

Review Article

Endodontic Irrigants: A Review

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Abstract

Irrigation in endodontic treatment is an essential and indispensable step, it has a multitude of beneficial functions and roles, the success of the treatment depends largely on the accuracy with which the organic and anorganic tissue is removed from the root canals using irrigation solutions in addition to mechanical treatment. The purpose of this article is to highlight the benefits of irrigation solutions, the roles of each solution and also comparisons between them. In the endodontic literature there is a wide variety of articles and opinions regarding the effectiveness of each solution, their roles as well as opinions about the best solution for root canal disinfection.

Keywords: Endodontic Irrigants; Root Canal System; Endodontic Infections Treatment; Irrigation Solutions

Introduction

The endodontic system is extremely complex from an anatomical point of view, most of the teeth having lateral channels, accessories, isthmuses that are very difficult or impossible to mechanically instrumentate. Therefore, even if the instrumentation is extremely well performed, it will continue to remain in the root canal, organic and anorganic tissue debris, which will endanger the success of the treatment. This is where irrigation solutions that have the ability to dissolve and remove these tissues come in [1].

Edgar Schäfer mentions in his article "Irrigation of the root canal" which are the main objectives and requirements of lavage solutions [2]:

- Reduction of bacteria inside the canals and neutralization of endotoxins
- Dissolution of vital or necrotic pulp tissue
- Lubrication of channel walls and instruments
- Removal of dentin particles

The following are the requirements of a canal irrigator also according to Edgar Schäfer [2]:

- A broad antimicrobial spectrum
- Biocompatibility
- Ability to dissolve tissues

Celaletin Topbas along with Ozkan Adiguzel, describe the properties of an ideal irrigant: ability to dissolve organic and anorganic tissue, do not cause irritation of the periapical tissues and not interfere with the healing of periapical tissue, instrumentation lubricant, bactericidal and fungicidal effects, to be able to exercise their functions in an environment where blood, serum and protein products are present, to show stability, to disinfect dentin and dentinal tubules, to not stain or weakening the dental structures, to not have negative effects on the sealing abilities of sealers and on the physical properties of the dentin, ease of application and low cost [3].

But as we already know, there is not a single endodontic irrigation solution that meets all these objectives, requirements, properties and qualities. No irrigant by its own forces has been able to dissolve the organic material in the pulp structure and demineralize the calcified organic portion of the canal walls [4]. An ideal irrigation is one in which the properties of two or more solutions are combined into a protocol [1].

The authors CD'Arcangelo, FDI Nardo Di Maio, N Stracci, G Spoto, Malagnino and S Caputi completes these statements with the mention that the dissolution capacity of irrigation solutions depends on certain factors such as: Temperature, concentrations, tissue, washing frequency, pH, tissue area and tissue type [5].

Many researchers and authors mention sodium hypochlorite as the solution of choice in root canal irrigation, as Hena Rahman reports in the article "Endodontic irrigation: an update" and I quote: "Sodium hypochlorite appears to be most ideal irrigant, as it covers more of the requirements for endodontic irrigant than any other compound known" [6]. Or M Haapasalo in his study "Irrigation in endodontics" where he writes the following: Sodium hypochlorite (NaOCl) is the most important irrigant in root canal treatment. It is the only presently used solution that can dissolve organic matter in the canal. Therefore, the use of hypochlorite is of utmost importance in removing necrotic tissue remnants as well as biofilm" [7]. Also, Rajesh Mahant describes NaOCl as „the most ideal, as it covers more of the requirements for endodontic irrigant than any other known compound" [8]. And last but not least CK Hope, G Burnside, SN Chan, LH Giles and FD Jarad in the study "Validation of an extracted tooth model of endodontic irrigation", where they studied the effectiveness of four irrigation solutions in the treatment of twelve extracted teeth using the same mechanical debridement methods. They concluded that of all these four irrigation solutions, 1% sodium hypochlorite was found to be the most effective [9].

