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A Comprehensive Review of Endodontic Irrigation Solutions

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A B S T R A C T

Irrigation is widely considered to be a crucial component of root canal treatment. It serves various functions and objectives, which can vary based on the type of irrigant employed. The irrigation process facilitates the removal of necrotic tissue, microorganisms, and dentin debris from the root canal by employing a flushing mechanism. It also aids in preventing the accumulation of debris at the apical region of the root canal and in the periapical areas. Its washing action serves both mechanical and chemical purposes, effectively flushing out debris while lubricating and dissolving organic and inorganic materials from the root canal. This process reduces friction between the instruments and dentin, thereby enhancing the efficiency of the files. Successful endodontic treatment relies on a combination of appropriate instrumentation, effective irrigation, and three-dimensional obturation of the root canal system. It is often stated that "instruments shape, irrigants clean." Irrigation serves as the sole method to create optimal streaming forces throughout the entire root canal system, including areas such as fins, isthmuses, and large lateral canals. This review highlights the various irrigating solutions that are used in the field of endodontics.

Keywords: Antibacterial, antifungal, chlorhexidine, dentin debris, EDTA, irrigation, microorganisms, NaOCl, necrotic tissue, root canal system.

Introduction

Chemical and mechanical debridement of the root canal are the principal techniques employed in endodontic therapy to eliminate all necrotic tissue, bacteria, and microbial byproducts from the canal. Various chemicals have been proposed as effective irrigating solutions for the disinfection of root canals. [1, 2] Among them, Sodium hypochlorite (NaOCl) is the most commonly utilized agent in endodontic procedures due to its potent broad spectrum antimicrobial properties and its capacity to dissolve organic matter. [3] The remarkable solvent characteristics of NaOCl contribute to its efficacy as an irrigating agent. [4] However, it is important to note that NaOCl can irritate periapical tissues, particularly when used in elevated concentration. [5-7]

Chlorhexidine gluconate (CHX) has been identified as a potential alternative to NaOCl for use as an irrigation agent in root canal disinfection and endodontic instrumentation. [8, 9] The antibacterial efficacy of CHX has been well-documented in various adjunctive treatments for oral diseases. [10, 11] Additionally, CHX exhibits strong antiseptic qualities, and its effectiveness in managing dental biofilms in individuals with periodontal disease has been established. [12-13] However, a significant drawback of CHX as an endodontic irrigant is its lack of capability to dissolve pulp tissue. [14]

Chelating agents commonly known as EDTA (Ethylenediaminetetraaceticacid) serve the purpose of eliminating the inorganic materials present in the smear layer. This irrigating solution is effective in removing the smear layer, although its efficacy diminishes in the apical third of the root canal. When employing irrigant activation devices, it is essential for the irrigating solutions to maintain direct contact with the entire surface of the root canal walls, particularly in the apical regions of narrow root canals. The significance of irrigants cannot be overstated, as they not only facilitate the cleaning of the canal but also promote the penetration of medicaments into the canal system. Hence it is essential to verify that the canal is in a healthy condition before proceeding with the obturation process. The relationship between the irrigants and the cleanliness of the canal is critically significant, as the effectiveness of endodontic root. The irrigants can be broadly categorized as chemical and natural agents **(Figure1)**.This review thus encompasses the contemporary application of different irrigating solutions and their effectiveness.

