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Endodontic irrigation : An update.

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Abstract

In pulpal and periapical diseases, many changes occur in the root canal space.

The aim of endodontic treatment is to remove the necrotic tissues, microorganisms and microbial byproducts from root canal system through chemical and mechanical debridement of root canal system.

This article describes the requirements of the irrigation solutions and activation techniques used in practice.

It also reviews the classical irrigants, their advantages and limitations and new irrigants and techniques of activation of these solutions to enhance the efficacy of endodontic treatment which can be used in future endodontic practice

Keywords: Activation, canal, debridement, irrigation, smear layer, solution.

Introduction

Bacteria,yeasts and viruses are the major cause of pulpal and periapical diseases which result in polymicrobial colonization of the entire root canal system, together with the dentinal tubules adjacent as a biofilm.

When pathological changes occur in the dental pulp, the root canal space acquires the ability to harbor various irritants including several species of bacteria, along with their toxins and byproducts **[1]**. Complexity of the root canal system, invasion of the dentinal tubules by microorganisms, formation of smear layer during instrumentation and presence of dentin as a tissue are the major obstacles for complete elimination of bacteria during cleaning and shaping of root canal systems **[1]**.

The goal of endodontic treatment is to remove all the vital and necrotic tissues, microorganisms and microbial byproducts from root canal system. This goal can be achieved through chemical and mechanical debridement of root canals **[1]**.

While most of the attention is paid to the mechanical aspects of a root canal treatment, this has not been the case for the irrigation which is an essential feature of it **[2].**

Endodontic Infection And Smear Layer

Studies have shown that current methods of cleaning and shaping root canals produce a smear layer that covers the instrumented walls.

The presence of smear layer influences directly the effectiveness of root canal cleansing **[3]** because its amorphous, irregular surface contains inorganic and organic substances **[4]** that include fragments of odontoblastic processes, microorganisms, and necrotic materials **[5]** of the root canal infections which are polymicrobial (10-30 bacterial species) and typically dominated by a variety of mainly anaerobic gram positive *cocci*,facultative rods,*Lactobacillus, and Streptococcus* **[7]** and gram negative bacteria; *Enterococcus faecalis, Streptococcus gordonii, Fusobacterium nucleatum, Actinomyces, Candida albicans, and Lactobacillus* **[6,7]**.

The obligate anaerobes are rather easily eradicated during root canal treatment. On the other hand, facultative bacteria such as *nonmutans Streptococci, Enterococci, and Lactobacilli* are more likely to survive chemomechanical instrumentation and root canal medication. The major part of microorganisms in the root canal are organised in biofilm adhered to the canal walls **[14]**. From a clinical standpoint,bacteria arranged in biofilms are more resistant to chemomechanical than the same cells grown in planktonic state.

In particular, *Enterococcus faecalis* has gained attention in the endodontic literature as it can frequently be isolated from root canals in cases of failed root canal treatments**[7]**. *Enterococcus faecalis* has been shown to survive in high pH levels and starvation **[8]** and is more likely to survive chemomechanical instrumentation and root canal medication and proceed to remain viable within the dentinal tubules included in the smear layer **[9]**.

In addition, smear layer decreases dentin permeability, interfering with diffusion of antimicrobial agents from irrigants and intracanal medications into root dentin**[10]**. Smear layers also block tubular entry of endodontic sealers and act as a barrier between obturation materials and canal walls, compromising root canal sealing and increasing chances of reinfection **[10,11]**.

The reason why the removal of smear layer is highly recommended because its presence can have deleterious effects on the endodontic treatment and then can compromise the disinfection process **[11]**. Thus,irrigation is the only way to impact the areas of the root canal wall and tubules that are not touched by mechanical instrumentation **[12]**.

I. Goals of Irrigation

II. Irrigation has a central role in an endodontic treatment.

An optimal irrigant should have a washing action, facilitate removal of microorganisms and dentin debris during and after instrumentation **[12]** by dissolving its inorganic and organic composants (collagen , bacterien biofilm,pulp tissue),it should allow the cleaning of areas inaccessible to endodontic instruments ,it should also lubrificate instruments during mechanical debridement,help destructing microorganisms and wetting the canal walls.this can also help prevent packing of the hard and soft tissues in the apical root canal,without irritating or damaging vital periapical tissue **[7,12,13,14]**.