When sodium hypochlorite interacts with organic tissue, the following phenomena result: saponification, amino acid neutralization and chloramine reactions. The main problem related to the use of hypochlorite in endodontics is related to its concentration. As Celaletin Topbas says, the higher the hypochlorite concentrations, the better the dissolving effects of organic tissues and in low concentrations, the higher the amount of solution, the closer the effectiveness is to that of the high-concentration solution [3].

When sodium hypochlorite solution is the first irrigant used in the root canal, it has a weak ability to dissolve organic tissues, because the surface of the collagen is covered by hydroxyapatite from the smear layer. To dissolve this layer of hydroxyapatite, it is necessary to use a descaling agent. In this way, NaOCl can act directly on the underlying collagen, causing rapid destruction of collagen in the superficial dentin [10].

But there are also articles and studies that mention the importance of EDTA irrigation solution along with sodium hypochlorite as reported in the article "Effect of endodontic irrigation with 1% sodium hypochlorite and 17% EDTA on primary teeth: a scanning electron microscope analysis" that NaOCl can't remove by itself the anorganic tissue from the endodontic system, therefore it is mandatory to associate ethylenediaminetetraacetic acid with NaOCl, increasing the rate of a successful treatment. [11].

However, these two irrigation solutions should be used in a well-established protocol, because on the tissue on which EDTA has acted, hypochlorite can no longer be used because it can cause erosion in the root dentine [7]. Grawehr, et al., concluded that the interaction between EDTA and sodium hypochlorite had led to the preservation of calcium binding capacity, but on the other hand it led to a sudden and rapid decrease in the amount of chlorine in the NaOCl solution, thus reducing the ability of sodium hypochlorite to degrade organic tissue [12]. Thus, for an optimal effect, it is recommended that the EDTA solution be used in the

final lavage, after the use with hypochlorite has ended [7].

The most commonly used EDTA solution concentration is 17%. By reacting with calcium ions in the dentin, the EDTA solution leads to the formation of soluble calcium chelates [13]. The authors of the article "Time-dependent effects of EDTA on dentin structures" demonstrated that for an efficient removal of the smear layer from the channel wall, irrigation for 1 minute with 17% EDTA solution is sufficient. They also showed an increase in the demineralization of dentin as the contact time between the irrigation solution and the canal walls increases [14].

Chlorhexidine gluconate is another endodontic irrigation solution that has been proposed to replace sodium hypochlorite solution, with some benefits such as much reduced toxicity on periapical tissues, but also disadvantages such as the inability to dissolve pulp tissues. Thus, opinions on chlorhexidine are divided, with authors claiming that CHX is a very good irrigant and others saying that sodium hypochlorite is far superior [15].

Chlorhexidine has a very important power of action against Gram-positive and Gram-negative germs, bacterial spores, fungi and dermatophytes. So CHX is very effective against bacteria, it does not have the ability to remove the biofilm and other organic substances. That is why it is recommended to use only at the end of chemomechanic treatment to benefit from the antibacterial effect, which is prolonged. Chlorhexidine binds to dentin and persists from 72 hours to 12 weeks. It has a collagenolytic effect, by inhibition with broad-spectrum matrices of metalloproteinase. Also, after attachment to the dentin, CHX increases the infiltration of resin into the dental canalicles, leading to increased resistance to the connection [3].

Sodium hypochlorite also reacts with chlorhexidine, producing Para-Chloroaniline (PCA). This reaction product is carcinogenic and covers the surfaces of the channels, leading to blockage of the dental tubules and compromise of the tightness of the canal filling [16].

