# Endodontic Irrigants: A Review

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**Abstract:**
Effective irrigant delivery and agitation are prerequisites to promote root canal disinfection and debris removal and improve successful endodontic treatment. A PubMed electronic search was conducted with appropriate key words to identify the relevant literature on this topic. After retrieving the full-text articles, all the articles were reviewed and the most appropriate were included in this review. In this article, the different actions and interactions of the most commonly used irrigants are discussed. The aim of this review is to analyze the relevant literature on root canal irrigants. It also presents an overview of the currently available technologies to improve the cleaning of the endodontic space and their debridement efficacy. A suggested protocol for irrigation in various scenarios will also help the clinician to achieve desired outcome.
A thorough knowledge of the irrigants, irrigation prorocol and activation systems will help to improve the intracanal bacterial decontamination and increase the clinical success of the endodontic treatment.
***Key words*: Root canal preparation, endodontic disinfection, biomechanical disinfection, root canal irrigants, activation systems.

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## INTRODUCTION

Infection of the root canal space occurs most frequently as a sequel to a large carious lesion or traumatic exposure. The aims of endodontic treatment are the elimination of this infection and prevent its recurrence. Successful root canal treatment is dependent on the removal of microorganisms from the pulp and other anatomical irregularities of the root canal system through chemo-mechanical instrumentation with the use of instruments and irrigating solutions. Irrigation is defined as washing out a body cavity or wound with water or medical fluid.[1] Irrigation is also the only way to impact those areas of the root canal wall that are not touched by mechanical instrumentation such as fins, isthmuses and large lateral canals.

Objectives of irrigation are as follows:[2]

- Reduction of intraradicular microorganisms and neutralization of their endotoxins
- Dissolution of vital or necrotic pulp tissue
- Lubrication of canal walls and instruments
- Removal of dentin particles and smear layer

The properties of an ideal irrigant are enumerated in table 1.[3]
The classifications for irrigants can be summarised in two ways in tables 2 & 3.[4,5]

### *Sodium hypochlorite*

Research and clinical experience have shown that NaOCl has several properties that contribute to effective chemomechanical debridement of a root canal system. NaOCl acts as a lubricant for instrumentation and can flush loose debris from root canals.[6,7]

**Table 1. Characteristics of an optimal irrigating solution in root canal treatment**

| |
|---|
| Low cost |
| Washing action |
| Reduction of friction |
| Improving cutting of dentine by the instruments |
| Temperature control |
| Dissolution of organic and inorganic matter |
| Good penetration within the root canal system |
| Killing of planktonic microbes |
| Killing of biofilm microbes |
| Detachment of biofilm |
| Non-toxic to periapical tissue |
| Non-allergenic |
| Does not react with negative consequences with other dental materials |
| Does not weaken dentin |

NaOCl is an effective antimicrobial agent with the capability of detoxifying the root canal system.[8] Also, NaOCl is effective in dissolving both vital and nonvital tissue.[9,10,11] Studies have shown that both the antibacterial and tissue-dissolving capabilities of 5.25% NaOCl decrease when it is diluted. Recent studies have shown that ultrasonic energy increases the debridement and antimicrobial capabilities of NaOCl.[12,13] Spangberg et al recommended 0.5% NaOCl for acceptably noncytotoxic levels.[14] Others have found only a minimal irritant effect for higher concentrations in animal models[15]; however, severe sequelae have been reported when 5.25% NaOCl is injected into human periapical tissue.[16]

**2% Chlorhexidine digluconate**

Chlorhexidine was developed in the late 1940s. 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. Chlorhexidine digluconate has antimicrobial activity but no tissue dissolving capability. However, it is biocompatible and does not possess some of the undesired characteristics of sodium hypochlorite, for example, the bad smell.[17-21]

**17% EDTA**

As sodium hypochlorite is active only against organic tissues, 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) and citric acid have therefore been recommended as adjuvants in root canal therapy. Ethylenediaminetetraacetic acid (EDTA) can effectively dissolve inorganic material, including hydroxyapatite, though it appears to have little or no effect on organic tissue and no antibacterial activity.[22] It can remove the smear layer, is biocompatible, able to condition dentine and has some positive effect on the root canal seal.[23] If extruded periapically, it shows cytotoxicity.[24]