An irrigant must have a broad antimicrobial spectrum and high efficacy against anaerobic and facultative microorganisms organized in biofilms and must be able to inactivate endotoxin**s.**

Irrigants should also able to open dentinal tubules by removal of the smear layer without weakening the tooth structure and are able to disinfect inaccessible areas to endodontic instruments **[7,12,13].**

However, irrigating solutions should not show cytotoxicity and should not cause a pain if they gain access into the periapical tissues **[14].**

Irrigation Solutions

Sodium Hypochlorite (NaOCl):

Sodium hypochlorite (NaOCl) is the gold standard of endodontic irrigants,it was first described in 1919. Until now,it is the main endodontic irrigant used, due to its antibacterial, sporicidal and virucidal properties and show far greater dissolving effects on organic and necrotic tissues.It is fast acting, has a large spectrum of action and commonly available and inexpensive.

NaOCl is used during the instrumentation phase to increase as much as possible its time of action within the canal without being chemically altered by the presence of other substances.

Hydroxyl ions damage both bacterial lipid membranes and DNA and the high pH created denatures proteins while chloride ions break peptide bonds dissolving protein and releasing further chloramines that are antibacterial **[15].**

NaOCl ionizes in water into Na1 and the hypochlorite ion, (OCl-), establishing equilibrium with hypochlorous acid (HOCl). At acidic and neutral pH, chlorine exists predominantly as HOCl, whereas at high pH of 9 and above, OCl- predominates. Hypochlorous acid is responsible for the antibacterial activity. Hypochlorous acid disrupts several vital functions of the microbial cell, resulting in cell death **[13].**

Its effectiveness has been shown to depend on its concentration, temperature, pH solution and storage conditions.

Heated solutions (45-60°C) and higher concentrations (5-6%) have greater tissue-dissolving properties. It appears that the majority of American practitioners use “full strength” 5.25% sodium hypochlorite **[7].** It should be stored in a cool, dark, air-tight and non-reactive bottle **[15].**

The weaknesses of NaOCl include the unpleasant taste, toxicity, and its inability to remove the smear layer by itself, as it dissolves only organic material. The limited antimicrobial effectiveness of NaOCl is due to problems in penetration to the most peripheral parts of the root-canal system such as fins, anastomoses, apical canal, lateral canals.

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 **[16].**

One of the methods to improve the efficacy of sodium hypochlorite was to use heated solutions.This improves their immediate tissue-dissolution capacity.Therefore, continuous irrigation and time are important factors for the effectiveness of hypochlorite **[7].**

In summary, sodium hypochlorite is the most important irrigating solution and the only one capable of dissolving organic tissue, including biofilm and the organic part of the smear layer. It should be used throughout the instrumentation phase **[13].**

Chlorhexidine

Chlorhexidine is a powerful antiseptic,which is widely used for chemical plaque control in the oral cavity with the concentration of 0.2%, is recommended for that purpose, while 2% is he concentration of root canal irrigating solutions usually found in the endodontic literature **[7,13].**

CHX is bacteriostatic at lower concentrations and bactericidal at higher concentrations **[1].**

Chlorhexidine (CHX) has a broad spectrum activity against both Gram positive and Gram negative bacteria, bacterial spores, lipophilic viruses, yeast and dermatophytes. It has also an antifungal activity. Its antimicrobial activity results from the disruption of bacterial cell walls and depends on the achievement of an optimal pH (5.5-7) **[1].**

Furthermore, it has substantivity; it bonds to dentin walls, maintaining its antibacterial properties for up to 12 weeks. However, it remains inferior as it does not possess the capacity to dissolve organic matter **[15].**

Despite its usefulness as a final irrigant, chlorhexidine cannot be advocated as the main irrigant in standard endodontic cases, because it is unable to dissolve necrotic tissue remnants,and it is ineffective in removing biofilm and other organic substances **[1].** It is also less effective on Gram-negative than on Gram-positive bacteria[7,13].

