Final irrigation protocols in Endodontics: systematic review

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ABSTRACT

Introduction: The mechanical action of instruments throughout the root canal system is limited to the main canal, which valorizvalueses the need for an irrigant with optimal properties in order to enhance cleaning and disinfection. **Objective:** The aim of this study was to carry out a review about different final irrigation protocols adopted in Endodontics. **Methods:** In vitro and in vivo studies were selected to highlight solutions, possible associations and agitation methods. RESULTS: The need for more than one substance during preparation was evinced, and so was the association with a chelating agent, under agitation, as means to enhance disinfection of root canals. **Conclusion:** 2.5% NaOCl associated with 17% EDTA or MTAD or 2% CHX , under agitation, seem to be the combinations considered by the literature as the most effective. They may be, therefore, indicated as final solutions in Endodontics.

Keywords: Endodontics. Root canal irrigants. Root canal preparation.

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Introduction

Endodontic therapy goals are cleaning, disinfection and shaping the root canal system.[1] They are achieved by the joint action of endodontic instruments on root canal walls and chemical solutions. However, instruments are limited to the main canal, which values the need for an irrigant with optimal properties. Nevertheless, a single solution may not be enough, so there is a need for associations in the form of protocols, which have been shown as being a good strategy.[2-10] These solutions may be used during preparation or as final solutions before intracanal medication or filling.[2- 7]

Several are the available solutions, but the most widespread one is sodium hypochlorite (NaOCl), which presents several properties that make it the first choice.[8,9] This can be used in isolation or in protocols, in which it is associated with ther solutions, such as EDTA, leading to an increase in dentin permeability; or even MTAD, maleic acid, cetrimide and peracetic acid.[2,3,10] Chlorhexidine (CHX) is also recommended as substitute for NaOCl due to its properties, especially in cases of allergy.[2] The literature also suggests the use of mechanical devices, such as Endoactivator, Plastic Endo, and IrriSafe Satelec in order to enhance root canals final irrigation.[11,12,13]

Thus, there are several solutions and protocols for final irrigation, which leads to stimulation of research in order to determine their effectiveness. The present study aimed to carry out a literature review to present and discuss final irrigation solutions and protocols with the highest scientific evidence of success.

Methods

The research strategy covered electronic databases and reference lists of articles published until October 2016 in the following electronic databases: PubMed (MEDLINE), Web of Knowledge, Scopus and Science Direct. The following combinations of keywords and medical subject heading terms in the Boolean operator were investigated: "final irrigation," "chemical and mechanical preparation," "irrigation methods." In vitro and in vivo studies were selected to highlight solutions, possible associations and agitation methods.

LITERATURE REVIEW

Final irrigants in Endodontics

Sodium hypochlorite

Among available solutions, the most used one is sodium hypochlorite (NaOCl) comprising different properties of which antimicrobial and tissue solvent activity are worth mentioning.[8] Several studies were conducted over the years in order to test the action of NaOCl, but more recently[9] studies have evaluated tissue dissolution of 1%, 2%, 4% and 5.8% NaOCl concentrations at temperatures of 37 °C and 45 °C and under agitation methods (ultrasound, sonic vibration, and mechanical agitation). The authors concluded that at higher concentrations and temperatures and under agitation there was an improvement in solvent capacity. NaOCl is the solution of choice during preparation of root canals; however, to be used as final solution, there is a need for association with other solutions in order to add properties and enhance the disinfection.[2-6]

Chlorhexidine

Chlorhexidine digluconate (CHX) is a cationic bisbiguanide with antibacterial properties, which is due to electrostatic attraction to the membrane, leading to cell lysis, besides the action on enzyme adenosine triphosphatase (ATPase). CHX also presents substantivity, which is slow and gradual release at therapeutic levels when the concentration of the medium decreases.[2,8,14] Schäfer[2] also suggests the use of CHX as substitute for NaOCl in cases of allergic patients. In in vivo studies[15] evaluating microbiological conditions after preparation of root canals with periapical lesions, the authors tested: 2.5% NaOCl, 2% CHX, and saline solution. The microbiological evaluation was performed 30 days after preparation. Results demonstrated that in NaOCl and CHX groups, bacterial count reduction was observed.