**3% to 5% Hydrogen peroxide**

Hydrogen peroxide is a clear, odourless liquid. Hydrogen peroxide has various applications in dentistry. It is a highly unstable compound which decomposes by heat and light. It acts by releasing nascent oxygen upon which coming in contact with tissue enzymes produces a bactericidal effect by interfering with bacterial metabolism. Also, the rapid release of nascent oxygen creates effervescence or bubbling action which is said to aid in mechanical debridement by dislodging necrotic tissue and dentinal debris from the root canal. However higher concentrations of hydrogen peroxide are toxic to the tissues. [25] It is anti-microbial but does not dissolve necrotic intra-canal tissue and exhibits toxicity to the surrounding tissue.[26]

**5% to 7% Maleic Acid**

Maleic acid is a mild organic acid can effectively remove smear layer when used as an endodontic irrigant. 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.[27] This surface roughness produces an important role in the micromechanical bonding of resin sealers.[28] 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 ($ClO_2$) is chemically similar to chlorine or hypochlorite. An in-vitro study compared organic tissue dissolution capacity of NaOCl and $ClO_2$. It was concluded that $ClO_2$ and NaOCl are equally efficient for dissolving organic tissue. $ClO_2$ produces little or no trihalomethanes. A study showed that trihalomethane is an animal carcinogen and a suspected human carcinogen $ClO_2$ might, therefore, be a better dental irrigant than NaOCl.[29]

**Qmix**

QMix is a novel one-step irrigating solution that contains a mixture of bisbiguanide antimicrobial agent, calcium–chelating agent, saline, and surfactant. QMix is reportedly as effective as 17% ethylenediaminetetraacetic (EDTA) in reducing the smear layer. QMix has also been proven to have an effective antimicrobial activity for the disinfection of hydroxyapatite discs infected with *E. Faecalis*. However, to date, little information is available on the antimicrobial ability of QMix in human teeth infected with *E. faecalis*.[30] Stojicic et al reported that QMix effectively killed E. faecalis biofilms grown on collagen-coated hydroxyapatite discs in vitro, and was superior to CHX and MTAD.

**MTAD (Mixture of Tetracycline, an Acid, And a Detergent)**

Torabinejad et al developed an irrigant that is a mixture of 3% doxycycline, 4.25% citric acid, and detergent (Tween 80, 0.5%),[31] with a pH of 2.15. It is effective in removing the smear layer due to its low pH, and it showed tissue-dissolving action as long as the canal was rinsed with NaOCl during mechanical preparation. [32] Recent protocol recommends an initial irrigation for 20 minutes with 1.3% NaOCl, followed by a 5-minute final rinse with MTAD.[32] MTAD works better in the apical third to remove the smear layer as compared to other root canal irrigants.[33] In MTAD preparation, the citric acid may serve to remove the smear layer, allowing doxycycline to enter the dentinal tubules and exert an antibacterial effect.[32] MTAD seems to adversely influence the physical properties of dentin and causes significant reduction in bond strength of both resin-based and calcium-hydroxide–based sealers due to precipitate formation.[34] Concerns have been expressed regarding the use of tetracycline (doxycycline) because of possible resistance to the antibiotic and staining of tooth hard tissue, as demonstrated by exposure to light in an in-vitro model.[35] However, no report of in vivo staining has been published.

**Tetraclean**

A mixture of doxycycline hyclate, an acid, and a detergent,[31] Tetraclean (Ogna Laboratori Farmaceutici, Milano, Italy) is similar to MTAD, but the concentration of antibiotic (doxycycline 50 mg/ ml) and the type of detergent (polypropylene glycol) differ from those of MTAD.[36] It can eliminate microorganisms and the smear layer in dentinal tubules of infected root canals with a final 5-minute rinse and opens up the dentinal tubules. It has low surface tension allowing better adaptation of the mixtures to the dentinal walls[36] and is effective against both strictly anaerobic and facultative anaerobic bacteria.[37]

**Laser**

In the Endodontics area several types of laser have been used to improve root canal disinfection: diode laser, gas laser ($CO_2$), erbium: YAG laser, neodymium: YAG laser. Bactericidal action of the laser depends on the wavelength and energy, and in many cases it is due to thermal effects that produce an alteration of the cell wall of the bacteria, leading to changes in osmotic gradients up to cell death. The laser energy emitted from the tip of the optical fiber is directed along the canal and not necessarily lateral to the walls. To overcome this limitation, a delivery system that allows lateral emission of the radiation aimed to improve the antimicrobial effect[38], but complete elimination of the biofilm and bacteria was not yet possible[39].

**Recommended Irrigation Protocols:**

Various clinical scenarios require different irrigant combinations and sequence. They are mentioned below:

**For Vital teeth:**[40]

1. NaOCl and/or urea peroxide
2. 2ml of sodium hypochlorite 5.25 percent (60°C)
3. A second application and its activation is obtained by using a K file (08-10).