Iodine Potassium Iodine (IKI)

Iodine potassium iodide (IKI) is a traditional root canal disinfectant and is used in concentrations ranging from 2% to 5% as an irrigant **[22].** IKI is a very potent antimicrobial irrigating solution.It is effective against a large variety of microorganisms and has a rapid antiseptic action,low toxicity, hypoallergenicity, and a very high probability of eliminating microorganisms including E. faecalis even when the contact time is as short as 10–15 min. Its low cytotoxicity and high antimicrobial properties give merit to its use as an endodontic irrigant. **[18,22].** The excellent penetration depth of IKI into the dentinal tubules,gives better antimicrobial effects and better results. It can penetrate deep up to 1000 μm into dentin when irrigated for only 5 min. A short period of exposure to IKI has a more efficient antibacterial effect in the dentinal tubule **[22].**

In vivo studies have indicated that IKI and CHX may be able to kill calcium hydroxide-resistant bacteria **[17].** However,an obvious disadvantage of iodine is a possible allergic reaction in some patients **[12].** The optimal protocol to use IKI as an irrigant is 5% IKI,its prepared as following: Ten parts potassium iodide and five parts iodine were added to 85 ml of distilled water. The solution obtained was filter sterilized and stored in tightly closed amber‑colored bottle with storage time of <1 month **[22].**

Acids as irrigants

EthyleneDiamine Tetraacetic Acid *(EDTA)*:

Complete cleaning of the root-canal system requires the use of irrigants that dissolve organic and inorganic materials. As hypochlorite is active only against the former, other substances must be used to complete the removal of the smear layer and dentin debris. EDTA effectively dissolves inorganic material including hydroxyapatite.

It has little or no effect on organic tissue and alone it does not have antibacterial activity.

EDTA is a decalcifying chelating agent,it acts as a chelator with calcium ions and removes the dentinal debris produced on the root canal walls during preparation as a 15% to 17% buffered solution.

Whenever the wall of a root canal is instrumented, by hand or mechanically, a smear layer must touch dentin walls surface. EDTA thus opens dentinal tubules, can help open very narrow root canals removing the smear layer and promoting better penetration of disinfectants **[14].**

Calt and Serper (2002) demonstrated that 10mL irrigation with 17% EDTA for 1 minute was effective in the removal of smear layer, but a 10 minute application caused excessive peritubular and intertubular dentin erosion. Increasing contact time has been shown to increase dentin demineralization **[7,13].**

In addition, EDTA which is manufactured as liquid or gel, is of a high cost which makes it worthwhile the use of diluted solution of EDTA **[12].**

Glycolic Acid (GA)

GA has low pKa, low molecular weight, and its organic nature makes it an excellent choice for its performance on mineral surfaces as dental structures.These characteristics indicate the potential of GA for use in the removal of the smear layer in endodontic therapy.

It is shown that GA 17% is effective in reducing the microhardness of the most superficial dentin layer which facilitates the biomechanical preparation considerably under clinical conditions **[19].**

GA by its acidic pH explains the demineralization of dentin which may lead to the reduction of the microhardness and the increase of the surface roughness.

Therefore, softening effects on the dentinal walls with microhardness reduction and increasing roughness, can be advantageous in the clinic because it may have an influence on the physical and chemical properties of the smear layer covering the dentinal tubules which facilitates its elimination especially in the middle and apical third of root canal **[19].**

Maleic Acid (MA)

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%. At high concentrations (10% or higher), it causes demineralization and erosion of the root canal wall. Ballal et al. reported that 1 min application of 7% MA as the final irrigation agent removed the smear layer more effectively than did 1 min irrigation with 17% EDTA especially in the apical third of the root canal system. It has been reported to cause more surface roughening of root canal walls. However, before routine clinical endodontic use, the effects of MA on periapical tissues, its biocompatibility, and appropriate usage techniques need to be investigated **[1].**

Citric Acid (CA)

The use of 10% CA as a final irrigation solution gives very good results in terms of smear layer removal. CA has shown a better good performance in removing the smear layer from root canal walls and was found to be ineffective in eradication of biofilms of *E faecalis* after 10 min of exposure than EDTA **[1].**

Calcium Hydroxide

Ca(OH)2 via its alkaline pH is generally very effective at eradicating intraradicular bacteria, with the exception of *E. faecalis.* Its effectiveness is increased especially when mixed with other common irrigating solutions. Although additive effects could not be confirmed, and a reduction in the antimicrobial action was detected.

The use of calcium hydroxide as an irrigation solution is possible by mixing 10 g of Ca(OH) per 100 ml of sterile water.