In addition to the properties that irrigation solutions have, their effectiveness depends to a great extent on how they are used. Traditionally, irrigation is done with syringe and needle with open end with gauge of 27, 30, 31, being indicated to use different syringes for each solution, given the reactions between irrigants [17]. This method is quite modest, because it is difficult to control that the solutions reach up to 1 mm of working length, in the lateral channels or isthmus, showing a high chance of treatment failure [18]. But over time, a multitude of devices have developed to agitate the solutions that have significantly increased their effectiveness, such as:

- EndoActivator

It is one of the most studied irrigant agitating devices, appearing in most studies with extremely good results on the teeth in which it was used [19]. This device is part of a range of endodontic ultrasonic instruments, operating at 167 Hz. [18] EndoActivator facilitates the penetration and renewal of the irrigant in the canal and after its agitation it also performs a mechanical cleaning of the canal walls [6].

- Vibringe System

This device uses the classic syringe to deposit the solution into the canal, but to which it adds sonic vibrations. The vibringe system has a single button and a white LED light [17].

- Endovac

This device uses negative pressure, when the irrigation solution is placed in the pulp chamber, the appliance pushes the solution into the root canal and then sucks it through a thin needle, thus reducing the risk of apical extrusion of the irrigants [17].

- Rinse Endo

Both authors Hena Rahman and Alagarsamy Venkatesh, describes this device as a system based on a pressure-suction mechanism with approximately 100 cycles per minute [17,6].

- **Eddy System**

It is a new ultrasonic system that works at a frequency of 6000 Hz. This high vibration produces "cavitation" and "acoustic flow", physical effects that are triggered by passive ultrasound irrigation [19].

Most authors conclude that the use of ultrasonic devices in endodontic irrigation has significantly improved the quality of treatments compared to traditional syringe irrigation. As Alagarsamy Venkatesh mentions in his study "Recent advances in endodontic irrigation devices", due to the safety factors, capacity of high volume irrigant delivery the newer irrigation devices might change the insight of conventional endodontic treatment. Endo activator, Vibringer, Rinsendo and Endovac are emerging in an effort to better address the challenges of irrigation and also Laurence J Walsh, in the study "Activation of Alkaline Irrigation Fluids in Endodontics", says that the performance of alkaline solutions of NaOCl and EDTA in endodontics can be improved significantly when these are agitated using ultrasonic energy or pulsed lasers [17,18].

Lasers

The development of lasers in medicine began in the 1950s. The laser acts as a light amplifier and promotes the exponential reproduction of photons due to induced emission. Over time, several types of lasers have developed, each with different purposes and roles in dentistry, depending on the wavelengths. The following types of lasers are most often used in dentistry: Nd: YAG with 1064 nm, CO₂ laser with 10600 nm, diode laser with 810-980 nm and erbium laser with 2940 nm/2780 nm. After several specialized studies, it was found that the light emission of lasers has a very good bactericidal effect in root canals [20].

Nd: YAG Laser Principle

Laser light is absorbed by the anorganic component of hard structures, such as phosphates and hydroxyapatite and by the phenomenon of thermochemical ablation leads to disorganization of crystalline structures. Subsequently, the dentin is transformed into an ionizing gas, without debris, porosity or cracks, thus reducing the permeability of the dentin by blocking the dental tubules [21].

On the other hand, the CO₂ laser is absorbed by water from tissues and leads to a rapid increase in temperature and intracellular pressure. These heated particles become incandescent and when deposited again on the irradiated tissue, form a charred layer. In mineral tissues, this irradiation is absorbed by calcium carbonate and phosphates, leading to molecular vibrations and generalized heat due to the removal of dental tissues [21].

The author Paloma Montero-Miralles and collaborators, in the study "Effectiveness of Nd:YAG Laser on the elimination of debris and Smear Layer. A comparative study with two different irrigation solution: EDTA and QMix® in addition to NaOCl", evaluated the effectiveness of the Nd: YAG laser in removing the dental debris from the root canals. They used 50 extracted teeth that they divided into 5 different groups, on each group using distinct irrigation protocols using EDTA and QMix solution. They concluded that the best cleaning in the apical third was obtained in the group in which the EDTA solution was used together with laser compared to the group in which it was used the EDTA solution alone and also in the group in which the QMix solution was used along with the Nd: YAG laser, the results were much higher compared to the group in which the QMix solution was used alone [22].