Due to the sum of properties, there are reports on the combined use of NaOCl and CHX. On the other hand, the literature points to the formation of a precipitate (parachloroaniline) resulting from hydrolysis of chlorhexidine digluconate. The clinical importance of this fact lies in its carcinogenic potential, which may lead to methemoglobinemia, in addition

to having the potential for loss of working length and chemical staining of the tooth. Thus, if this association is the choice, copious irrigation of root canal with distilled water or saline solution is recommended before CHX use.[8,15]

Another solution that may be associated with CHX is cetramine (CTR) which, according to previous studies,[6,7] is effective in antibiofilm and antimicrobial activity in a similar manner to CHX. Additionally, when associated with a chelating agent or even isolated, it presents satisfactory results against *Enterococcus faecalis*. The authors also consider that the combination of CHX with CTR provides prolonged antimicrobial action.

Chelating solutions

During endodontic treatment, there is production of smear layer, which results from mechanical action of instruments on root canal walls and solutions used during preparation. This structure is attached to the canal walls, forming a film composed of organic and inorganic matter s well as microorganisms.[26] Smear layer may serve as a substrate for bacteria, reduce dentin permeability and act as a barrier between filling material and canal walls, which may favor apical percolation and recontamination.

EDTA, or disodium ethylenediaminetetraacetic acid, is a substance that has the property of chelating calcium ion of dentin calcium phosphate, forming calcium chelate. This reaction leads to reduction of dentin microhardness and to increase in dentin permeability by removing smear layer. The recommended protocol as final solution is after preparation of root canal with NaOCl, application of EDTA 17% (5 minutes) and removal with NaOCl.[2,3]

In order to evaluatethe increase in dentin permeability by scanning electron microscopy (SEM), a study[16] compared EDTA to maleic acid (MA). The authors did not found differences in the cervical and middle thirds of the canal; however, in the apical third, MA appeared to be more effective. In 2010, another study[4] evaluated the effect of EDTA and NaOCl on the reduction of *Enterococcus faecalis* in root canals of individuals up to 30 and over 60 years old by means of SEM. The following protocols were tested: 17% EDTA + 2.5% NaOCl; or isolated solutions. The authors found a reduction in microbiological count, but in the group older than 60 years of age, the number remained high, perhaps due to reduction of dentin permeability that occurs with age.

In a similar study,[5] 5.25% NaOCl and 17% EDTA, whether isolated or associated with other solution, were tested. Samples were collected before, after and 14 days following preparation. Results at the end of preparation were similar for both protocols; however, in 14 days, alternate use provided negative cultures. For EDTA used in isolation, persistent microorganisms were found. Another chelating solution is citric acid (CA), or 2-hydroxypropane tricarboxylic, which is a biocompatible organic acid that acts on dentin leading to decalcification. Although being considered active against *Enterococcus faecalis* due to denaturation of proteins and enzymes, its antimicrobial effect is still questionable.[10,17] This acid may be used as a final solution in its pure form or in a commercially available combination: MTAD (minoxyline, tween 80, citric acid). In relation to protocol, root canal preparation is recommended to be carried out with NaOCl and, at the end, MTAD irrigation (5 minutes) and removal with NaOCl.[18,19]

When comparing MTAD to 17% EDTA in terms of increase in dentin permeability, other authors[20] concluded that both solutions have similar efficacy in the middle and cervical thirds, but MTAD had higher efficacy in the apical third. Additionally, evaluation was carried out on increase in dentin permeability in maxillary incisors after final irrigation. A previous study tested 1% NaOCl, 15% citric acid and 2% CHX.[21] The authors did not find differences in the cervical and middle thirds; but in the apical third, association of 1% NaOCl + 2% CHX presented reduction of permeability by parachloroaniline formation.