To achieve optimal antimicrobial activity, it requires prolonged exposure or higher temperatures for use as an endodontic irrigant **[14].**

Currently, there are several systems and devices available that provide the delivery of warm irrigating solutions. One study suggests that delivering 10% Ca(OH)2 at 46°C would increase its antibacterial efficacy without the addition of more cytotoxic materials. Further studies are needed to test these devices for their effectiveness in maintaining the prescribed level of heat **[22].**

Ozonated water

Ozone has been discussed as a possible alternative antiseptic agent in dentistry because of its reported high antimicrobial power.Ozone (O3) can effectively kill bacteria, including spores even at low concentrations

(0.01 pm) **[14]** without the development of drug resistance. Ozone gas is used clinically for endodontic treatment and can be produced easily with an ozone generator.Ozone dissolves easily and rapidly in water **[14,20]**.

However, results of studies into its efficacy against endodontic pathogens has been inconsistent **[20].** One studie shown that the ozonated water is slightly less cytotoxic than NaOCl (2.5%) ,it is showed that is essentially no toxicity to oral cells in vitro **[20].**

Herbal irrigants

Many plant species have been tested to determine their abilities to disinfect the root canal system in endodontic treatment. Root canal disinfection with garlic, propolis, miswak, neem tree, Morinda citrifolia (MC), Myrtus communis, Myristica fragrance, turmeric, aloe vera, triphala, green tea polyphenols (GTP), Fufang Bingpeng, and other terrestrial plant products has been attempted.

The main advantages of the use of herbal alternatives in root canal treatment are that the products are easy to acquire and inexpensive, have long shelf lives,low toxicity, and cause no microbial resistance.

The most commonly used alternatives include the following:

Triphala: Triphala is a plant blend created by drying and pulverizing the fruit of three plants (termina bellerica, termina chebula, and emblica officinalis) and the mixture is used for medicinal purposes. Triphala kills 100% of *E. faecalis* within 6 min. When used at different rates, its effects can be increased synergistically **[7].**

Green Tea Polyphenols (GTP): GTP are derived from fresh leaves of tea (Camellia sinensis). They have shown a significant antibacterial activity in *E. faecalis* biofilms grown on dental culture, killing E. faecalis completely within 6 min. According to Prabhakar et al. 5% of sodium hypochlorite exhibited excellent antibacterial activity in both 3-week and 6-week biofilm, whereas Triphala showed a complete eradication only in 3-week biofilm. Triphala and GTPs are proven to be safe, containing active constituents that have a beneficial physiologic effect apart from its curative property such as antioxidant, anti inflammatory, and radical scavenging activity and may have an added advantage over the traditional root canal irrigants **[7,13].**

Morinda Citrifolia (MC): MC (noni fruit) has a wide range of therapeutic effects such as antibacterial, antiviral, antifungal, analgesic and anti-inflammatory effects. It contains

L-asperuloside and alizarin, which have antibacterial properties and have an equal ability as NaOCl (6%) and EDTA (17%) to remove the smear layer as a final irrigant.

In addition, it has no harmful effect on the patient or the environment, which is relevant in the context of NaOCl irrigation accidents **[7,13].**

Fufang Bingpeng irrigant presents a promising alternative for use as a root canal irrigant in clinical use.

As an irrigant, it has a low minimum inhibitory concentration (MIC) and a minimum bactericidal concentration (MBC) against *Porphyromonas gingivalis, Fusobacterium nucleatum* and *Enterococcus faecalis.*

It effectively removes the remaining debris and increased the number of open dentinal tubules in root canals compared to the NaCl irrigant by eliminating the organic material in addition to smear layer. Fufang Bingpeng irrigant also presented a low cytotoxicity toward human cells **[21].**

Allium sativum (Garlic extract): It is known by its bacteriostatic and bacterial propertiesIt is capable to damages the cell membrane of the bacteria,it is effective against Gram-positive species.

In 2015 birring et al concluded that garlic extract was effective and showed similar antibacterial efficacy as 5.25% sodium hypochlorite against *E. faecalis* biofilm **[24].**

Propolis: It can be used as an irrigant or temporary medication for its antibacterial,antioxidant and anti-inflammatory properties. In 2014, a study showed that propolis is as effective as 5.25% sodium hypochlorite against E *faecalis* biofilm as many herbal extract.

Miswak :Al-salman et al suggested that 10% of water extract of miswak is an effective antimicrobial when utilised as root canal irrigant with necrotic pulp.

