁵⁻²⁷. It depends on its concentration, temperature & time of application.

Biofilm

If thick layers of biofilm grow on pre-dentin, they may interfere with the effectiveness of NaOCl irrigation in these areas.

Effect on dentin

When NaOCl is used as the first irrigant, the hydroxyapatite coating on collagen seems to protect the collagen fibers and the effect of the NaOCl on dentin is limited. However, when decalcifying solution is used, the hydroxyapatite is quickly dissolved exposing the underlying collagen fibers. If NaOCl is used again at this stage, it can directly attack the protein (collagen) and in a relatively short time cause considerable destruction of the collagen of surface dentin which impairs flexural and elastic strength of dentin²⁸. Recently, it has been shown by in vitro studies that long-term exposure of dentin to a high concentration sodium hypochlorite can have a detrimental effect on dentin elasticity and flexural strength. This short-term irrigation with hypochlorite after EDTA or CA at the end of chemomechanical preparation causes strong erosion of the canal-wall surface dentin⁶.

Increasing the efficacy of NaOCl

Possible ways to improve the efficacy of sodium hypochlorite preparations in tissue dissolution are the temperature of the solutions, ultrasonic activation, and prolonged working time⁵.

Temperature

One alternative approach to improve the effectiveness of hypochlorite irrigants in the root canal system could be to increase the temperature of low-concentration NaOCl solutions. This improves their immediate tissue-dissolution capacity. The capacity of a 1% NaOCl at 45°C to dissolve human dental pulps was found to be equal to that of a 5.25% solution at 20°C [29]. The systemic toxicity of preheated NaOCl irrigants is lower than the one of more concentrated nonheated counterparts.

Mechanical agitation

The impact of mechanical agitation of the NaOCl solutions on tissue dissolution was found to be very important by Moorer & Wesselink who emphasized the great impact of violent fluid flow and shearing forces caused by ultrasound on the ability of NaOCl to dissolve tissue²².

Surface tension

Some investigators have proposed adding a biocompatible surfactant (e.g. polysorbate) to sodium hypochlorite, so as to lower its surface tension and improve its penetrative ability in canal but this concept was no more accepted³⁰.

Ultrasonic

The use of ultrasonic agitation increased the effectiveness of 5% NaOCl in the apical third of the canal wall³¹ as this would “accelerate chemical reactions, create cavitation effects, and achieve a superior cleansing action”³². If ultrasonic activation of the hypochlorite irrigant is to be used, it appears important to apply the ultrasonic instrument after the canal preparation has been completed. A freely oscillating instrument will cause more ultrasound effects in the irrigating solution than a counterpart that binds to canal walls (122)³³. Passive ultrasonic irrigation with a nickel-titanium tip produced superior tissue-dissolving effects as compared to sonic irrigant activation³⁴.

Effect on resin bonding

The reduction of the bond strength seen between adhesive systems and dentin walls may be because of the removal of collagen fibrils from the dentin surface by NaOCl, impeding the formation of a consistent hybrid layer³⁵. It requires a reversal agent (ascorbic acid or sodium ascorbate) because of its ability to affect the polymerization of the resin sealer³⁶⁻³⁷.

Interaction of NaOCl and chlorhexidine

The reaction between NaOCl and CHX produces a carcinogenic product, parachloroaniline (PCA), the potential leakage of which into the surrounding tissues is a concern. The presence of PCA was confirmed by the Beilstein test for the presence of chlorine and the HCl solubility test for the presence of aniline. This reaction coats the canal surface and significantly occludes the dentinal tubules and affects the seal of the root canal³⁸. A study conducted by Mortenson D et al in 2012 on the effect of using an alternative irrigant between sodium hypochlorite and chlorhexidine to prevent the formation of para-chloroaniline within the root canal system concluded that citric acid used as the intermittent irrigant had the least amount of PCA formation in the canal system as compared to sterile saline and EDTA³⁹.

Interaction of NaOCl & EDTA

Grawehr concluded that EDTA retained its calcium complexing ability when mixed with NaOCl, but however it instantaneously reduces the amount of chlorine of NaOCl & ultimately NaOCl loses its tissue-dissolving capacity⁴⁰. Short-term irrigation with hypochlorite after EDTA or CA at the end of chemomechanical preparation causes strong erosion of the canal-wall surface dentin⁶.

Interaction with H₂O₂ Many clinicians mix NaOCl with hydrogen peroxide for root canal irrigation. Despite more vigorous bubbling, the effectiveness of the mixture has not been shown to be better than that of NaOCl alone⁴¹.

As a final rinse

As a final sodium hypochlorite rinse after EDTA increase erosion of dentin, it is not recommended.

Safety

Several mishaps during root canal irrigation range from damage to the patient's clothing, splashing the irrigant into the patient's or operator's eye, injection through the apical foramen, and allergic reactions to the irrigant, to inadvertent use of an irrigant as an anesthetic solution were described⁴². Furthermore, sodium hypochlorite solutions are cheap easily available, demonstrate good life⁴³.