In 2011, other authors[18] evaluated removal of smear layer, debris and erosion of root canal walls after final irrigation by means of SEM. To this end, the following protocols were tested: 17% EDTA (1 min) + 2.6% NaOCl; activated MTAD with #15 K-file + MTAD; 17% EDTA + US; and MTAD + US. The authors did not find differences regarding permeability increase, but in relation to tubules erosion, EDTA promoted greater erosion in the cervical and middle thirds. Two years later, dentin permeability after different final irrigation protocols was also evaluated by SEM.[19] The following protocols were tested: 17%

EDTA, 17% EDTA + US, 25% CA and MTAD. The authors concluded that the tested solutions presented satisfactory results in the middle and cervical thirds; but in the apical third, MTAD presented the best results.

In 2014, Ahir et al[22] evaluated removal of smear layer in the apical third in 75 maxillary central incisors after 2.5% NaOCl used in isolation or associated with 17% EDTA, 10%citric acid, and 1% tetracycline hydrochloride. Teeth were manually instrumented and divided into groups. After final irrigation, teeth were prepared for evaluation by SEM for quantification of dentinal tubules. Results demonstrated that except for NaOCl group with the substance used in isolation, there was an increase in dentin permeability, but no significative difference was observed.

In relation to reduction of microbiological count, Baca et al[6] tested final irrigation protocols, with isolated use of 2.5% NaOCl, 2% CHX, 0.2% cetrimide (CTR) , 17% EDTA and 7% MA, or in associations (2.5% NaOCl + 17% EDTA or 7% MA + 0.2% CTR or 2% CHX). When used as a single final irrigant, 0.2% CTR, 2% CHX or 0.2% CTR were capable of reducing *Enterococcus faecalis* count, but the first two presented the best results. In a similar study,[23] 2.5% NaOCl, apple vinegar, 2% CHX, 1% peracetic acid, were evaluated in isolation or in associations: NaOCl + 10% citric acid and NaOCl + apple cider vinegar. Samples were collected before, right after and seven days following preparation. Results showed some reduction, but no group presented a negative count.

Alves et al[13] evaluated bacterial reduction after different final irrigation protocols in oval canals. The root canals were prepared with BTRace + 2.5% NaOCl. The sample was divided according to the protocols: 2.5% NaOCl + mechanical agitation (Hedströem file); 0.2% CHX + ultrasonic agitation. Results showed that agitation of NaOCl in isolation did not contribute to reduction of *Enterococcus faecalis*; however, the authors observed reduction with NaOCl + CHX under mechanical agitation. Also assessing microbial reduction, other authors[7] evaluated bacterial recolonization after four final irrigation protocols in canals contaminated with *Enterococcus faecalis*. The following were tested: 17% EDTA + 5.25% NaOCl; 7% MA + 5.25% NaOCl; 17% EDTA + 2% CHX + 0.2% CTR; and 7% MA + 2% CHX + 0.2% CTR. Samples were collected daily for analysis within a total period of 60 days. The authors considered that when 5.25% NaOCl was used, positive cultures were obtained from the fifth day on; while with other protocols, 70% of negative cultures were observed at the end of the evaluated period.

In addition, inhibition of different micro-organisms[24] (*Candida albicans, Enterococcus faecalis, Fusobacterium nucleatum, Peptostreptococcus anaerobius*) was also evaluated after use of: 5% and 3% NaOCl, 0.12% CHX 0.01% and 0.005% doxycycline (DOX) and MTAD. For evaluation of the inhibition zone, agar plates were inoculated with microorganisms, in which paper disks to containing the solutions under test were inserted. The highest activity was found for MTAD; except for Candida albicans, when NaOCl and CHX were more effective. Table 1 shows the different irrigation protocols published in the literature.