All studies have proven the effectiveness of herbal irrigant alternatives as the same as the hypochlorite of sodium in solving the organic debris and in disinfecting the root canals with less side effects and low cytotoxicity **[24].**

Mixture of irrigants:*MTAD, *QMIX

There is no single irrigating solution that alone sufficiently covers all of the functions required from an irrigant. Optimal irrigation is based on the combined use of 2 or several irrigating solutions **[12,19].**

MTAD (Mixture of Tetracycline isomer, citric Acid and Detergent) and QMIX® have been developed more recently. Both contain surfactants that may lower the surface tension of the irrigant and promote penetration within dentine.

MTAD consists of a Mixture of Tetracycline isomer, citric Acid and Detergent.

Torabinejad et al. introduced a combination of 3% doxycycline, 4.25% CA, and detergent as an alternative to EDTA with the aim of improving smear layer removal. This mixture of three substances expected to affect bacteria synergistically and then acts as a chelator. This mixture shows an excellent smear layer removal, less negative effects on dentine, and good biocompatibility **[1].**

The citric acid component in MTAD effectively removed a smear layer **[14].**

MTAD is effective in removing the smear layer along the whole length of the root canal and in removing organic and inorganic debris and does not produce any signs of erosion or physical changes in dentine,whereas a mixture of 5.25% sodium hypochlorite and 17% EDTA does.

In particular, MTAD mixture is effective against *E. faecalis*, and it is also less cytotoxic than a range of endodontic medicaments, including eugenol,hydrogen peroxide (3%), EDTA, and calcium hydroxide paste **[7,13].**

QMIX® is a mixture of chlorhexidine, EDTA and a surfactant. This solution will not dissolve organic debris and is thus of limited application alone **[15].** If used, these mixture should be regarded as an adjunct to NaOCl at the end of chemomechanical preparation, not a replacement.

Irrigation Devices And Techniques

Several methods of employment of an irrigant inside the canal space are available.

Manual needle irrigation (MNI

The classical way of irrigating the root canal is with a syringe and needle **[12,25].** This conventional irrigation is a widely accepted method for irrigant delivery **[26].** When carefully used, needle irrigation can be effective and sufficient. The choice of an appropriate irrigating needle, therefore, is important. Although larger-gauge needles allow the irrigant to be flushed and replenished more quickly, the wider needle diameter does not allow cleaning of the apical and narrower areas of the root canal system.Irrigant exchange beyond the needle tip reaches only one to three millimeter, depending on the needle type and irrigant flow **[12].**Application of an irrigant into a canal by means of a syringe allows exact placement, replenishing of existing fluid, rinsing out of larger debris particles, as well as allowing direct contact to microorganisms in areas that are reached by the needle tip **[14].**

The actual exchange of irrigant is restricted to 1 to mm apical to the needle tip. Both the diameter and position of the needle outlet determine successful chemomechanical debridement; placement close to working length is required to guarantee fluid exchange.Volume and speed of fluid flow are proportional to the cleansing efficiency inside a root canal.

Excess pressure or wedging of needles into canals during irrigation with no possibility of backflow of the irrigant should be avoided under all circumstances to prevent extrusion of the irrigant into periapical space **[14].**

Recently, different irrigation delivery devices have been recommended to increase the flow and distribution of irrigants within the root canal system **[26].**

Extrusion of irrigating solution through the periapical tissues has been described. For this reason, irrigation needles with a side opening have been developed to minimize the risk of extrusion and tissue damage**[37]**.

Manual Agitation Techniques

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. Agitation of the irrigant and constant refreshment greatly increases the effectiveness of the solutions **[16,27].**

If the apical third of canal system cannot be easily reached by the irrigation needle, a gutta-percha point in a size corresponding to the dimensions of the apical canal can be used to facilitate irrigant exchange in this region.A recent study showed that agitation of the irrigant by active needle irrigation, is effective in increasing the speed of tissue dissolution compared to passive irrigation (no activation or refreshment). This result suggests that movement of the irrigant and refreshment are the key factors in its effectiveness **[14,16].**

Endodontic brushes and specific needles for endodontic irrigation with bristles on their surface is another technique suggested in order to move the irrigant more effectively within the canals. These systems have shown to be valid in the removal of smear layer from root canal walls thus they can be indicated during irrigation with EDTA to improve their efficacy at the end of the preparation **[16].**

Activation systems of irrigant

Multiple activation methods have been proposed to improve the efficacy of irrigants, including negative apical pressure irrigation, ultrasonically activated irrigation, as well as laser activation **[28].**

Negative Pressure Irrigation

Another approach to afford a better access of irrigation solution is so-called negative-pressure irrigation.

