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Major root endodontic treatments: a systematic review

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Abstract

Introduction: In the root canal treatment scenario, irrigation is one of the most important aspects of the biomechanical preparation of the root canal. A condition for successful endodontic retreatment is adequate cleaning of the root canals, therefore, special attention should be paid to the technique used to remove the filling material, the most commonly used being cement, pastes, and gutta-percha cones. **Objective:** This study aimed to present the main root endodontic treatments to analyze and compare the techniques for removing pulp tissue debris resulting from root preparation and microorganisms from the canals of the root canal system, seeking complete cleaning and asepsis. **Methods:** The PRISMA Platform systematic review rules were followed. The search was conducted from April to July 2024 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:** 129 articles were found, 39 were evaluated and 21 were included in this systematic review. Considering the Cochrane tool for risk of bias, the global assessment resulted in 25 studies with a high risk of bias and 27 studies that did not meet GRADE. Most studies showed homogeneity in their results, with X^2 =91.5% >50%. It was concluded that the system of root canal instrumentation with rotary files maintains the quality of root preparation and, at the same time, reduces the number of files required to obtain a canal, which would consequently reduce the operative time and also considerably reduce the risk of torsion fracture within the root canal than with files. Irrigation plays a fundamental role in the success of endodontic treatment. Although hypochlorite is the most important irrigant solution, no irrigant can perform all the tasks required by irrigation. A detailed understanding of the mode of action of various solutions is important for optimal irrigation. Within the limitations of this study, the use of the self-adjusting file with the combination of EDTA and NaOCl improved $Ca(OH)_2$ removal. Passive ultrasonic irrigation and the self-adjusting file were more effective in removing $Ca(OH)_2$ from the lateral sulci in the apical parts of the root canal than the EndoVac and conventional syringe irrigation systems.

Keywords: Root treatments. Endodontic treatments. Irrigation systems. Cleaning. Asepsis.

Introduction

In the context of root treatment, endodontic therapy aims to remove pulp tissue debris resulting from root preparation and microorganisms from the canals of the root canal system, seeking complete cleaning and asepsis. 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, due to the complex anatomy of the root system [1,2].

In this sense, the arsenal of irrigation solutions designed for endodontic treatment and commercially available is wide. 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 [3]. In cases where the pulp is mortified and there is an infection, irrigating solutions have the function of promoting asepsis, dissolving 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 due to its chelating action by removing the smear layer. EDTA in endodontics was introduced in 1957 by Ostby, in the form of a 15.5% aqueous solution and pH 7.3. It facilitates the atresia of the irrigating instrumentation canals and can demineralize dentin through stable calcium ions. Since EDTA is one of the most widely used endodontic irrigants, the clinician needs to be aware of the properties of the irrigator [7].

In addition, the drug calcium hydroxide - $Ca(OH)_2$ - with good antimicrobial properties against most endodontic-2 is used in endodontic treatment as tactically relevant intracanal pathogens. Research has shown that remaining $Ca(OH)_2$ in the dentin walls can affect the penetration of sealers into the dentinal tubules and increase apical leakage. Therefore, complete removal of $Ca(OH)_2$ deposited within the root canal is recommended before root obturation [8].

Thus, the most frequently described method for $Ca(OH)_2$ removal is root canal instrumentation with an apical main file at working length and copious irrigation with sodium hypochlorite (NaOCl) and EDTA. Previous studies have investigated the efficacy of $Ca(OH)_2$ removal with different devices and irrigation systems. Continuous passive ultrasonic irrigation (PUI) uses an ultrasound-activated file within the root canal with a continuous irrigant delivered by the handpiece. Studies have shown that PUI was more effective in removing $Ca(OH)_2$ from the root canal walls than positive-pressure irrigant delivery [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 dislodges debris [10].

Also, the self-adjusting file (SAF) system (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 the irrigants by vibration. The SAF system is operated by vibrating a mildly abrasive lattice in an in-and-out motion to remove dentin. The SAF is more effective in removing dentin debris from the root canal than rotary instrumentation. However, whether SAF can remove $Ca(OH)_2$ from the root canal wall is not known [11].

A condition for successful endodontic retreatment is adequate cleaning of the root canals, therefore, special attention should be paid to the technique used to remove the filling material, the most commonly used being sealers, pastes, and gutta-percha cones. In retreatment, we have to reach the actual working length and completely remove the filling material, clean the root canal, and the final obturation. Several techniques are described in endodontic retreatment for the removal of gutta-percha, including rotary instruments, hand instruments, solvents, and their associations [2,3].