Mechanical agitation of solutions

In order to enhance disinfection and cleaning of root canals after preparation, the literature highlights the use of mechanical agitation of the final solution with gutta-percha cones, K-file or mechanical devices, as EndoVac, which works under irrigation system and simultaneous aspiration with negative pressure, allowing for safe irrigation without risk of solution overflow via foramen.[25]

Another option is EndoActivator, a device using conventional aspiration cannula, activated with a different sonic device (1500 cycles) that emits vibrations to the irrigant to produce agitation of the solution and enhance irrigation.[26] An ultrasonic device that may be used is EndoSonic, which sets a #15 or #20 K-file into motion driven by a ultrasonic unit (25,000 cycles).[25] These devices are committed to improving irrigation by removing smear layer and reducing microbiological count. Aiming to evaluate (SEM) the increase in dentin permeability in the apical third, a study was performed.[11] 5% NaOCl was used under different mechanical agitation methods: gutta-percha, K-file, Endoactivator, Plastic Endo, IrriSafe Satelec and ESI File. The best results were found for Endoactivator. In a similar study, however, using an association of 3% NaOCl + 17% EDTA, the best results were found for Endoactivator.[12]

Table 1. Analysis of different irrigation protocols published in the literature regarding substances, agitation, property investigated, and statistical significance.

Author(s) and year	Substances
Baca et al.[6] (2011)	1) NaOCl 2,5%; 2) CHX 2%; 3) CTR 0,2%; 4) EDTA 17%; 5) MA 17%; 6) NaOCl 2,5%+EDTA 17%; 7) NaOCl 2,5% + EDTA 17% + CHX 2%; 8) NaOCl 2,5% + EDTA 17% + CTR 0,2%; 9) NaOCl 2,5% + MA 7%; 10) NaOCl 2,5% + MA 7% + CHX 2%; 11) NaOCl 2,5% + MA 7% + CTR 0,2%
Dadresanfar et al.[18] (2011)	1) Control group (distilled water); 2) 17% EDTA + 2.6% NaOCl without agitation; 3) MTAD with mechanical agitation; 4) 17% EDTA with ultrasonic agitation; 5) MTAD with ultrasonic agitation
Alves et al.[13] (2014)	1) 2.5% NaOCl with ultrasonic agitation + 0.2% CHX 2) 2.5% NaOCl with manual stirring with Hedstrom lime
Dornelles-Morgental et al.[23] (2011)	1) 2.5% NaOCl; 2) 2.5% NaOCl + 10% CA; 3) 2.5% NaOCl + apple cider vinegar; 4) Apple cider vinegar; 5) 2% CHX; 6) 1% Paracetic Acid; 7) Control group
Baca et al.[7] (2011)	1) EDTA 17% + NaOCl 5,25%; 2) MA 7% + NaOCl 5,25%; 3) EDTA 17% + CHX 2% + CTR 0,2%; 4) MA 7% + CHX 2% + CTR 0,2%
Zand et al.[34] (2010)	1) NaOCl 2,5% + EDTA 17%; 2) NaOCl 2,5% gel + distilled water + EDTA 17%
Akisue et al.[21] (2010)	1) Control group without final irrigation; 2) CA 15% + CHX 2%; 3) NaOCl 1% + CHX 2%
Soares et al.[5] (2010)	1) 5.25% NaOCl+ 17% EDTA final+ 5.25% NaOCl; 2) 5.25% NaOCl alternating with 17% EDTA
Mello et al.[3] (2010)	1) Control group, 1% NaOCl; 2) 1% NaOCl + continuous irrigation with 17% EDTA; 3) 1% NaOCl + 17% EDTA alternating drenching and irrigation
Paragliola et al.[11] (2010)	1) No agitation group; 2) Guta-percha or K-file agitation; 3) Sonic agitation (Endoactivator, Plastic Endo); 4) Ultrasonic agitation (Satelec, EMS)
Ozdemir et al.[4] (2010)	1) EDTA 17% + NaOCl 2,5%; 2) EDTA 17%; 3) NaOCl 2,5%
Caron et al.[12] (2010)	1) No agitation; 2) Guta-percha manual agitation; 3) Rinsendo system agitation; 4) Sonic agitation (Endoactivator)
Stojicic et al.[9] (2010)	1%, 2%, 4% and 5.8% NaOCl / Ultrasonic, sonic and mechanical agitation
Mozayeni et al.[20] (2009)	1) NaOCl 5,25%; 2) NaOCl 5,25% + EDTA 17%; 3) NaOCl 5,25% + MTAD
Ballal et al.[16] (2009)	1) NaOCl 2,5% + EDTA 17% + NaOCl 2,5%; 2) NaOCl 2,5% + MA 7% + NaOCl 2,5%
Malkhassian et al.[10] (2009)	1) 1.3% NaOCl; 2) 1.3% NaOCl + MTAD+ CHX as medication for 7 days + 1.3% NaOCl; 3) 1.3% NaOCl + destiled water+ CHX for 7 days + 1.3% NaOCl
Tanomaru Filho et al.[15] (2006)	1) 2.5% NaOCl; 2) 2% CHX; 3) Saline solution; 4) Control (without biomechanical preparation)

