MedNEXT
Journal of Medical an Health Sciences

REVIEW ARTICLE

DOI: 10.54448/mdnt24S103

Clinical significance of the main methods of root canal irrigation in endodontics: a systematic review

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DOI: https://doi.org/10.54448/mdnt24S103
Received: 12-07-2023; Revised: 02-10-2024; Accepted: 02-15-2024; Published: 02-17-2024; MedNEXT-id: e 24S103

Abstract

Introduction: In the context of endodontic treatments, irrigation is one of the most important aspects of the biomechanical preparation of the root canal. The arsenal of irrigation solutions designed for endodontic treatment and commercially available is broad. The choice of the correct solution depends on the combination of the properties of the solution associated with the effects to be obtained with irrigation, according to the clinical condition. **Objective:** It was to carry out a systematic review of the different endodontic irrigation methods, as well as to show the different clinical indications for use, comparing the effectiveness, biocompatibility, and influence on the dentin surface of irrigation solutions. **Methods:** The PRISMA Platform systematic review rules were followed. The search was carried out from October to December 2023 in the Scopus, PubMed, Science Direct, Scielo, and Google Scholar databases. The quality of the studies was based on the GRADE instrument and the risk of bias was analyzed according to the Cochrane instrument. **Results and Conclusion:** A total of 115 articles were found, 50 articles were evaluated in full and 41 were included and developed in the present systematic review study. Considering the Cochrane tool for risk of bias, the overall assessment resulted in 10 studies with a high risk of bias and 25 studies that did not meet GRADE and AMSTAR-2. Most studies did not show homogeneity in their results, with X^2=57.8%<50%. It was concluded that irrigation plays a fundamental role in the success of endodontic treatment. Although hypochlorite is the most important irrigating solution, no irrigant can perform all of the tasks required by irrigation. A detailed understanding of the mode of action of various solutions is important for optimal irrigation. New developments such as mechanical devices will help promote safe and effective irrigation. Within the limitations of this study, the use of the selfadjusting file system with the combination of EDTA and NaOCl improved $Ca(OH)_2$ removal. The passive ultrasonic irrigation and the self-adjusting file system were more effective in removing $Ca(OH)_2$ from the lateral grooves in the apical parts of the root canal than the EndoVac and conventional syringe irrigation systems.

Keywords: Endodontic treatment. Endodontic irrigation. Clinical indications. Effectiveness. Biocompatibility.

Introduction

In the context of endodontic treatments, endodontic therapy aims to remove debris from the pulp tissue resulting from root preparation and microorganisms from the root canals, seeking complete cleaning and antisepsis [1,2]. Irrigation is one of the most important aspects of the biomechanical preparation of the root canal, since, through this procedure, the irrigating solution can reach places where instruments cannot reach, due to the complex anatomy of the root system [1,3].

The arsenal of irrigation solutions designed for endodontic treatment and commercially available is broad. The choice of the correct solution depends on the combination of the properties of the solution associated with the effects to be obtained with irrigation, according to the clinical condition [1-3]. In cases where the pulp is mortified and there is an infection, irrigating solutions have the function of promoting asepsis, dissolving the necrotic tissue, and facilitating its removal, in addition to neutralizing the bacterial toxin [4-6].

In this context, ethylenediaminetetraacetic acid (EDTA) is generally used after endodontic instrumentation for its chelating action by which it removes the smear layer. EDTA in endodontics was introduced in 1957 by Ostby, in the form of a 15.5% aqueous solution with pH 7.3. This facilitates atresia of the irrigating instrumentation channels and can demineralize dentin through stable calcium ions. As EDTA is one of the most commonly used endodontic irrigants, the clinician needs to be aware of the properties of the irrigator [7].

Added to this, the drug calcium hydroxide, $Ca(OH)_2$ with good antimicrobial properties against the majority of endodon-2 is used in endodontic treatment as tactically relevant intracanal pathogens. Research shows that remaining $Ca(OH)_2$ in dentin walls can affect the penetration of sealers into dentinal tubules and increase apical leakage. Therefore, it is recommended to completely remove the $Ca(OH)_2$ placed inside the root canal before filling the root system [8].

Thus, the most frequently described method for $Ca(OH)_2$ removal is root canal instrumentation with a main apical file at working length and copious irrigation of sodium hypochlorite (NaOCl) and EDTA. Previous studies have investigated the effectiveness of $Ca(OH)_2$ removal with different irrigation devices and systems. Continuous passive ultrasonic irrigation (PUI) uses an ultrasound-activated file inside the root canal with a continuous irrigant delivered by the handpiece. Studies showed that PUI was more effective in removing $Ca(OH)_2$ from root canal walls than positive pressure irrigant release [9].