EDTA

Complete cleaning of the root-canal system requires the use of irrigants that dissolve organic and inorganic material. As hypochlorite is active only against the former, other substances must be used to complete the removal of the smear layer and dentin debris. In addition, calcifications hindering mechanical preparation are frequently encountered in the canal system. Demineralizing agents such as ethylenediamine tetraacetic acid (EDTA)⁴⁴ and citric acid⁴⁵ have therefore been recommended as adjuvants in root canal therapy. Chelating agents were introduced into endodontics as an aid in preparation of narrow and decalcified canals by Nygaard –Ostby in 1957 who recommended the use of 15% EDTA at pH 7.3. Mechanism of action EDTA reacts with the calcium ions in dentine and forms soluble calcium chelates. It has been reported that EDTA decalcified dentin to a depth of 20–30 µm in 5 min⁴⁶. The decalcifying process is self-limiting, because the chelator is used up.

Smear layer

A continuous rinse with 5 ml of 17% EDTA, as a final rinse for 3 min efficiently removes the smear layer from root canal walls⁴⁷. EDTA is most commonly used as a 17% neutralized solution (disodium EDTA, pH 7), but a few reports have indicated that solutions with lower concentrations (eg, 10%, 5%, and even 1%) remove the smear layer equally well after NaOCl irrigation.

Biofilm

In addition to their cleaning ability, chelators may detach biofilms adhering to root canal walls.

Dentinal property

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 erosion⁴⁸. Increasing contact time and concentration of EDTA from 10% to 17% as well as a pH of 7.5 versus pH 9.0 has been shown to increase dentin demineralization. A 1-min application of 17% EDTA combined with ultrasonics is efficient for smear layer and debris removal in the apical region of the root canal⁴⁹.

Form

Although there are no comparative studies about the effectiveness of liquid and gel products to demineralize dentin, it is possible that the small volume of the root canal (only a few microliters) contributes to a rapid saturation of the chemical and thereby loss of effectiveness. In such situations, the use of liquid products and continuous irrigation should be recommended⁵⁻⁵⁰

Interaction with CHX

CHX is not degraded by EDTA under normal conditions. The precipitate is most likely a salt formed by electrostatic neutralization of cationic CHX by anionic EDTA. The suspected net ionic equation is: $2\text{HEDTA}^{3-}(\text{aq}) + 3\text{H}_2\text{CHX}^{2+}(\text{aq}) \leftrightarrow (\text{HEDTA})_2(\text{H}_2\text{CHX})_3(\text{S})$. The clinical significance of this precipitate is largely unknown⁵¹. It seems that the ability of EDTA to remove the smear layer is reduced.

Citric acid (CA)

CA is also marketed and used in various concentrations, ranging from 1% to 50%.

Smear layer

The use of 10% citric acid as final irrigation has shown good results in smear layer removal⁵². Although citric acid appears to be slightly more potent at similar concentration than EDTA, both agents show high efficiency in removing the smear layer⁵³.

Cytotoxicity

In vitro studies have shown their cytotoxicity, and 10% citric acid has proven to be more biocompatible than 17% EDTA⁵⁴⁻⁵⁵.

Antimicrobial action

The use of 25% citric acid was found to be ineffective in eradication of biofilms of *E. faecalis* after 1, 5, and 10 min of exposure⁵⁶.

HEBP

Hydroxyethylidene bisphosphonate (HEBP) (1-hydroxyethylidene-1,1-bisphosphonate), also known as etidronic acid or etidronate, is a decalcifying agent that shows only little short term interference with sodium hypochlorite. It has recently been suggested as a possible alternative to citric acid or EDTA⁵³⁻⁵⁷. HEBP prevents bone resorption and is used systemically in patients suffering from osteoporosis or Paget's disease⁵⁸. However, whether this agent will improve or abbreviate endodontic irrigation will have to be shown in future studies. The demineralization kinetics promoted by both 9% HEBP and 18% HEBP were significantly slower than those of 17% EDTA⁵⁹. De-Deus et al. reported that the soft chelating irrigation protocol (18% HEBP) optimized the bonding quality (3.1–6.1 MPa) of Resilon/Epiphany^{®60}.

Chlorhexidine

Chlorhexidine is a potent antiseptic, which is widely used for chemical plaque control in the oral cavity⁶¹. 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 literature³⁶.

Structure and mechanism of action

CHX is a synthetic cationic bis-guanide that consists of two symmetric 4-chlorophenyl rings and two biguanide groups connected by central hexamethylene chains. CHX is a positively charged hydrophobic and lipophilic molecule that interacts with the negatively charged phosphate groups on microbial cell walls⁶²⁻⁶³, which alters the cells' osmotic equilibrium. As a consequence, the cytoplasm becomes congealed, with resultant reduction in leakage. CHX antimicrobial activity is pH dependant, with the optimal range being 5.5–0.7⁶⁴. CHX at low concentration will result in bacteriostatic effect but at higher concentrations, it is bactericidal due to extensive cell damage, coagulation of cytoplasm, and precipitation of proteins and nucleic acids⁶⁵.

Form

CHX is marketed as a water-based solution and as a gel (with Natrosol). Some studies have indicated that the 2% CHX gel has a slightly better performance than the 2 % CHX liquid.⁶⁶This has been found to be more effective in the least time.