4. Once the preparation of the canal has begun, Smear Clear to be used.
5. Distilled water is used between each irrigating solution to prevent an acid/ base reaction, between sodium hypochlorite and EDTA, for a more efficient action of the chemicals on the tissues.
6. Chlorhexidine can be used for total elimination of the bacteria inside the canal.

**For Necrotic teeth:[40]**

1. Irrigation will be initiated with either sodium hypochlorite (5.25%, 60˚C) for its bacterial effect or with chlorhexidine (0.2%) (10 minutes).
2. Distilled water to neutralize the effect of these irrigants.
3. Then repeat the same irrigation sequence described previously for vital teeth.

In both clinical situations (vital and necrotic teeth) it is necessary to end our sequence by using distilled water in order to eliminate the chemical agents or to neutralize their effects.

It will inhibit:
- Their flow towards the periodontal tissues
- The alteration of the filling material
- The formation of a precipitating layer due to the crystallization of sodium hypochlorite after drying the canal walls.

**For presence of resorptions:[40]**
When we suspect internal resorption,
1. NaOCl and/or urea peroxide (2ml of sodium hypochlorite 5.25 percent at 60°C)
2. A second application and its activation is obtained by using a K file (08-10).
3. Once the preparation of the canal has begun, Smear Clear to be used.
4. Distilled water is used between each irrigating solution.
5. Chlorhexidine can be used for total elimination of the bacteria inside the canal.
6. Citric acid 50 percent (10 minutes) in order to eliminate the granulation tissue and to obtain smooth dentinal walls. The citric acid is eliminated by NaOCl and distilled water.

**External apical resorptions:**
The same sequence is adopted for external apical resorptions but with an activation of the patency.

## OLD AND NEW EQUIPMENT FOR IRRIGATION

The classical way of irrigating the root canal is with a syringe and needle. When carefully used, needle irrigation can be effective and sufficient.[41,42] Small size 27-gauge or preferably 30-gauge needles should be used to gain access to the apical canal. Irrigant exchange beyond the needle tip reaches only one to three mm, depending on the needle type and irrigant flow.[43] Side-vented needles (tip) may offer safer irrigation than open-ended needles in positive pressure irrigation. It offers superior penetration in lateral canals in the apical one third. Also, there are fewer chances of apical extrusion of irrigant when using side-vented needles. To maximize the effectiveness of hypochlorite irrigation, the solution should frequently be refreshed and kept in motion by agitation or continuous irrigation. The speed of tissue dissolution can be increased with effective agitation and refreshment.

**Manual agitation:**

The simplest of all mechanical activation techniques is the manual irrigant agitation, which can be performed with different systems. The easiest way to achieve this effect is moving vertically and passively the endodontic file within the root canal. The file promotes the irrigant penetration and reduces the presence of air bubbles in the canal space, but does not improve the final cleaning.[44] Another similar technique advises moving vertically a gutta-percha cone until reaching the working length while the canal is filled with irrigant. Endodontic brushes and specific needles for endodontic irrigation with bristles on their surface is another technique suggested to move the irrigant more effectively within the canals.[45]

**Table 2: Classification of the commonly used irrigating solutions (5)**

**A) Chemical agents:**

*a. Tissue dissolving agents: NaOCl*

*b. Antibacterial agents:*
i. Bacteriostatic: CHX, some antibiotics
ii. Bactericidal: Some antibiotics, NaOCl

*c. Chelating agents:*
i. Weak: HEBP
ii. Strong: EDTA, Citric acid

*d. Combination products (tissue dissolution & antibacterial effect):*
MTAD, QMiX, SmearClear, Tetraclean

**B) Natural agents:**
a. Antibacterial agents:
e.g., Green tea, Triphala, Morinda Citrifolia (NONI), Propolis

**Table 3: 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
- SmearClear
- QMix

**Table 4.Newer Irrigating solutions:**

- HEBP (Etidronic Acid)
- Chlorine dioxide
- Ozonated water
- Silver Diamine Fluoride
- Triclosan and Gantrez
- Electrochemically Activated Solutions

| Properties | Naocl | Edta | Chx | $H_2O_2$ | Qmix | Maleic acid | $Clo_2$ |
|---|---|---|---|---|---|---|---|
| Tissue dissolution | Excellent | Poor | No | | | Poor | Good |
| Antimicrobial | Excellent | Poor | Excellent | Poor | Good | Poor | Excellent |
| Smear removal | Poor | Excellent | No | Poor | Good | Good | Poor |
| Concentration | 0.5%-6% | 17% | 0.2-2% | 3%-5% | Poor | Poor | 0.5%-13.8% |
| Substantivity | | | Excellent | | good | | Poor |

**Machine-Assisted Agitation Systems:**

### 1. Sonic Activation

Sonic activation has shown to be an effective method to disinfect the root canals.[46] Sonic activation operates at a lower frequency (1-6 kHz). Eg. Endoactivator, Vibringe.