The EndoVac system (Discus Dental, Culver City, CA) is an apical negative pressure (ANP) irrigation device designed to deliver irrigation solutions to the apical portion of the canal system and to aspirate debris. The ANP of the EndoVac system effectively cleans dentin surfaces. ANP irrigation with sufficient volume and flow removes smear layers and displaces debris [9].

Furthermore, the self-adjusting file system (SAF) (Re-Dent-Nova, Ra'nana, Israel) adapts to the three-dimensional shape of the root canal to allow continuous irrigation during the preparation and activation of irrigants by vibration. The SAF system is operated by vibrating a mildly abrasive lattice in an in-and-out motion to remove dentin. SAF is more effective in removing dentin debris from the root canal than rotary instrumentation. However, whether SAF can remove the drug $Ca(OH)_2$ from the root canal wall is not known [10].

Given this, the present study carried out a systematic review of the different endodontic irrigation methods, as well as showing the different clinical indications for use, comparing the effectiveness, biocompatibility, and influence on the dentin surface of irrigation solutions.

METHODS

Study Design

The present study followed the international systematic review model, following the rules of PRISMA (preferred reporting items for systematic reviews and meta-analysis). Available at: http://www.prisma-statement.org/?AspxAutoDetectCookieSupport=1. Accessed on: 11/21/2023. The methodological quality standards of AMSTAR-2 (Assessing the methodological quality of systematic reviews) were also followed. Available at: https://amstar.ca/. Accessed on: 11/21/2023.

Data Sources and Research Strategy

The literary search process was carried out from October to December 2023 and was developed based on Scopus, PubMed, Lilacs, Ebsco, Scielo, and Google Scholar, covering scientific articles from various eras to the present. The descriptors (MeSH Terms) were used: *"Endodontic treatment. Endodontic irrigation. Clinical indications. Effectiveness. Biocompatibility"*, and using the Boolean "and" between the MeSH terms and "or" between historical discoveries.

Study Quality and Risk of Bias

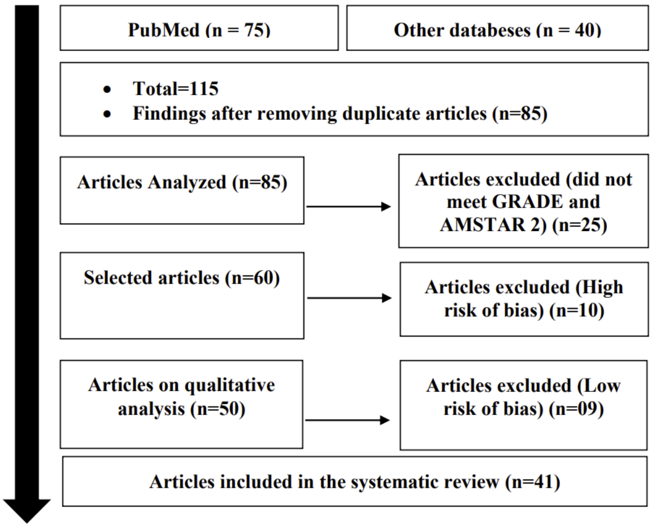
Quality was classified as high, moderate, low, or very low in terms of risk of bias, clarity of comparisons, precision, and consistency of analyses. The most evident emphasis was on systematic review articles or meta-analyses of randomized clinical trials, followed by randomized clinical trials. The low quality of evidence was attributed to case reports, editorials, and brief communications, according to the GRADE instrument. The risk of bias was analyzed according to the Cochrane instrument by analyzing the Funnel Plot graph (Sample size versus Effect size), using the Cohen test (d).

Results and Discussion

Summary of Findings

A total of 115 articles were found that were subjected to eligibility analysis, with 41 final studies being selected to compose the results of this systematic review. The studies listed were of medium to high quality (Figure 1), considering the level of scientific evidence of studies such as meta-analysis, consensus, randomized clinical, prospective, and observational. The biases did not compromise the scientific basis of the studies. According to the GRADE instrument, most studies showed homogeneity in their results, with X^2=57.8%<50%. Considering the Cochrane tool for risk of bias, the overall assessment resulted in 10 studies with a high risk of bias and 25 studies that did not meet GRADE and AMSTAR-2.