Antimicrobial activity

CHX is active against Gram-positive and Gram-negative bacteria, bacterial spores, lipophilic virus, yeast, and dermatophytes⁶⁷. The antimicrobial action is related to type, concentration, and presentation form of the irrigants as well as the microbial susceptibility. In vivo, it inhibits experimentally induced inflammatory external root resorption when applied for four weeks⁶⁸

Final rinse

2% CHX may be a good choice for maximized antibacterial effect at the end of the chemomechanical preparation. Substantivity⁶⁹ 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. Antimicrobial substantivity depends on the number of CHX molecules available to interact with the dentine⁷⁰. White et al. evaluated the antimicrobial substantivity of a 2% CHX solution as an endodontic irrigant and reported that the substantivity lasted 72 h to upto 12 weeks⁷¹⁻⁷²

Tissue dissolution capacity

Chlorhexidine gluconate has been recommended as a root canal irrigant because of its broad spectrum antimicrobial action, substantivity and low toxicity. However, CHX's incapacity of tissue dissolution has been pointed out as its major disadvantage. Some attempts have been made to evaluate the activity of CHX to dissolve organic matter, demonstrating that both preparations of this substance, aqueous solution or gel, were not able to dissolve pulp tissues⁷³.

CHX and dentin bonding (Anticollagenolytic Activity)

CHX known to have a broad-spectrum MMP inhibitory effect⁷⁴ & so significantly improved the integrity of the hybrid layer in a 6-month clinical trial. Adsorption of CHX by dentin improves the resin infiltration in dentinal tubules and thereby increasing bond

Cytotoxicity of CHX

The toxic potency of CHX is dependent on the length of exposure and the composition of the exposure medium⁷⁵. While Chlorhexidine does not appear to cause any long-term damage to host tissues, it may still cause an inflammatory response in these tissues if expressed beyond root canal.

Temperature

As with sodium hypochlorite (see below), heating a chlorhexidine irrigant of lesser concentration could increase its local efficacy in the root canal system while keeping the systemic toxicity low⁷⁶.

Disinfection of obturation cones

Comparing the two solutions, CHX was a better disinfectant compared with NaOCl, that is, presented high values of surface free energy. Cones disinfected with CHX presented smaller contact angles than NaOCl, favoring the interaction between the solid surface (cone) and the liquid, in this case, the sealer.

Versions

The antibacterial activity of a chlorhexidine product with surface active agents (CHX-Plus have shown superior killing of planktonic and biofilm bacteria by the combination product⁷⁷⁻⁷⁸. There are no studies about whether adding surface-active agent increases the risk of the irrigants escaping to the periapical area in clinical use.

Q MIX

Q mix is an irrigation solution used as a final rinse. It is a combination of CHX with EDTA and a surfactant solution to improve penetration in dentinal tubules. It is in the market for very short time, so, there is no research available yet.

MTAD

It was introduced as an alternative to EDTA to remove the smear layer by Torabinejad et al. It is a mixture of 3% doxycycline, 4.25% citric acid and detergent-Tween 80. It has a combined chelating and antibacterial properties⁷⁹. They do not dissolve organic tissue and are intended for use at the end of chemomechanical preparation after sodium hypochlorite.

Antibacterial activity and smear layer removal

MTAD is composed of three constituents that are expected to act synergistically against bacteria⁷⁹. The bactericidal effect of MTAD was inferior to 1%–6% NaOCl against *E faecalis* biofilm⁸⁰. The antibacterial activity of MTAD might also be inhibited by the buffering effect of dentin and the serum albumin present in the root canal⁸¹. In the MTAD preparation, the citric acid may serve to remove the smear layer, allowing doxycycline to enter the dentinal tubules and exert an antibacterial effect⁸².

Final rinse

The recently revised protocol for clinical use of MTAD advises an initial irrigation for 20 min with 1.3% NaOCl, followed by a 5-min final rinse with MTAD.

Bond strength

The use of MTAD as a final rinse with gutta-percha/AH Plus® resulted in a significant reduction in bond strength (1.76 ± 1.67 Mpa) when compared with EDTA⁸³ to the precipitate formation⁸⁴. As for MTAD, resistance to tetracycline is not uncommon in bacteria isolated from root canal⁸⁵. Generally speaking, the use of antibiotics instead of biocides such as hypochlorite or chlorhexidine appears unwarranted, as the former were developed for systemic use rather than wound debridement.⁸⁶

Tetraclean

Tetraclean (Ogna Laboratori Farmaceutici, Muggiò (Mi), Italy), like MTAD, is mixture of an Citric Acid, doxycycline, 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. Tetraclean is a mixture of doxycycline hyclate (at a lower concentration than in MTAD), an acid, and a detergent¹⁵⁻⁷⁹. They do not dissolve organic tissue and are intended for use at the end of chemomechanical preparation after sodium hypochlorite.

Antimicrobial action

It shows a high action against both, strictly anaerobic and facultative anaerobic bacteria [87]. It is also more effective than MTAD against *E. faecalis* in planktonic culture and in mixed species in vitro biofilm. Comparative studies on MTAD and Tetraclean have indicated better antibacterial effects by the latter.

Smear layer

It is able to eliminate microorganisms and smear layer in dentinal tubules of infected root canals with a final 5-min rinse.

Surface tension

It has low surface tension which enables a better adaptation of the mixtures to the dentinal walls.