Given this information, the present study aimed to present the main root endodontic treatments to analyze and compare the techniques for removing pulp tissue debris resulting from root preparation and microorganisms from the canals of the root canal system, seeking complete cleaning and antisepsis.

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: 04/15/2024. The methodological quality standards of AMSTAR-2 (Assessing the methodological quality of systematic reviews) were also followed. Available at: https://amstar.ca/. Accessed on: 04/15/2024.

Research Strategy and Search Sources

The literary search process was carried out from April to July 2024 and was developed based on Scopus, PubMed, Science Direct, Scielo, and Google Scholar, covering scientific articles from various eras to the present. The Health Science Descriptors (DeCS/MeSH Terms) were used: *"Root treatments. Endodontic treatments. Irrigation systems. Cleaning. Asepsis"*, and using the Boolean "and" between the terms MeSH and "or" between historical discoveries.

Study Quality and Risk of Bias

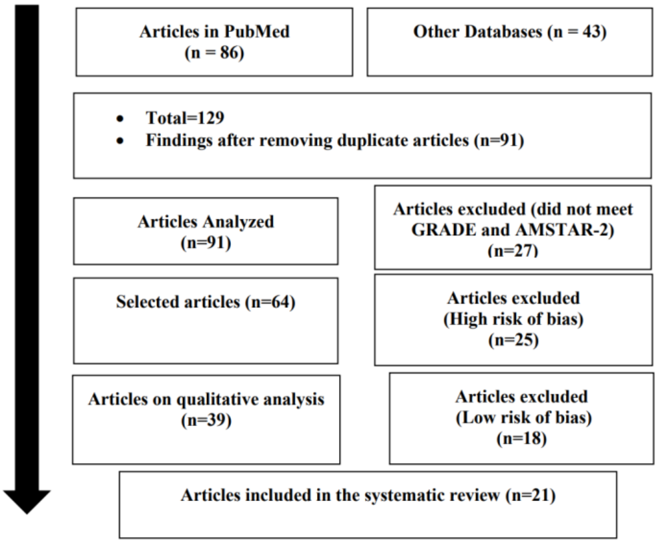
Quality was classified as high, moderate, low, or very low in terms of risk of bias, clarity of comparisons, precision, and consistency of analyses. The most evident emphasis was on systematic review articles or meta-analyses of randomized clinical trials, followed by randomized clinical trials. The 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

As a corollary of the literary search system, a total of 129 articles were found that were subjected to eligibility analysis and, subsequently, 21 of the 26 final studies were selected to compose the results of this systematic review. The studies listed were of medium to high quality (Figure 1), considering in the first instance 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=91.5%>50%. Considering the Cochrane tool for risk of bias, the overall assessment resulted in 25 studies with a high risk of bias and 27 studies that did not meet GRADE and AMSTAR-2.

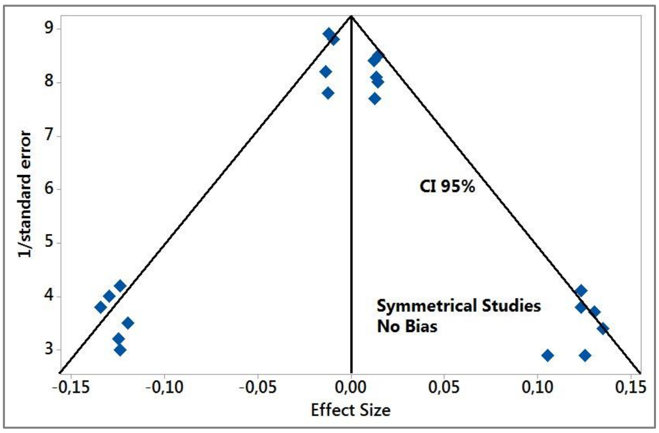
Figure 1. Flowchart showing the article selection process.



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 plot. High confidence and high recommendation studies are shown above the graph (n=21 studies).



Source: Own Authorship.