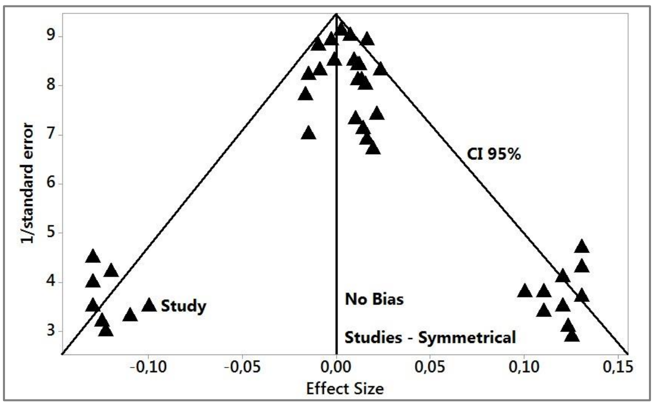
Figure 1. Article selection - exclusion process.



Source: Own authorship.

Figure 2 presents the results of the risk of bias of the studies using the Funnel Plot, showing the calculation of the Effect Size (Magnitude of the difference) using the Cohen Test (d). Precision (sample size) was determined indirectly by the inverse of the standard error (1/Standard Error). This graph had a symmetrical behavior, not suggesting a significant risk of bias, both between studies with a small sample size (lower precision) that are shown at the bottom of the graph and in studies with a large sample size that are presented at the top.

Figure 2. The symmetric funnel plot suggests no risk of bias among the small sample size studies that are shown at the bottom of the graph. High confidence and high recommendation studies are shown above the graph (n=41 studies).



Source: Own authorship.

Major Clinical Outcomes

The success of endodontic treatment depends on eradicating microbes (if present) from the root canal system and preventing reinfection. The root canal is formed with manual and rotary instruments under constant irrigation to remove inflamed and necrotic tissue, microbes/biofilms, and other debris from the root space [1,2]. The main purpose of instrumentation is to facilitate effective irrigation, disinfection, and filling. Several studies using advanced techniques such as microcomputed tomography have demonstrated that proportionally large areas of the main root canal wall remain untouched by instruments, emphasizing the importance of chemical means to clean and disinfect all areas of the root canal [1-3].

There is no single irrigation solution that, by itself, sufficiently covers all the functions required of an irrigant [2,3]. Optimal irrigation is based on the combined use of 2 different irrigating solutions, in a specific sequence, to predictably achieve the objectives of safe and effective irrigation. Traditionally, irrigants are distributed into the chest canal space using syringes and metal needles of different sizes and designs [4]. Clinical experience and research have demonstrated, however, that this classical approach typically results in ineffective irrigation, particularly in peripheral areas such as the canals, fins, and the most apical part of the main root canal [11-14]. Therefore, many of the compounds used for irrigation have been chemically modified and several mechanical devices have been developed to improve the penetration and effectiveness of irrigation [15-19].

In this sense, the removal of the smear layer generated during instrumentation of the root canal walls is an essential condition for better antimicrobial efficacy of the irrigation solution in the dentinal tubules, in addition to improving the sealing capacity of the obturator [10]. The power of removing the smear layer by the EDTA chelator makes it one of the most used in root canal irrigation. This is often used as the gold standard for smear layer removal in comparative studies conducted in research comparing the effectiveness of 17% EDTA to 7% maleic acid and observed greater effectiveness of maleic acid in removing the smear layer from apical third of single-rooted human teeth. When compared to maleic acid, 5% EDTA and 17% proved to be equally effective [11].

Also, in a study that evaluated the removal of the smear layer in scanning electron microscopy (SEM) for various irrigation agents (EDTA, apple cider vinegar, 5% maleic acid, acetic acid, and distilled water as control), EDTA promoted the best results, proving to be the most effective solution [12]. Another work, noting the removal of the smear layer with an SEM evaluation, was carried out by Cehreli et al. (2013) [20]. This work, carried out in vivo, promoted instrumentation and irrigation channels with 5.25% NaOCl or 17% EDTA or MTAD Biopure, and were immediately extracted. Among these irrigation solutions, EDTA showed significantly better results at the expense of greater dentin erosion.

In a study by Zia et al. (2014) [21] carried out on extracted teeth, it was possible to observe the equivalence of EDTA to MTAD Biopure, being more efficient than brine. Another study compared three different formulations of QMix with EDTA and found better efficacy of QMix in removing the smear layer in the apical third and equivalence between the results of the solutions in the middle and cervical thirds, showing a viable alternative to EDTA for the end of irrigation. The alternative would be to use EDTA gel, which is as effective as liquid under the same concentrations and conditions of use.