Maleic Acid

Maleic acid is a mild organic acid used as an acid conditioner in adhesive dentistry⁹¹. It efficiently removes the smear layer at 5% and 7% concentration. However, at 10% or more concentration it can result in demineralization and damage to root canal wall.³⁴ 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. Also 7% Maleic acid produces maximum surface roughness on root canal walls as compared to 17% EDTA. This surface roughness produces an important role in micromechanical bonding of resin sealers. However, the technique of use and biologic effects of Maleic acid on periapical tissues needs evaluation, before it is routinely employed for clinical use.

Chlorine Dioxide

Chlorine dioxide (ClO₂) is chemically similar to chlorine or hypochlorite, the familiar household bleach. An In vitro study compared organic tissue dissolution capacity of NaOCl and ClO₂. It was concluded that ClO₂ and NaOCl are equally efficient for dissolving organic tissue⁹². ClO₂ produces little or no trihalomethane⁹³. A study showed that trihalomethane is an animal carcinogen and a suspected human carcinogen⁹⁴. ClO₂ might therefore be a better dental irrigant than NaOCl⁹⁵.

Silver Diamine Fluoride

A 3.8% w/v silver diamine fluoride (Ag [NH₃]₂ F) solution has been developed for intracanal irrigation. This represents a 1:10 dilution of the original 38% Ag [NH₃]₂ F solution used for root canal infection⁹⁶. The study on the antibacterial effect of 3.8% Ag [NH₃]₂ F against a *E. faecalis* biofilm model concluded that Ag[NH₃]₂ F for 60 min has potential for use as an antimicrobial root canal irrigant or inter appointment medicament to reduce bacterial loads⁹⁷. The silver deposits were found to occlude tubular orifices after removal of the smear layer

Triclosan and Gantrez Triclosan is a broad spectrum antimicrobial agent, active against gram-positive and gram-negative bacteria as well as some fungi and viruses⁹⁸⁻⁹⁹. Nudera et al. 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*¹⁰⁰. The MBC of triclosan ranged from 12–94 µg/ml.

Herbal

Triphala

Triphala consists of dried and powdered fruits of three medicinal plants *Terminalia bellerica*, *Terminalia chebula*, and *Emblica officinalis*¹⁰¹. Triphala achieved 100% killing of *E faecalis* at 6 min. This may be attributed to its formulation, which contains three different medicinal plants in equal proportions; in such formulations, different compounds may help enhance the potency of the active compounds, producing an additive or synergistic effect¹⁰². Triphala contains fruits that are rich in citric acid, which may aid in removal of the smear layer. The major advantages of using herbal alternatives are easy availability, cost-effectiveness longer shelf life, low toxicity, and lack of microbial resistance

Green tea

Green tea polyphenols, the traditional drink of Japan and China is prepared from the young shoots of the tea plant *Camellia sinensis*. Green tea polyphenols showed statistically significant antibacterial activity against *E faecalis* biofilm formed on tooth substrate. It takes 6 min to achieve 100% killing of *E faecali*.

Suggested irrigation regimen

A hypochlorite solution should be employed throughout instrumentation, without altering it with EDTA or citric acid. Between instruments, canals should be irrigated using copious amounts of the hypochlorite solution. Once the shaping procedure is completed, canals can be thoroughly rinsed using aqueous EDTA or citric acid. Generally each canal is rinsed for at least 1 min using 5 to 10ml of the chelator irrigant. After the smear layer removal procedure, a final rinse with an antiseptic solution appears beneficial. Chlorhexidine appears to be the most promising agent for use as a final irrigant in this situation. It has an affinity for dental hard tissues and, once bound to a surface, it has prolonged antimicrobial activity, a phenomenon called substantivity. After the introduction of MTAD irrigant, newer irrigating regimen followed was initial rinse with 1.3% NaOCl for 20 min and followed by final rinse with MTAD for 5 min. Future research on irrigants needs to focus on finding a single irrigant that has tissue dissolving capacity, smear layer removal property, and antibacterial efficacy.

References

1. Paque F, Ganahl D, Peters OA. Effects of root canal preparation on apical geometry assessed by micro-computed tomography. *J Endod* 2009; 35: 1056–1059.
2. Peters OA, Scheonenberger K, Laib A. Effects of four Ni–Ti preparation techniques on root canal geometry assessed by micro computed tomography. *IntEndod J* 2001; 34:221–230.
3. Basrani B, Haapasalo M. Update on endodontic irrigating solutions *Endodontic topics* 2012; 27:74–102.
4. Kandaswamy D, Venkateshbabu N. Root canal irrigants. *J Conserv Dent* 2010; 13: 256–264.
5. Zehnder M. Root canal irrigants. *J Endod* 2006; 32: 389–398.