In root canal irrigation, of major importance is the level at which the needle must be inserted into the canal, depending on this, the success or failure of removing all pulp or necrotic debris from the apical third, achieving the most favorable result when the irrigation solution reaches as close as possible to the apical foramen. But with this, there are also risks, with the possibility that the irrigants can overcome the endodontic system and penetrate into the periapical tissues, leading to complications. Hacer Aksel conducted a study of 30 extracted straight-rooted uniradicular teeth in which he demonstrated the amount of irrigant that exceeds the apical foramen during lavage at different levels of needle application in the canal, which is at 2 and 4 mm from the apical foramen and at different apical-enlargement, so that the teeth were separated in two groups, one with a diameter of 1.10 mm and the other one with a diameter of 1.70 mm. He concluded that the extrusion of the irrigation solution is greatly influenced by the apical diameter of the canal and the level at which the needle is inserted, so that the largest extrusion of the irrigant was found to be in teeth with an apical diameter of 1.10 mm, if the needle was placed at 2 mm from the apical foramen [23].

Also, the prevention of irrigation can be done using the above mentioned sonic and ultrasonic irrigation devices, which are designed so that they draw the solution already used out of the canal.

As mentioned in the study "Endodontic irrigants: Different methods to improve efficacy and related problems" by Mario Dioguardi, the activation of ultrasonic irrigation can solve the problem of the inability of the conventional irrigation method to place the solutions in the apical third, leading to the failure to completely remove the detritus and the risk of extrusion of the irrigant when the needle is placed too deep in the canal. It also says that there are risks also in sonic/ultrasonic systems, but much lower and the best device to avoid any inconvenient is the EndoVac system [24].

Eudes Gondim and the collaborators reached the same conclusion in the study "Postoperative Pain after the Application of Two Different Irrigation Devices in a Prospective Randomized Clinical Trial", where they compared postoperative pain in patients endodontic treated using two different irrigation systems, namely the EndoVac system and an endodontic syringe. The conclusion was that in patients using the apical negative pressure system, postoperative pain after 4, 24 and 48 hours was significantly lower than in patients using conventional irrigation as well as the intake of analgesics [25].

Many times, endodontic treatments cannot be completed in a single session and it is necessary to place intracanal fillings between treatment sessions, which have many benefits in eliminating the infection from the root canals, relieving pain, reducing inflammation. Among these pansaments are calcium hydroxide and triple antibiotic paste, a mixture of metronidazole, ciprofloxacin and minocycline. But the problem comes when we have to remove these medicaments from the root canals.

Hacer AKSEL studied several irrigation protocols and systems in order to remove Triple Antibiotic Paste (TAP) from root canals, including passive ultrasonic irrigation, sonic irrigation and brush-covered needles. The study was based on fifty-six front teeth. Irrigation was done using 2 ml of 2% NaOCl solution and the mechanical instrumentation was done with the Protaper rotativ system. The teeth were divided into 5 groups, each group using a different irrigation system, namely: first group - Conventional irrigation with syringe, second group - NaviTip FX system, third group - Vibringe-Syringe irrigation, fourth group - Vibringe NaviTip FX and fifth group - Passive ultrasonic irrigation. The most effective removal of antibiotic paste from the channels was provided by NaviTip FX and Vibringe NaviTip FX systems [26].

On the same subject is the article "Efficacy of different endodontic irrigation protocols in calcium hydroxide removal" written by Elka N Radeva and Desislava M Tsanova. This study was conducted on 36 monoradicular teeth, all of which were instrumented with the same Revo-S rotary system and irrigated with 2 ml sodium hypochlorite solution with a concentration of 5.25%, after which calcium hydroxide was applied. Four irrigation methods were used to remove the paste from the canals: conventional syringe irrigation, irrigation and reshaping with the Revo-S system, passive ultrasonic irrigation and a control group in which distilled water irrigation was carried out. The results were a success for the Revo-S system followed by ultrasonic irrigation, but the authors conclude that there is no standard technique for removing this type of intracanal medicaments from the root canals and more complex protocols are needed [27].