Antimicrobial Action

As it is well used in the endodontic irrigator, EDTA has studied its antimicrobial properties, as is usually the final irrigating treatment [9]. Bryce et al. (2009) [22] carried out a study to verify the antimicrobial action of irrigating agents on biofilms of microorganisms isolated from root canals. The authors observed low antimicrobial efficacy of EDTA on biofilm, especially when compared to sodium hypochlorite. Furthermore, EDTA, which conditions dentin in a way that allows an increase in the number of attached microorganisms, as well as in the resistance to their adhesion, and compared to other types of irrigation, has low retention power in reinfection or residual activity is low, which can only be improved by adding auxiliaries to a composition [23-25].

In mixed biofilms developed in situ in the oral cavity, Ordinola-Zapata et al. (2012) [26] evaluated the effectiveness of irrigation agents commonly used in endodontics and found that sodium hypochlorite was the most effective for dissolving and exhausting biofilm. However, EDTA was not effective for this purpose and had a share compared to saline. Low effectiveness of EDTA results was found in another study in which we compared EDTA to Qmix, 0.2% cetrimide, 2% chlorhexidine, and EDTA, the antimicrobial activity, and also the substantivity. However, some contradict these findings. There is a study that shows almost no potential for disrupting the biofilm structure; however, a high antimicrobial potential of EDTA, reaching levels similar to those of sodium hypochlorite when used at pH 12 and 50 mmol/L, affecting the integrity of the biofilm membrane 24 hours *E. faecalis, L. paracasei and S. anginosus* [26].

Furthermore, EDTA also has antifungal activity against *Candida albicans*, which is a fungus commonly associated with endodontic failures. Evaluation of the antifungal effect of EDTA on ethylene glycol tetraacetic acid, titanium tetrafluoride, sodium fluoride, nystatin, ketoconazole, EDTA, and titanium tetrafluoride showed better antifungal activity. This study corroborates another previous study that compared EDTA halo inhibition about various antifungals and sodium hypochlorite and EDTA with more satisfactory results [27].

One way to improve the antimicrobial action of EDTA would be its association with cetrimide. Ferrer-Luque et al. (2010) [24] found that EDTA associated with the same 15% cetrimide, compared to maleic acid, has a lower antimicrobial activity. Furthermore, EDTA has a low potential to prevent root canal recolonization and, therefore, another irrigant solution can be associated with it to improve the substantive action of the final irrigant. One of the viable options studied is the addition of cetrimide EDTA with promising results [28,29].

Biocompatibility

Chandrasekhar et al (2013) [30] injected 0.1 mL of various solutions into the back of mice and found that EDTA had toxicity similar to QMix and was less toxic when compared to 3% NaOCl, and more toxic than saline solution. In a more recent study, Prado et al (2015) compared the cytotoxicity of 17% EDTA compared to 37% phosphoric acid, 10% citric acid, 5.25% NaOCl, and 2% chlorhexidine. In this study, a lower cytotoxicity of EDTA and citric acid can be observed, when compared to other substances tested, showing a good biocompatibility of EDTA.

An alternative EDTA (EDTA-T) to the conventional one was studied and showed good results for removing the smear layer and good antimicrobial action, but demonstrated a greater potential to generate inflammation than conventional 17% EDTA and 10% citric acid. Even when compared to light-sensitized personnel, FotoSan EDTA showed similar cytotoxic action, showing a biocompatible material and similar to other decontamination methods used [14].

Changes in Dentin

Studies have shown that, in addition to removing microorganisms, and dissolved organic and inorganic matter irrigators are capable of damaging the microstructure of dentin, leading to changes in the organic material/inorganic surface [15]. The type and intensity of these changes in the proportion of dentin components depend on the irrigation solution used and can influence the quality of adhesion of sealants and cement used for intraradicular cementation [16].

Another study evaluated the effects of QMix EDTA Chlorhexidine + EDTA + NaOCl and maleic acid on the microhardness of root dentin. In this study, the authors found that maleic acid has a high ability to reduce dentin hardness compared to the other groups. The smallest reduction in hardness was found in the combination of EDTA + NaOCl, which can be explained by the fact that one substance has the power to neutralize the other [28].