6. Haapasalo M, Shen Y, Qian W, Gao Y. Irrigation in endodontics. *Dent Clin North Am* 2010; 54: 291–312.
7. Bloomfield SF, Miles G. The relationship between residual chlorine and disinfection capacity of sodium hypochlorite and sodium dichloroisocyanurate solutions in the presence of *Escherichia coli* and milk. *MicrobiosLett* 1979; 10: 33–43.
8. Cotter JL, Fader RC, Lilley C, Herndon DN. Chemical parameters, antimicrobial activities, and tissue toxicity of 0.1 and 0.5% sodium hypochlorite solutions. *Antimicrob Agents Chemother* 1985; 28: 118–122.
9. Christensen CE, McNeal SF, Eleazer P. Effect of lowering the pH of sodium hypochlorite on dissolving tissue in vitro. *J Endod* 2008; 34: 449–452.
10. Cunningham WT, Balekjian AY. Effect of temperature on collagen-dissolving ability of sodium hypochlorite endodontic irrigant. *Oral Surg Oral Med Oral Pathol* 1980; 49: 175–177.
11. Cunningham WT, Joseph SW. Effect of temperature on the bactericidal action of sodium hypochlorite endodontic irrigant. *Oral Surg Oral Med Oral Pathol* 1980; 50: 569–571.
12. Abou-Rass M, Oglesby SW. The effects of temperature, concentration, and tissue type on the solvent ability of sodium hypochlorite. *J Endod* 1981; 7:
13. Kamburis JJ, Barker TH, Barfield RD, Eleazer PD. Removal of organic debris from bovine dentin shavings. *J Endod* 2003; 29: 559–561.
14. Sirtes G, Waltimo T, Schaetzle M, Zehnder M. The effects of temperature on sodium hypochlorite short-term stability, pulp dissolution capacity, and antimicrobial efficacy. *J Endod* 2005; 31: 669– 671.
15. Giardino L, Ambu E, Becce C, Rimondini L, Morra M. Surface tension comparison of four common root canal irrigants and two new irrigants containing antibiotic. *J Endod* 2006; 32: 1091–1093.
16. Lui JN, Kuah HG, Chen NN. Effect of EDTA with and without surfactants or ultrasonics on removal of smear layer. *J Endod* 2007; 33: 472–475.
17. Dakin HD. On the use of certain antiseptic substances in treatment of infected wounds. *Br Med J* 1915;2:318 –320.
18. Pecora JD, Sousa-Neto MD, Estrela C. Soluçõesirrigadorasauxiliares dopreparo do canal radicular. In: Estrela C, Figueiredo JA. editors. *Endodontia - Princípiosbiológicos e mecânicos*. São Paulo: ArtesMédicas 1999; p. 552-569.
19. Spanó JC, Barbin EL, Santos TC, Guimarães LF, Pécora JD. Solvent action of sodium hypochlorite on bovine pulp and physico-chemical properties of resulting liquid. *Braz Dent J* 2001;12:154-157.
20. Esterla C, Cyntia RA. Esterla, Barbin EL. Mechanism of action of sodium hypochlorite. *Braz Dent J* 2002;13:113-117.
21. Martinho FC, Gomes BP. Quantification of endotoxins and cultivable bacteria in root canal infection before and after chemomechanical preparation with 2.5% sodium hypochlorite. *J Endod* 2008;34:268-272.
22. Moorer W, Wesselink P. Factors promoting the tissue dissolving capability of sodium hypochlorite. *IntEndod J* 1982; 15: 187–196.

23. Siqueira JF Jr, Rôças IN, Favieri A, Lima KC. Chemomechanical reduction of the bacterial population in the root canal after instrumentation and irrigation with 1%, 2.5%, and 5.25% sodium hypochlorite. *J Endod* 2000; 26: 331–334.
24. Spångberg L, Engström B, Langeland K. Biologic effects of dental materials. 3. Toxicity and antimicrobial effect of endodontic antiseptics in vitro. *Oral Surg Oral Med Oral Pathol* 1973; 36: 856–864.
25. Blum H. Hypochlorit und seine Anwendung in der zahnärztlichen Praxis. *DtschZahnärztlWschr* 1921;24:21–
26. Grossman LI, Meiman BW. Solution of pulp tissue by chemical agents. *J Am Dent Assoc* 1941;28:223–225.
27. Naenni N, Thoma K, Zehnder M. Soft tissue dissolution capacity of currently used and potential endodontic irrigants. *J Endod* 2004;30:785–787.
28. Grigoratos D, Knowles J, Ng YL, Gulabivala K. Effect of exposing dentine to sodium hypochlorite and calcium hydroxide on its flexural strength and elastic modulus. *IntEndod J* 2001;34:113–119.
29. Sirtes G, Waltimo T, Schaetzle M, Zehnder M. The effects of temperature on sodium hypochlorite short-term stability, pulp dissolution capacity, and antimicrobial efficacy. *J Endod* 2005;31:669-671.
30. Childer H, Yee FS. Canal debridement and disinfection. In: Cohen S, Burns RC, eds. *Pathways of the Pulp*. 3 edn. St. Louis: The C.V. Mosby Company 1984; 175.
31. Paragliola R, Franco V, Fabiani C. Final Rinse Optimization: Influence of Different Agitation Protocols. *J Endod* 2010;36:282-285.
32. Martin H. Ultrasonic disinfection of the root canal. *Oral Surg Oral Med Oral Pathol* 1976;42:92–99.
33. Roy RA, Ahmad M, Crum LA. Physical mechanisms governing the hydrodynamic response of an oscillating ultrasonic file. *IntEndod J* 1994;27:197–207.
34. Jadaa AA, Paqué F, Attin T. Acoustic hypochlorite activation in simulated curved canals. *J Endod* 2009;35:1408-1411.
35. Nikaido T, Takano Y, Sasafuchi Y, Burrow MF, Tagami J. Bond strengths to endodontically-treated teeth. *Am J Dent* 1999;12:177-180.
36. Morris MD, Lee KW, Agee KA, Bouillaguet S, Pashley DH. Effect of sodium hypochlorite and RC prep on bond strengths of resin cement on endodontic surfaces. *J Endod* 2001;27:753-757.
37. Ari H, Yasar E, Belli S. Effects of NaOCl on bond strengths of resin cements to root canal dentin. *J Endod* 2003;29:248-251.
38. Bui TB, Baumgartner CJ, Mitchell CJ. Evaluation of the interaction between sodium hypochlorite and chlorhexidine gluconate and its effect on root dentin. *J Endod* 2008;34:181-185.
39. Mortenson D. The effect of using an alternative irrigant between sodium hypochlorite and chlorhexidine to prevent the formation of para-chloroaniline within the root canal system. *IntEndod J* 2012; 45: 878-82.
40. Grawehr M, Sener B, Waltimo T, Zehnder M. Interactions Of EthylenediamineTetracetic Acid With Sodium Hypochlorite In Aqueous Solutions. *IntEndod J* 2003;36:411-417.
41. Heling I, Chandler NP. Antimicrobial effect of irrigant combinations within dentinal tubules. *IntEndod J* 1998;31:8–14.