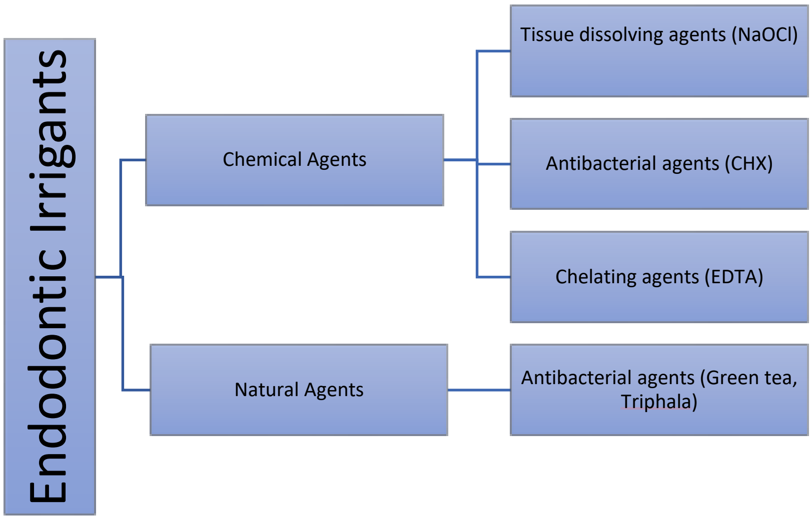


Figure 1: Classification of Endodontic Irrigant Solutions

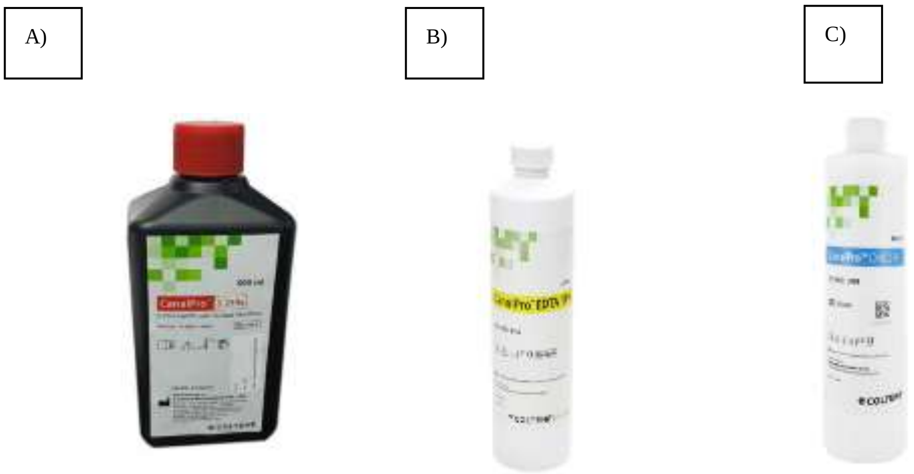


Figure 2: (A) 5.25%NaOC (Coltene), (B) 17%EDTA (Coltene), (C) 2%Chlorhexidine (Coltene)

1. Sodium Hypochlorite (NaOCl)

NaOCl functions as a potent organic tissue solvent and exhibits a broad spectrum of antibacterial properties, making it an excellent disinfectant for surfaces. **(Figure 2 A)**

1.1. Historical perspective

The initial production of NaOCl was done in 1789 in Javelle, France, through the introduction of chlorine gas into a sodium carbonate solution, although this method proved to be inefficient. During World War I, chemist Henry Drysdale Dakin and surgeon Alexis Carrel expanded the application of a buffered 0.5% sodium hypochlorite solution for the irrigation of infected wounds, known as "Eusol" and "Dakin" solution.[15] Subsequently, Coolidge introduced sodium hypochlorite into the field of endodontics.[16,17] NaOCl is employed in concentrations varying from 0.5% to 8%. Lower concentrations, specifically 0.5% or 1%, primarily dissolve necrotic tissue, while higher concentrations are more effective against *Enterococcus faecalis* and *Candida albicans*.[18,19,20] When the pH exceeds 7.6, hypochlorite is formed, whereas a pH below 7.6 results in the formation of hypochlorous acid, which is recognized for its superior bactericidal properties compared to hypochlorite.

1.2. Mechanism of Action

NaOCl undergoes ionization to yield hypochlorous acid and the hypochlorite ion, which are the active agents responsible for its antimicrobial properties. Estrela reported in 2002 that NaOCl exhibits a Dynamic balance. [21] The steps involved in its mechanism can be described as follows:

Step I: Saponification: NaOCl acts as an organic and fat solvent that degrades fatty acids and transforms them into fatty acid salts and glycerol reducing the surface tension of the remaining solution.

Step II: Amino acid neutralization: NaOCl neutralizes amino acids by forming water and salt. The departure of hydroxyl ions leads to a decrease in Ph.

Step III: Chloramination: A chemical reaction with the protoplasm of the bacterial cell, leading to the disruption of DNA synthesis, as cholramines impede cell metabolism

The most effective concentration used is 0.5 % to 5.25% NaOCl as irrigant in root canals. It serves as a highly effective antimicrobial agent, proficiently dissolving pulpal remnants and organic materials present in dentin, as illustrated in scanning electron microscope image of root canal dentin surface after irrigation process.