Still, other work examined the effect of final irrigation protocols (17% EDTA, Biopure MTAD, and SmearClear QMiX) on dentin root canal hardness and erosion [31-34]. All irrigating agents promoted a reduction in dentin hardness and EDTA promoted erosion of the dentinal tubules. When compared to alternative chelating agents, such as 2.25% peracetic acid, which has demonstrated good antimicrobial power, 17% EDTA shows similar erosion on dentin walls [35-38]

Also, Ballal et al (2013) [39] evaluated the influence of irrigants (EDTA, 2.5% NaOCl, maleic acid, and 7% QMix) on the wettability of two types of cement (AH Plus and ThermaSeal) in intra-radicular dentin. QMix proved to be the most favored irrigator over the wettability of cement in the root canal dentin, which promoted better adhesion and sealing of the obturator. As Aranda-Garcia et al 2013 [38] studied the influence of three different irrigating adhesives (QMix, EDTA, and Smear Clear) on an epoxy cement resin, not verifying the interference of the adhesiveness of these materials on the root canal wall.

Besides, Elnaghy (2014) [40] carried out a study that evaluated the influence of various irrigations on the adhesion of sealants, dentine, and MTA. The author found that QMix did not influence the adhesion of the materials and obtained results similar to those of EDTA and NaOCl. Another study carried out by Elnaghy (2014) [41] to evaluate the influence of EDTA associated with chlorhexidine on the adhesion of fiberglass posts cemented with resin cement in the root canal and showed that QMix and EDTA associated with chlorhexidine provided the best adhesion results.

There are contradictory results in the literature regarding the need for $Ca(OH)_2$ removal [17-21]. However, it is well established that residual $Ca(OH)_2$ must be removed because it influences the bonding and sealing of endodontic materials. The use of the SAF system with the combination of EDTA and NaOCl enhanced $Ca(OH)_2$ removal [22].

Thus, the combination of EDTA and NaOCl as a final rinse did not play an important role in removing $Ca(OH)_2$ residues from the dentin walls. The differences between the studies may have originated from the use of SAF to remove $Ca(OH)_2$. Previous studies have used a standardized artificial groove design in assessments of $Ca(OH)_2$ drug removal. Furthermore, this model allows standardizing the size and location of the grooves and the amounts of medication used before irrigation. A disadvantage of this standardized artificial groove design is that it does not represent the complexity of a natural root canal system [23].

Thus, a study showed that passive ultrasonic irrigation (PUI) with continuous irrigation and SAF were more effective than EndoVac and conventional syringes in removing $Ca(OH)_2$ medication from a standardized artificial groove in the apical part of the root canal. Similar to these findings, several previous studies showed that $Ca(OH)_2$ drug removal was superior to PUI compared to conventional syringe irrigation and sonic irrigation [24-28]. The higher irrigating flow velocity generated by PUI may explain its efficiency in removing $Ca(OH)_2$ from root canals. The efficiency of PUI is also improved by replacing fresh irrigants [29-32].

It can be assumed that the removal of $Ca(OH)_2$ medication may influence the suction effect of the microcannula and result in insufficient removal of Ca(OH)2. The SAF system improved gutta-percha removal from the root canal. However, there is no data available in the literature on the effect of SAF on $Ca(OH)_2$ drug removal [32-37]. The artificial groove model was created in the apical part of the root canal to simulate non-instrumented extensions of the canal [38]. Studies report that removal of $Ca(OH)_2$ medication from the apical part of the root canal wall is very difficult [39]. After the removal of the $Ca(OH)_2$ drug from the main channel, remnants may remain in channel extensions or irregularities [40,41].

Conclusion

It was concluded that irrigation plays a fundamental role in the success of endodontic treatment. Although hypochlorite is the most important irrigating solution, no irrigant can perform all of the tasks required by irrigation. A detailed understanding of the mode of action of various solutions is important for optimal irrigation. New developments such as mechanical devices will help promote safe and effective irrigation. Within the limitations of this study, the use of the SAF system with the combination of EDTA and NaOCl improved $Ca(OH)_2$ removal. The passive ultrasonic irrigation and the self-adjusting file system were more effective in removing $Ca(OH)_2$ from the lateral grooves in the apical parts of the root canal than the EndoVac and conventional syringe irrigation systems.

Acknowledgement

Not applicable.

Ethical Approval
Not applicable.

Informed consent
Not applicable.

Funding
Not applicable.

Data sharing statement
No additional data are available.

Conflict of interest
The authors declare no conflict of interest.

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