Major Clinical Results

The success of endodontic treatment depends on the eradication of microbes (if present) from the root canal system and the prevention of reinfection. The root canal is shaped with hand and rotary instruments under constant irrigation to remove inflamed and necrotic tissue, microbes/biofilms, and other debris from the root space. 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 wall of the root canal 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. Optimal irrigation is based on the combined use of 2 different irrigant solutions, in a specific sequence, to predictably achieve the goals of safe and effective irrigation. Traditionally, irrigants are distributed into the thoracic canal space using syringes and metal needles of different sizes and designs [3]. Clinical experience and research have shown, however, that this classic approach typically results in ineffective irrigation, especially in peripheral areas such as the canals, fins, and the most apical part of the main root canal. Therefore, many of the compounds used for irrigation have been chemically modified and several mechanical devices have been developed to improve penetration and irrigation efficacy [3,4]. In this sense, the removal of the smear layer generated during instrumentation of the root canal walls is an essential condition for the best antimicrobial efficacy of the irrigation solution in the dentinal tubules, in addition to improving the sealing capacity of the obturator [10].

The power of EDTA to remove the smear layer makes it one of the most widely used chelators in root canal irrigation. This is often used as the gold standard for smear layer removal in comparative studies conducted in research comparing the efficacy of 17% EDTA to 7% maleic acid and observed greater efficacy of maleic acid in removing smear layer from the apical third of single-rooted human teeth. When compared to maleic acid, 5% to 17% EDTA proved to be equally effective [11].

A recent study evaluated smear layer removal in SEM for various irrigating agents EDTA, apple cider vinegar, 5% maleic acid, acetic acid, and distilled water as a control), EDTA provided the best results, proving to be the most effective solution [12]. Another study noting smear layer removal with an SEM evaluation was performed by Cehreli et al. (2013) [13]. This study carried out in vivo, promoted the instrumentation and irrigation canals with 5.25% NaOCl or 17% EDTA or MTAD Biopure, and they were extracted immediately. Among these irrigation solutions, EDTA showed significantly better results at the cost of greater erosion of the dentin.

In a study by Zia et al. (2014) [14] 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 a 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 the irrigation. The alternative would be the use of EDTA gel, which is as effective as the liquid in the same concentrations and conditions of use [10].

Antimicrobial Action

As it is widely used in endodontic irrigators, EDTA has studied its antimicrobial properties, as it is usually the final irrigating treatment [10]. Bryce et al. (2009) [15] conducted a study to verify the antimicrobial action of irrigating agents in biofilms of microorganisms isolated from root canals. The authors observed low antimicrobial efficacy of EDTA in the biofilm, especially when compared to sodium hypochlorite. In addition, EDTA, which conditions the dentin in a way that allows an increase in the number of attached microorganisms, as well as in their adhesion resistance, and compared to other types of irrigation, has low retention power in reinfection or low residual activity, which can only be improved with the addition of auxiliaries in composition [16-18].

In mixed biofilms developed in situ in the oral cavity, Ordinola-Zapata et al. (2012) [19] evaluated the efficacy of irrigation agents commonly used in endodontics and found that sodium hypochlorite was the most effective for dissolving and depleting biofilm. However, EDTA was not effective for this purpose and had a share compared to saline. Low efficacy of EDTA results was found in another study in which we compared EDTA to Qmix, 0.2% cetrimide, 2% chlorhexidine, and EDTA, antimicrobial activity, and also substantivity.

However, some contradict these findings. There is a study that shows almost no potential for disruption of 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* [19]. Furthermore, EDTA also has antifungal activity against *Candida albicans*, which is a fungus commonly associated with endodontic failures. The evaluation of the antifungal effect of EDTA concerning ethylene glycol tetraacetic acid, titanium tetrafluoride, sodium fluoride, nystatin, ketoconazole, EDTA, and titanium tetrafluoride showed better antifungal activity [19]. This study corroborates another previous study that compared the inhibition of halo EDTA concerning several antifungals and sodium hypochlorite and EDTA with more satisfactory results [20].

One way to improve the antimicrobial action of EDTA would be the association with cetrimide. Ferrer-Luque et al. (2010) [18] found that EDTA associated with the same cetrimide at 15%, in comparison with maleic acid, has a lower antimicrobial activity. Furthermore, EDTA has a low potential to prevent root canal recolonization and therefore another irrigating solution can be associated with it to improve the substantivity of the final irrigant action. One of the viable options studied is the addition of cetrimide EDTA with promising results [19].

Biocompatibility

Chandrasekhar et al (2013) [21] injected 0.1 mL of various solutions into the backs of mice and found that EDTA had similar toxicity to QMix and was less toxic when compared to 3% NaOCl, and more toxic than saline solution. Authors compared the cytotoxicity of 17% EDTA compared to 37% phosphoric acid, 10% citric acid, 5.25% NaOCl, and 2% chlorhexidine. In this study, lower cytotoxicity of EDTA and citric acid could be observed when compared to other substances tested, showing good biocompatibility of EDTA [4].