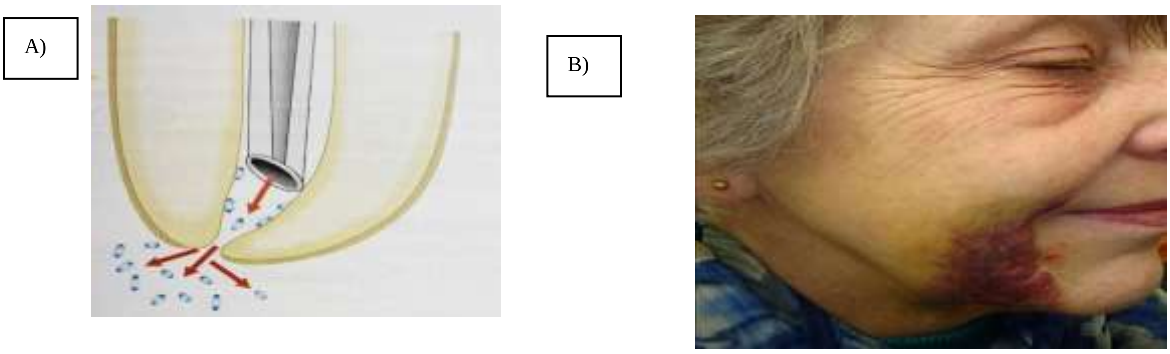
1.3. Factors affecting NaOCl efficacy can be summarized as follows:

- Time: Antimicrobial effectiveness is directly related to its contact time with canal.
- Heat : Increase in temperature by 25^0C enhances efficacy by factor of 100.
- pH: On dilution its dissolving property gets decreased.
- Activation: Ultrasonic Activation of NaOCl accelerates the chemical reaction, creates cavitation effect and hence achieve a superior cleansing action.

1.4. Safety measures to observe while utilizing NaOCl solution

It is essential to recognize that while NaOCl is non-toxic when used intracanal, a concentration of 5.25% NaOCl can inflict significant harm to surrounding tissues if injected periapically **(Figure3 A)**.This can result in severe pain, periapical hemorrhage, and swelling constitute a triad of signs/symptoms pathognomonic of NaOCl extrusion as shown in **Figure3 B**. Consequently, to prevent the inadvertent extrusion of NaOCl, it is crucial to exercise caution and employ passive irrigation techniques, and using side vent needles particularly in cases where there is an apical opening.

Figure3: (A) periapical extrusion of sodium hypochlorite solution due to forceful irrigation, (B) Clinical picture of hypochlorite accident



1.5. Limitations of NAOCL

The substance is considered toxic if it extends beyond the apical foramen and comes into contact with the periapical tissue. It lacks substantivity, has the potential to corrode metal instruments, and emits an unpleasant odour.

2. CHLORHEXIDINE SOLUTION (CHX)

It was first marketed in United Kingdom in 1953 as an antiseptic cream. [22] Since 1957, it has been used for general disinfection purposed and has been used as an irrigant in Endodontics. It belongs to polybiguanide antibacterial family, consisting of two symmetrical four chlorophenyl rings and two bisguanide groups connected by central hexamethylene chain. **(Figure 2 B)**

2.1. Properties

It has excellent antimicrobial activity, and an effective antifungal efficacy. Its antibacterial substantivity in dentin is upto 120 days. [23] It has no ability to dissolve organic or inorganic tissue. Combination of NaOCl and CHX cause color changes and formation of precipitate which may interfere with the seal of root filling. **Basrani et al.** evaluated the chemical nature of this precipitate and reported the formation of 4-chloroaniline (PCA). [24] CHX improves the integrity of hybrid layer and resin dentin bond stability.

2.2. Mode of action

At high concentrations CHX acts as detergent, by damaging cell membrane, it causes precipitation of the cytoplasm and thereby exerts a bactericidal effect. And at low sublethal concentrations CHX is bacteriostatic, causing low molecular-weight substances (i.e., potassium phosphorous) to leak out without the cell being irreversibly damaged. [25]

2.3. Substantivity

CHX possesses the capability to be absorbed by anionic substrates, such as the oral mucosa and has the potential to bind with proteins. Additionally, it can absorb onto hydroxyapatite and dental surfaces. This reversible process of CHX uptake contributes to its significant antimicrobial properties, a phenomenon known as substantivity. The time and concentration of CHX play a crucial role in determining its antibacterial substantivity. At lower concentrations, particularly within the range of 0.005% and 0.01% a stable monolayer of CHX is observed to adhere to the surface of the tooth. In contrast, at elevated concentrations (>0.02%), a multilayer of CHX is established on the surface.