* MA - maleic acid; m.o. - microorganisms; NaOCl - sodium hypochlorite; EDTA - ethylenediaminetetraacetic acid; CHX - chlorhexidine; MTAD - tetracycline isomer (doxycycline) + citric acid + detergent; CTR - cetremide (cetyl trimethyl ammonium bromide); CA- citric acid.

Agitation	Results	*p* < 0.05
No	**Biofilm** NaOCl alonepresented the worst result. The use of 0.2% CTR alone and the use of 2% CHX or 0.2% CTR as a final irrigant are the most effective. **Antimicrobial activity.** EDTA alone presented the worst result. 2.5% NaOCl and 0.2% CTR alone or associated with other substances are effective.	Yes
Yes	No significative difference regarding removal of smear layer. MTAD promotes lower dentin erosion than EDTA and is effective in removing smear layer.	No, regarding removal of smear layer. Yes, regarding dentin erosion.
Yes	Only the use of ultrasound was not enough for reduction of bacteria. Final irrigation with CHX after ultrasound significantly reduced bacterial counts.	No, between types of agitation; and Yes, for final irrigation with CHX.
No	After 7 days of PQM, groups 1, 5, 6 had significative reduction over other groups. No group was able to eradicate E. faecalis.	Yes
No	Groups 1 and 2 with positive culture. Groups 3 and 4 > 1 and 2. Groups 3 and 4 without significative difference.	Yes, between groups 1 and 2, with 3 and 4.
No	NaOCl solution = NaOCl gel	No
No	Cervical region and average without difference. Apical region groups 2 > 1 > 3.	Yes
No	Group 2 with negative culture right after PQM and 14 days later. Group 1 with m.o. Persistent 14 days later.	Yes
No	Control group < 2 and 3 Group 2 with less surface debris than group 3. In the apical region of root canal, there was no significant difference between groups 2 and 3.	Yes, to the control group.
Yes	Control group = group 2. Group 4 (ultrasonic agitation) with significant difference for other groups.	Yes
No	EDTA + NaOCl more efficient.	Yes
Yes	Group 1 < groups 2, 3 and 4. Group 3 < group 2 < group 4.	Yes, but between groups 2 and 4 no.
Yes	Temperature and agitation increased the efficacy of NaOCl.	Yes
No	EDTA = MTAD in coronary and middle canal regions. MTAD > EDTA in apical canal region.	Yes
No	NaOCl+7% MA more efficient in the apical region than 17% EDTA.	Yes
Yes, manual.	Final irrigation with MTAD and medication with CHX did not reduce n. of m.o.	No
No	Groups 1 and 2 > 3 and 4.	Yes