An alternative EDTA (EDTA-T) to conventional EDTA was studied and showed good results for removing the smear layer and good antimicrobial action, but demonstrated a greater potential for generating 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 similar to other decontamination methods used [22].

Dentin Changes

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. 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 [2-4]. A 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 capacity to reduce dentin hardness compared to the other groups. The smallest reduction in hardness was found in the EDTA + NaOCl combination, which can be explained by the fact that one substance has the power to neutralize the other [21].

In addition, another study examined the effect of the final irrigation protocols (17% EDTA, Biopure MTAD, and SmearClear QMiX) on dentin root canal hardness and erosion. All irrigating agents promoted a reduction in dentin hardness and EDTA promoted erosion of dentinal tubules. When compared with alternative chelating agents, such as peracetic acid at 2.25%, which demonstrated good antimicrobial power, EDTA 17% presented a similar power erosion in the dentin walls [23].

The authors Ballal et al (2013) [24] evaluated the influence of irrigants (EDTA, 2.5% NaOCl, maleic acid, and 7% QMix) on the wettability of two sealers (AH Plus and ThermaSeal) in intra-radicular dentin. QMix proved to be the most favored irritant than the wettability of the sealers in the root canal dentin, which promoted better adhesion and sealing of the obturator. Authors studied the influence of three different irrigating adhesives (QMix, EDTA, and Smear Clear) on an epoxy cement resin, they did not verify the interference of the adhesiveness of these materials on the root canal wall [21,23,25].

Elnaghy (2014) [25] conducted a study that evaluated the influence of various irrigations on the adhesion of sealants, dentin, and mineral trioxide aggregate (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 conducted by Elnaghy (2014) [26] to evaluate the influence of EDTA associated with chlorhexidine on the adhesion of glass fiber 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 [1,2]. However, it is well established that residual $Ca(OH)_2$ should 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 improved $Ca(OH)_2$ removal. Thus, the combination of EDTA and NaOCl as a final rinse did not play a significant role in the removal of $Ca(OH)_2$ residues from the dentin walls. The differences between the studies may have originated from the use of SAF for $Ca(OH)_2$ removal.

Previous studies have used a standardized artificial groove design in the evaluations of $Ca(OH)_2$ drug removal. In addition, this model allows standardization of the size and location of the grooves and the amounts of drug 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 [1,2,4]. Thus, studies have shown that passive ultrasonic irrigation (PUI) with continuous irrigation and the self-adjusting file (SAF) was more effective than EndoVac and conventional syringes in removing $Ca(OH)_2$ drug from a standardized artificial groove in the apical part of the root canal. Similar to these findings, several previous studies have shown that $Ca(OH)_2$ medicament removal was superior to conventional syringe irrigation and sonic irrigation. The higher irrigant 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 [2,4].

Finally, it can be hypothesized that $Ca(OH)_2$ medicament removal may influence the suction effect of the microcannula and result in insufficient $Ca(OH)_2$ removal. 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 $Ca(OH)_2$ medicament removal. The artificial sulcus model was created in the apical part of the root canal to simulate uninstrumented canal extensions. Studies have reported that $Ca(OH)_2$ medicament removal from the apical part of the root canal wall is very difficult. After the removal of $Ca(OH)_2$ from the main canal, remnants may remain in canal extensions or irregularities [1,2,4].

Conclusion

It was concluded that the system of root canal instrumentation with rotary files maintains the quality of root preparation and, at the same time, reduces the number of files required to obtain a canal, which would consequently reduce the operative time and also considerably reduce the risk of torsion fracture within the root canal than with files. Irrigation plays a fundamental role in the success of endodontic treatment. Although hypochlorite is the most important irrigant solution, no irrigant can perform all the tasks required by irrigation. A detailed understanding of the mode of action of various solutions is important for optimal irrigation. Within the limitations of this study, the use of the self-adjusting file with the combination of EDTA and NaOCl improved $Ca(OH)_2$ removal. Passive ultrasonic irrigation and the self-adjusting file were more effective in removing $Ca(OH)_2$ from the lateral sulci in the apical parts of the root canal than the EndoVac and conventional syringe irrigation systems.

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Conflict of Interest

The authors declare no conflict of interest.

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