42. Hülsmann M, Rödiger T, Nordmeyer S. Complications during Root Canal Irrigation. *Endod Topics* 2007;16:27. 43. Fraiss S, Ng YL, Gulabivala K. Some factors affecting the concentration of available chlorine in commercial sources of sodium hypochlorite. *IntEndod J* 2001;34:206-215.
44. NygaardÖstby B. Chelation in root canal therapy. *OdontolTidskr* 1957;65:3-11.
45. Loel DA. Use of acid cleanser in endodontic therapy. *J Am Dent Assoc* 1975;90:148-151.
46. Von Der Fehr FR, NygaardÖstby B. Effect of EDTAC and sulfuric acid on root canal dentine. *Oral Surg Oral Med Oral Pathol* 1963;16:199-205.
47. Mello I, Kammerer BA, Yoshimoto D. Influence of Final Rinse Technique on Ability of Ethylenediaminetetraacetic acid of removing smear layer. *J Endod* 2010;36:512-514.
48. Calt S, Serper A. Time-dependent effects of EDTA on dentin structures. *J Endod* 2002;28:17-19.
49. Kuah HG, Lui JN, Tseng PS, Chen NN. The Effect of EDTA with and without Ultrasonics on Removal of the Smear Layer. *J Endod* 2009;35:393-396.
50. Hülsmann M, Heckendorff M, Lennon A. Chelating agents in root canal treatment: mode of action and indications for their use. *IntEndod J* 2003;36:810-830.
51. Rasimick BJ, Nekich M, Hladek MM, Musikant BL, Deutsch AS. Interaction between chlorhexidine digluconate and EDTA. *J Endod* 2008;34:1521-1523.
52. Smith J, Wayman B. An evaluation of the antimicrobial effect of citric acid as root canal irrigants. *J Endod* 1986;12:54-58.
53. Zehnder M, Schmidlin P, Sener B, Waltimo T. Chelation in root canal therapy reconsidered. *J Endod* 2005;31:817-820.
54. Scaiza MF, Daniel RL, Santos EM, Jaeger MM. Cytotoxic effects of 10% citric acid and EDTA-T used as root canal irrigants: An In vitro Analysis. *J Endod* 2001;7:741-743.
55. Malheiros CF, Marques MM, Gavini G. In vitro evaluation of the cytotoxic effects of acid solutions used as canal irrigants. *J Endod* 2005;31:746-748.
56. Moliz MT, Luque CM, García ME, Baca P. Enterococcus faecalis Biofilms eradication by root canal irrigants. *J Endod* 2009;35:711-714.
57. Zehnder M, Schicht O, Sener B, Schmidlin P. Reducing surface tension in endodontic chelator solutions has no effect on their ability to remove calcium from instrumented root canals. *J Endod* 2005;31:590-592.
58. Russell RG, Rogers MJ. Bisphosphonates: from the laboratory to the clinic and back again. *Bone* 1999;25:97-106.
59. De-Deus G, Zehnder M, Reis C, Fidel S, Fidel RA. Longitudinal co-site optical microscopy study on the chelating ability of etidronate and edta using a comparative single-tooth model. *J Endod* 2008;34:71-75.
60. De-Deus G, Namen F, Galan J, Zehnder M. Soft chelating irrigation protocol optimizes bonding quality of resilon/epiphany root fillings. *J Endod* 2008;34:703-705.
61. Addy M, Moran JM. Clinical indications for the use of chemical adjuncts to plaque control: chlorhexidine formulations. *Periodontol* 2000 1997;15:52-54.
62. Gomes BP, Souza SF, Ferraz CC, Teixeira FB, Zaia AA, et al. Effectiveness of 2% chlorhexidine gel and calcium hydroxide against Enterococcus faecalis in bovine root dentine In vitro. *IntEndod J* 2003;36:267-275. 63. Gomes BP, Sato E, Ferraz CC, Teixeira FB, Zaia AA, et al. Evaluation of time required for recontamination of coronally sealed canals medicated with calcium hydroxide and chlorhexidine. *IntEndod J* 2003;36:604-609. 64. Siqueira JF, Paiva SS, Roca IN.