This system comprises a macrocannula for the coronal and middle portions and a microcannula for the apical portion **[31]** which are connected to a syringe for irrigation and the aspiration system integrated with the dental unit **[16].** Here, irrigant is delivered into the access chamber, and a very fine needle connected to the dental unit’s suction device is placed into the root canal. Excess irrigant from the access cavity is then transported apically and ultimately removed via suction. Such a system is commercially available (EndoVac) and may prove a valuable adjunct in canal disinfection. Another device that makes use of pressure-suction technology is the RinsEndo system (Dürr Dental, Germany).

It aspirates the delivered rinsing solution into an irrigation needle that is placed close to working length and at the same time activates the needle with oscillations.

The negative pressure irrigation systems (EndoVac) were demonstrated to be significantly more successful and safer in terms of apical extrusion **[31].** The cleaning effect of the RinsEndo unit was found to be superior to conventional needle irrigation **[14].**

Most of the studies on this technique have shown that it is very effective to ensure a greater volume of irrigant in the apical third and excellent removal of debris in this area and in inaccessible areas, with results in most cases similar to those of the ultrasonic activation techniques **[16.]** It has been shown to improve the antimicrobial efficacy of irrigants and to result in a significant reduction of postoperative pain **[30].**

Recent studies have shown that another advantage of the reversed flow of irrigants may be good apical cleaning at the 1-mm level and a strong antibacterial effect when hypochlorite is used, **[11].**

Ultrasonically Activated Irrigation

To enhance irrigation effectiveness,ultrasonically powered instruments have become indispensable now, with well-adapted tips from various manufacturers **[14,32].**

During preparation, ultrasonic tips are able to remove minimal amounts of dentin, conserving as much tooth structure as possible.The tips can be diamond coated to increase their efficiency.

The temperature elevation also takes place during use of ultrasonic power during root canal irrigation and improves the antibacterial effect through warming of the irrigating solution.

Passive ultrasonic agitation

Passive ultrasonic irrigation is defined as activation of the rinsing agent without simultaneous preparation of the root canal walls.The mechanism of action for debris removal was described as acoustic streaming by Ahmad et al. Acoustic streaming is maximized when the tips of the smaller instruments operate at high power and vibrate freely in a solution **[5]**.It is believed to promote tissue removal and tissue dissolution and may be done with a smooth insert to avoid damaging canal walls and altering the canal shape. This strategy allows cleaning of isthmus areas, fins, or C-shaped canals by acoustic streaming and to a lesser extent cavitation, as well as dentinal tubules or lateral canals **[14].**

Active ultrasonic agitation

Active ultrasonic irrigation is defined as a procedure where the irrigant is directed into the canal through the vibrating tip. Several reports have indicated that the various devices may facilitate irrigation such as the EndoActivator ,and Photon Initiated Photoacoustic Streaming Activation **[5,12].**

EndoActivator system Activation (EA)

EndoActivator (EA) (Dentsply, York, PA,USA) is a battery-operated sonic handpiece that uses plastic tips to agitate irrigant solutions vigorously. The activator tips are available in 3 different sizes and produce 2000–10,000 cycles/min **[26,28].**

On the other hand, EA had an improved performance at the apical third, which may be attributed to the maximum oscillation of the amplitude formed at the activator tip located in the apical third of the canal **[28].**

Photon Initiated Photoacoustic Streaming Activation (PIPS)

Recently, a photoacoustic technique called photon-induced photoacoustic streaming (PIPS) has been introduced and gained attention because of its properties that appear to enhance the disinfection of the root canal system **[28].** A light energy phenomenon was reported to enable effective debris and smear layer removal with a newly designed radial and stripped tip or endodontic fiber **[32].**

In this technique,an ultrasonic tip is activated in the canal up to working length and is moved passively in an up-and-down motion without binding to the root canal walls.**[26].**

PIPS operates by transferring the energy to the irrigation molecules, resulting in rapid and powerful shock waves, forcing the irrigant throughout the entire root canal system and appears to be most effective in killing the bacteria deep in the dentinal tubules **[30].** Studies show that there is no significant difference between PIPS or EA in bacterial reduction in the main root canal space.