2.4. Cytotoxicity

CHX is normally used with concentrations of 0.12-2%, and it has low level of tissue toxicity, both locally and systemically. But toxic product called as parachloroaniline (PCA) (**Figure 4)** is formed when it gets mixed with NaOCl, which is harmful for tissues. [24]

A)

B)

Figure 4:(A) parachloroaniline (PCA) is formed when CHX is mixed with NaOCl, (B)Mixing sodium hypochlorite (left container) and chlorhexidine (middle container) creates a reddish brown precipitate (right container) that is carcinogenic and may impair disinfection.

2.5. Allergic reaction

CHX is relatively safe solution but may induce allergic reactions. Conditions like anaphylaxis, contact dermatitis, and urticaria have been reported following direct contact to mucosal tissue or open wounds. [26-28]

2.6. CHX APPLICATION IN ENDODONTICS

It is commonly utilized as both an irrigant and an intracanal medication. In cases of infected root canals, its antibacterial properties significantly diminish bacterial presence, with 2%Chlorhexidine (CHX) proving effective in eradicating the biofilm of *Enterococcus faecalis*. The use of 2% CHX as an irrigant demonstrates superior antibacterial efficacy compared to 0.12% solutions.**3. EDTA (ETHEYLENEDIAMINETERACETICACID)**

Chelating agents are defined as a chemicals which combine with a metal to form a chelate. EDTA is the most commonly used chelating agent in dental practice. **(Figure2 C)**

EDTA was first described in 1935 By Ferdinand Munzz. The introduction of chelating agents in endodontics began in 1957, when Nygaard-Ostby employed them to facilitate the treatment of narrow and calcified root canals. [29]

The chelating agents play a crucial role in removing the inorganic components of the smear layer and aiding in the eradication of bacteria within the root canal. Additionally, EDTA may exhibit antifungal properties and contributes to the demineralization of dentin, typically ranging from 20 to 50 micrometres, while maintaining a low level of toxicity.

3.1. APPLICATION IN ENDODONTICS

EDTA is employed at a concentration of 17%, which is capable for opening occluded, very fine dentinal tubules. A continuous irrigation with 5 ml of 17% EDTA for a duration of 1-3 minutes serves as an efficient final rinse, effectively removing the smear layer from the walls of the root canalas illustrated in SEM image. [30] **(Figure5 A, B, C)**

A **B** **C**

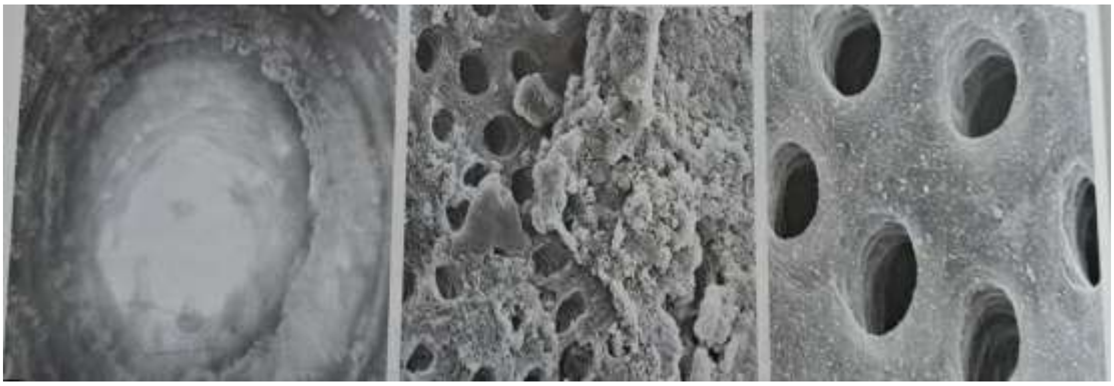


Figure5: Scanning electron microscope (SEM): (A) Dentin tubules blocked with smear layer; (B) Application of chelating agent causes removal of smear layer; (C) Opening of dentinal tubules.

4. Interactions of EDTA with NaOCI, and CHX

1. **EDTA + NaOCl:** EDTA causes NaOCl to lose its tissue dissolving capacity, and virtually no free chlorine is available.

2 **EDTA + CHX**

Immediate formation of a white, foggy precipitate and Precipitate involves the chemical degradation of chlorhexidine.

5. CONCLUSION

An effective irrigation protocol for root canals should aim to eradicate bacteria, biofilm, and smear layer while ensuring thorough disinfection of all elements within the root canal system, including its complex anatomical features. The integration of different irrigating solutions and activation techniques is essential to improve cleanliness, reduce the adverse effects of irrigants on the physical properties of exposed dentin, and enhance the sealing ability of filling materials.

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