Since conventional irrigants have their limits, nanoparticles have been used to create new irrigation materials. Chitosan nanoparticles have demonstrated improved antibiofilm effectiveness and the ability to neutralize bacterial endotoxins. An organized release of singlet oxygen species is used to demonstrate how these nanoparticles accelerate bacterial breakdown. They are advised for use as a final rinse in root canal irrigation since they are not harmful to eukaryotic cells [28].

With each passing year, the impact of nanoparticles on dentistry and particularly endodontics for the treatment of numerous oral disorders, is advancing quickly. Due to their superior physical, mechanical, chemical and biological characteristics, Nanomaterials (NMs) have recently become more significant in technological breakthroughs. When compared to the performance of their conventional counterparts, these features have produced better results [29]. Nanomaterials have demonstrated considerable potential in reducing biofilm development, enhancing tooth remineralization by preventing demineralization and combating caries-related and endodontic microorganisms. These positive findings have paved the way for additional clinical research that will confirm the therapeutic efficacy of materials derived from nanotechnology [29].

Antimicrobial nanoparticles are also more effective in penetrating biofilms, require fewer dosages to exert their effects and could potentially reduce the need for antibiotics, whose use is on the rise. The similar modes of action seen in several antibacterial nanoparticles. Nanoparticles have the ability to embed themselves into biofilms and engage in electrostatic interactions with bacterial cell walls. This causes cell membrane damage, increased cell permeability, the production of reactive oxygen species, disruption of cellular processes, protein degradation, DNA damage, and, ultimately, cell death [30,31].

Several disasters that may occur during the use of endodontic irrigation solutions in the patient have been described in the specialized studies. These include:

- **Destruction of Clothes**

This accident can occur when, during manual irrigation with conventional syringe, the needle-syringe system is not properly connected and as a result of pressure they unwind, or during the use of ultrasound systems, aerosols can reach patients' clothes, destroying them, causing them to be damaged, when adequate protection is not used for the patient.

- **Damage to the Eyes**

When irrigation solutions come into contact with the eyes of patients, pain, tears, burns, erythema may occur. It is recommended to wash the eye area with plenty of water and the patient should go to an ophthalmological examination.

- **Allergic Reactions to Sodium Hypochlorite Solution**

When the patient has this allergy, during treatment suddenly pain, burning sensation, swelling of the soft parts and abundant bleeding from the root canal occurs. The pain goes away quite quickly, but the swelling can persist for up to 3 days. The patient is recommended general antibiotic treatment and if he has breathing problems, he is sent to an emergency care unit.

- **Extrusion of Hypochlorite in Periapical Tissues**

This accident can occur in teeth with wide apical foramen, teeth with root resorbs, or in teeth where apical constriction has been over instrumented. The presence of irrigation solutions beyond the apex can lead to tissue necrosis. In these cases, severe pain, echimosis, hematoma and heavy bleeding from the canal can occur. The patient is recommended to take antibiotics generally, leaving the canal open for drainage. The pain relieves quickly and cold compresses are applied to the tumefaction, then replaced with warm compresses to stimulate blood circulation [32].

Conclusion

Besides these disadvantages that irrigation solutions present, they have a lot of benefits for endodontic treatment, without which it could not be realized. As we have previously presented, in the specialized literature sodium hypochlorite is considered the irrigant of choice for the success of endodontic treatment along with ethyldiaminotetraacetic acid and to increase the effectiveness of irrigation solutions, it is recommended to use ultrasonic lavage techniques, as shown to have a much higher success rate compared to conventional syringe irrigation.

Contribution Note

All the authors equally contributed to the drawing up of the present paper.

Conflict of Interest

The authors have no conflict of interest to declare.

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