EDDY® Activation System

Recently, EDDY® (VDW, Munich, Germany), a sonic powered irrigation activation system made of flexible polyamide was introduced. According to the manufacturer, it allows an efficient cleaning of complex root canal systems without the limitations of ultrasound-activated devices.

EDDY® is activated with 5000 to 6000 Hz by an air driven handpiece. The instrument is claimed to create a three-dimensional movement which have only been caused by passive ultrasonic irrigation. EDDY® is a non-cutting, sterile single-use instrument **[3].**

Flexible tips may have an advantage compared to commonly used rigid metal tips when performing the passive ultrasonic irrigation as they may easily reach the crucial apical canal portion even in severely curved root canals and may oscillate despite contact to the canal walls **[3].**

Laser Activation

The first use of laser in endodontics was reported by Weichman and Johnson in 1971 who attempted to seal the apical foramen in vitro with a high power carbon dioxide (CO_2) laser **[38].**

The laser described for cleaning and disinfecting the root canal system are: erbium: yttrium aluminium garnet (Er:YAG), erbium, chromium: yttrium scandium galium garnet (Er,Cr:YSGG); neodymium:yttrium aluminium garnet (Nd:YAG), carbon dioxide (CO_2).

The physical effect of these lasers in root canals depends on the absorption of their wavelengths in biological components such as water, apatite minerals, and various pigmented substances (microorganisms).

Laser activated irrigation is based on the creation of specific cavitation phenomena and acoustic streaming in intracanal fluids as a result of photothermal and photomechanical effects. The strong absorption of laser energy in water and NaOCl causes vaporization and formation of large elliptical vapour bubbles which cause a volumetric expansion of up to 1,600 times the original volume of an irrigant with high intracanal pressure which drives the fluid out of the canal. The bubbles create pressure which sucks fluid back into the canal. This technique was demonstrated to be effective in the removal of intracanal dentine debris and smear layer **[33].**

To improve the surface area of the root canal dentine being irradiated, a helicoidal withdrawing motion from apical to coronal part is proposed when using fibre tips.

Moreover, the root canal preparation with laser and plain fibres is dangerous in curved root canals because of the risk of creating ledges and perforations **[33].**

Several investigators have reported that the effectiveness of lasers depends on many factors, including the power level, the duration of exposure, the absorption of light in the tissue, the geometry of the root canal, and the tip-to-target distance **[34,36].**

Discussion

Unfortunately none of the available irrigating solutions can be regarded as optimal.

In clinical practice, use of a combination of solutions in the correct and a specific sequence is necessary in order to maximally contributes to a successful treatment outcome **[12].**

The main problems related to the use of irrigant solutions, which are highly underlined in the literature, are their inability to reach the apical third and most complex anatomical structures (isthmi and anastomosis), their effectiveness being influenced by the presence of infected organic and inorganic debris, the clinical usage time, and their toxicity to the periapical tissues.

The inability to reach the apex to remove the smear layer in an appropriate manner can be solved using ultrasonic activation or photoactivation systems with greater antimicrobial activity **[35].**

Irrigants are essential for successful debridement of the root canals, but no single solution has been shown to be capable of removing both organic and inorganic parts of the smear layer. Activation of irrigant with different techniques(laser,ultrason pressure….) has been introduced to supplement conventional endodontic cleaning procedures **[33].**

Between fillings, root canals should be irrigated with copious amounts of 2.5% NaOCl solution all along during root canal preparation. After the completion of shaping, the canals should be irrigated with 17% liquid EDTA.

Generally, each canal should be irrigated for at least 1 min with 5–10 ml of chelating solution. After smear layer removal, irrigation with an antiseptic solution can be helpful.

CHX is one of the most promising solutions for final irrigation in this context. It has high affinity for dental hard tissues and its antimicrobial activity persists for a long time once it is bound to the surface **[1,12].**

Conclusion

This article reviewed the potential new irrigants that could substitute the traditional endodontic irrigants. Available literature and studies demonstrate advantages and limitations of each irrigant under consideration and none of them satisfy the requirements of the ideal root canal irrigant completely.

Presently these newer irrigants could be used as an adjunct to NaOCl to enhance its effectiveness.

Recently, differents devices and systems are developed to boost the effects of irrigants by the use of lasers, ultrasonic and others but still not easily available and have no suffisant clinical track.

Future studies of irrigants should focus on the production of a single solution that is biocompatible, easily manipulated,has tissue-solubilizing properties, removes the smear layer, and has antibacterial effects.

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