Reduction in the cultivable bacterial populations in infected root canals by a chlorhexidine-based antimicrobial protocol. *J Endod* 2007;33:541-547.

65. Jones C.G. Chlorhexidine: is still the gold standard? *Periodontology* 2000 15 : 55-62
66. Ferraz CC, Gomes BP, Zaia AA, In vitro assessment of the antimicrobial action and the mechanical ability of chlorhexidine gel as an endodontic irrigant. *J Endod* 2001;27:452-455.
67. Denton GW. Chlorhexidine. In: block SS. *Disinfection, sterilization and preservation*. 4th ed. Philadelphia: lea & febiger 1991: 274-289.
68. Lindskog S, Pierce AM, Blomlof L. Chlorhexidine as a Root Canal Medicament For Treating Inflammatory Lesions In The Periodontal Space. *Endod Dent Traumatol* 1998; 14:181.
69. Russell AD, Day MJ. Antibacterial activity of chlorhexidine. *J Hosp Infect* 1993;25: 229-238.
70. Zamany A, Safavi K, Spangberg LS. The effect of chlorhexidine as an endodontic disinfectant. *Oral Surg Oral Med Oral Pathol Oral RadiolEndod* 2003;96:578-581.
71. Mohammadi Z, Abbott PV. The properties and applications of chlorhexidine in endodontics. *IntEndod J* 2009;42:288-302.
72. White RR, Hays GL, Janer LR. Residual antimicrobial activity after canal irrigation with chlorhexidine. *J Endod* 1997;23:229-231.
73. Gomes PFA. Chlorhexidine in Endodontics. *Braz Dent J* 2013; 24: 89-102.
74. Rosenthal S, Spangberg L, Safavi KE. Chlorhexidine substantivity in root canal dentine. *Oral Surg Oral Med Oral Pathol Oral RadiolEndod* 2004;98:488-492.
75. Gendron R, Grenier D, Sorsa T, Mayrand D. Inhibition of the activities of matrix metalloproteinases 2, 8, and 9 by chlorhexidine. *ClinDiagn Lab Immunol* 1999;6:437-439.
76. Babich H, wurzburger BJ, rubin YL, sinensky MC, Blau L, An in vitro study on the cytotoxicity of chlorhexidine digluconate to human gingival cells, *cell biology & toxicology* 1995;11:79-88.
77. Evanov C, Liewehr F, Buxton TB, Joyce AP. Antibacterial efficacy of calcium hydroxide and chlorhexidine gluconate irrigants at 37 degrees C and 46 degrees C. *J Endod* 2004;30:653-657.
78. Shen Y, Qian W, Chung C, Evaluation of the effect of two chlorhexidine preparations on biofilm bacteria in vitro: a three-dimensional quantitative analysis. *J Endod* 2009;35:981-985.
79. Williamson AE, Cardon JW, Drake DR. Antimicrobial susceptibility of monoculture biofilms of a clinical isolate of *Enterococcus faecalis*. *J Endod* 2009;35:95-97.
80. Torabinejad M, khademi AA, babagoli j, cho y, Johnson WB, A new solution for removal of smear layer. *J endod* 2003; 29: 170-175.
81. Haapasalo M, Qian W, Portenier I, Waltimo T. Effects of dentin on the antimicrobial properties of endodontic medicaments. *J Endod* 2007;33:917-925.
82. Dunavant TR, Regan JD, Glickmann GN, Solomon GS, Honeyman AL, Agrawal Vineet S Austin Publishing Group Comparative evaluation of endodontic irrigants against *Enterococcus faecalis* biofilms. *J Endod* 2006;3
83. Torabinejad M, ChoY, Khademi AA, Bakland LK, Shabahang S. The effect of various concentrations of sodium hypochlorite on the ability of MTAD to remove the smear layer. *J Endod* 2003;29:233-239.
84. Hashem AA, Ghoneim AG, Lufty RA, Fouda MY. The effect of different irrigating solutions on bond strength of two root canal filling systems. *J Endod* 2009;35:537-540.