EndoActivator has smooth plastic tips of different sizes activated at a sonic frequency by a hand piece. Vibringe uses a syringe with sonic vibration that allows the delivery and activation of the irrigant in the root canal at the same time.

### 2. Passive Ultrasonic Activation

The range of frequencies used in the ultrasonic unit is between 25 and 40 kHz. The effectiveness of ultrasound in the irrigation is determined by its ability to produce "cavitation" and "acoustic streaming." Ultrasonic activation of NaOCl from 30 s to 1 min for each canal with 3 cycles of 10-20 s (with constant irrigant renewal) seems to be a sufficient time to obtain cleaned canals at the end of the preparation.[47] Ultrasound appears to be less effective to enhance the activity of EDTA, although it may contribute to a better removal of the smear layer.[48]

**3. Continuous Irrigation during Instrumentation**

The Self Adjusting File (SAF) system uses a particular instrument with an abrasive surface that enlarges the canal by friction and in a vibrating motion allows the irrigant to flow through the file itself. This system has shown excellent results regarding anatomy preservation and cleaning ability.[49]

**4. Apical Negative-Pressure Irrigation**

In the EndoVac system the irrigant is applied to the pulp chamber or coronal root canal (teeth with one single root canal) from where it is sucked down the canal and back via the needle. In other words, the direction of the irrigant flow has been reversed, which creates the negative pressure at the apical foramen and thereby prevents the possibility of irrigant extrusion.

**5. Photon-Initiated Photoacoustic Streaming**

The mechanism of this interaction has been attributed to the effective absorption of laser light by sodium hypochlorite. This leads to the vaporization of the irrigant and to the formation of vapor bubbles, which expand and implode with secondary cavitation effects. The PIPS technique is based on the power of Erbium: YAG laser to create photoacoustic shock waves within the irrigant introduced in the canal.

**Interactions of various irrigants:**

Although such a combination of irrigants may enhance the overall antimicrobial effectiveness, the possible chemical interactions amongst the irrigants need to be considered.

***NaOCl and CHX:***

The reaction between NaOCl and CHX produces a the occurrence of a color change and precipitation when NaOCl and CHX are combined(Orange brown precipitate). It contains a carcinogenic product, parachloroanaline (PCA), the potential leakage of which into the surrounding tissues is a concern. Furthermore, concern has been raised that the color change may have some clinical relevance because of staining and that the precipitate might interfere with the seal of the root filling.[50]

***NaOCl & EDTA:***

Grawehr concluded that EDTA retained its calcium complexing ability when mixed with NaOCl, but it instantaneously reduces the amount of chlorine of NaOCl & ultimately NaOCl loses its tissue-dissolving capacity.[51] Short-term irrigation with hypochlorite after EDTA or CA at the end of chemomechanical preparation causes strong erosion of the canal-wall surface dentin.[52] Clinically, this suggests that EDTA and NaOCl should be used separately.

***NaOCl & $H_2O_2$ :***

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 alone.[53]

***NaOCl and QMix :***

When NaOCl and QMiX are mixed, there is no formation of a precipitate, but there is a change of color in the combination. This is the reason why the manufacturer recommends rinsing with saline solution before using QMiX.

***EDTA with CHX:***

The combination of chlorhexidine and EDTA produces a white precipitate.The precipitate is most likely a salt formed by electrostatic neutralization of cationic CHX by anionic EDTA. The clinical significance of this precipitate is largely unknown. It seems that the ability of EDTA to remove the smear layer is reduced.

**Conclusion:**

Irrigation has a key role in successful endodontic treatment. The extra time we gain by using rotary NiTi instruments should be used for abundant irrigation to achieve better cleaning of the root canal system, thereby contributing to the improved success of the treatment. For optimal irrigation, a combination of different irrigating solutions must be used. The dentist should be aware of the interactions between the various chemicals found in irrigants as they may weaken each others' activity and result in the development of products that are harmful to the host. Developing a rational irrigation sequence so that the chemicals are administered properly to release their full potential is imperative for successful endodontic treatment.

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