85. Gopikrishna V, Venkateshbabu N, Datta K, Kandaswamy D. Evaluation of the effect of MTAD in comparison with EDTA when employed as the final rinse on the shear bond strength of three endodontic sealers to dentine. *AustEndod J* 2011;37:12-17.
86. Dahlén G, Samuelsson W, Molander A, Reit C. Identification and antimicrobial susceptibility of Enterococci isolated from the root canal. *Oral Microbiol Immunol* 2000;15:309–312.
87. McDonnell G, Russell AD. Antiseptics and disinfectants: activity, action, and resistance. *ClinMicrobiol Rev* 1999;12:147–179.
88. Luciano Giadino, Enrico savoldi, E. Ambu, Roberto Rimodini, Alberto palezona. Antimicrobial effect of MTAD, tetraclean, Cloreximix and sodium hypochlorite against three common endodontic pathogens. *Indian J Dent Res* 2009; 20: 391.
89. F G Pappen, Y Shen, W.Gian, M R Leonardo, L giardino. In vitro antimicrobial action of Tetraclean, MTAD and five experimental irrigation solutions *IntEndod J* 2010; 43:528-535.
90. Giardino L, Ambu E, Savoldi E. Comparative evaluation of antimicrobial efficacy of sodium hypochlorite, MTAD, and Tetraclean against *Enterococcus faecalis* biofilm. *J Endod* 2007;33:852–855.
91. Ballal NV, Kandian S, Mala K, Bhat KS. Comparison of the efficacy of maleic acid and ethylenediaminetetraacetic acid in smear layer removal from instrumented human root canal: A Scanning Electron Microscopic Study. *J Endod* 2009;35:1573-1576.
92. NV Ballal, S. Kandian, Kundanbala Mala, K S Bhat. Evaluation of the effect of maleic acid & EDTA on micro hardness & surface roughness of human root canal dentin. *J Endod*; 2010;36:1385-1388.
93. Cobankara FK, Ozkan HB, Terlemez A. Comparison of Organic Tissue Dissolution Capacities of Sodium Hypochlorite and Chlorine Dioxide. *J Endod* 2010;36:272-274.
94. Hua G, Reckhow DA. Comparison of disinfection byproduct formation from chlorine and alternative disinfectants. *Water Res* 2007;41:1667-1678.
95. Lévesque B, Ayotte P, Tardif R, Ferron L, Gingras S, et al. Cancer risk associated with household exposure to chloroform. *J Toxicol Environ Health A* 2002;65:489-502.
96. Nishikiori R, Nomura Y, Sawajiri M, Masuki K, Hirata I, et al. Influence of chlorine dioxide on cell death and cell cycle of human gingival fibroblasts. *J Dent* 2008;36:993-998.
97. Eto JN, Niu W, Takeda FH, Kimura Y, Matsumoto K. Morphological and atomic analytical changes of root canal wall dentin after treatment with thirty eight percent $\text{Ag}(\text{NH}_3)_2\text{F}$ solution and CO laser. *J Clin Laser Med Surg* 1999;17:19-24.
98. Hiraishi N, Yiu CK, King NM, Tagami J, Tay FR. Antimicrobial Efficacy of 3.8% silver diamine fluoride and its effect on root dentin. *J Endod* 2010;36:1026-1029.
99. Zambon JJ, Reynolds HS, Dunford RG, Bonta CY. Effect of a triclosan/ copolymer/ fluoride dentifrice on the oral microflora. *Am J Dent* 1990;3:S27-S34.
100. Nudera WJ, Fayad MI, Johnson BR, Zhu M, Wenckus CS, et al. Antimicrobial effect of triclosan and triclosan with gantrez on five common endodontic pathogens. *J Endod* 2007;33:1239-1242.
101. Jagetia GC, Baliga MS, Malagi KJ, Kamath SM. The evaluation of the radioprotective effect of Triphala (an Ayurvedic rejuvenating drug) in the mice exposed to gamma- radiation. *Phytomedicine* 2002;9:99-108.

102. Prabhakar J, Senthilkumar M, Priya MS, Mahalakshmi K, Sehgal PK, et al. Evaluation of antimicrobial efficacy of herbal alternatives (Triphala and Green Tea Polyphenols), MTAD, and 5% sodium hypochlorite against Enterococcus faecalis Biofilm Formed on Tooth Substrate: An In vitro Study. J Endod 2010;36:83-8.

Author Details:

Mukta Bansal - ¹Senior Lecturer, Department of Conservative Dentistry and Endodontics,
Rama Dental College Hospital and Research Centre, Kanpur,UP, India
drmuktabansal92@gmail.com
9736653155.

Asheesh Sawhny - ²Principal and Head, Department of Conservative Dentistry and Endodontics,
Rama Dental College Hospital and Research Centre, Kanpur ,UP, India
drasheeshmydentist@gmail.com
9838500100

Richa singh - ³Reader, Department of conservative Dentistry and Endodontics,
Rama Dental College Hospital and Research Centre, Kanpur UP India
richasingh.2804@gmail.com
9838870041.

Pankaj kumar priyadarshi- ⁴Reader, Department of Conservative Dentistry and Endodontics,
Rama Dental College Hospital and Research Centre, Kanpur UP India
pankaj.priyadarshi24@gmail.com
9451751213

Saurav paul – ⁵Senior lecturer,Department of Conservative Dentistry and Endodontics,
Rama Dental College Hospital and Research Centre, Kanpur UP India
sauravpaul819@gmail.com
7908367062

Saurabh Sharma-⁶Senior lecturer, Department of conservative Dentistry and Endodontics,
Rama Dental college Hospital and Research Centre,Kanpur, UP, India
saurabhsharmamds@gmail.com
9918783056.

Corresponding Author:

Mukta Bansal - ¹Senior Lecturer, Department of Conservative Dentistry and Endodontics,
Rama Dental College Hospital and Research Centre, Kanpur, UP, India

drmuktabansal92@gmail.com

9736653155.