Reduction of *Enterococcus faecalis* after different final irrigation protocols in oval canals was evaluated.[13] Root canals were prepared with BTRace + 2.5% NaOCl and then divided according to the following protocols: 2.5% NaOCl + mechanical agitation (Hedströem file); passive ultrasonic irrigation with 2.5% NaOCl (PUI) + 0.2% CHX. Conclusion was that in the NaOCl group, there was no significative reduction; however, reduction was observed for NaOCl + CHX.

A recent study[25] evaluated (SEM) removal of smear layer from the apical third of maxillary incisors after EndoVac and Max-I probe. Root canals were prepared with Protaper and irrigated with 3% NaOCl and 17% EDTA. EndoVac was more effective, which can be explained by negative pressure that this system generates on root canal.

Final irrigation protocols

According to the literature, the most indicated protocol is the alternate use of NaOCl and EDTA; however, there are reports on the combined use of this protocol with other solutions, as well as the use of other substances having with bactericidal properties. Table 2 presents different final irrigation protocols considered the most effective according to the literature regarding. Table 3 shows a suggested protocol for final irrigation.

Table 2. Final irrigation protocols considered the most effective according to the literature, particulalry in relation to the evaluated property.

Property	Effective protocol	Author, year
Antimicrobial activity	Association of 17% EDTA + 2% CHX + 0.2% CTR or 7% MA + 2% CHX + 0.2% CTR	Baca et al.[7] (2011)
	2.5% NaOCl or 2% CHX or 1% peracetic acid	Dornelles-Morgental et al.[23] (2011)
	2.5% NaOCl with ultrasonic agitation + 0.2% CHX as final irrigant	Alves et al.[13] (2011)
	2.5% NaOCl alone, 0.2% CTR alone or associated with other substances	Baca et al.[6] (2011)
	17% EDTA + 2.5% NaOCl	Ozdemir et al.[4] (2010)
	5.25% NaOCl alternated with 17% EDTA	Soares et al.[5] (2010)
	2.5% NaOCl or 2% CHX	Tanomaru Filho et al.[15] (2006)
Antibiofilm activity	0.2% CTR alone or the use of 2% CHX or 0.2% CTR as final irrigant	Baca et al.[7] (2011)
	17% EDTA + 2.5% NaOCl	Ozdemir et al.[4] (2010)
Smear layer removal	Sonic or manual agitation	Caron et al.[12] (2010)
	1% NaOCl + irrigation with 17% EDTA	Mello et al.[3] (2010)
	2.5% NaOCl + 7% MA+ 2.5% NaOCl	Ballal et al.[16] (2009)
	5.25% NaOCl + MTAD	Mozayeni et al.[20] (2009)
Depth of penetration	MTAD promotes less dentin erosion than EDTA	Dadresanfar et al.[18] (2011)
	Temperature and agitation increase the efficacy of NaOCl	Stojicic et al.[9] (2010)
	Ultrasonic agitation (Satelec, EMS)	Paragliola et al.[11] (2010)
	Association of 15% CA + 2% CHX	Akisue et al.[21] (2010)

* MA - maleic acid; NaOCl - sodium hypochlorite; EDTA - ethylenediaminetetraacetic acid; CHX - chlorhexidine; MTAD - tetracycline isomer (doxycycline) + citric acid + detergent; CTR - cetremide (cetyl trimethyl ammonium bromide); CA- citric acid.

Table 3. Suggested protocol for final irrigation according to the literature.

Sequence	Substance/concentration	Usage phase	Agitation	Time (min)
1	2.5% NaOCl	During PQC	No	Minimum 30
2	17% EDTA	*Final irrigation*	Sonic/manual	5
3	2.5% NaOCl	EDTA removal	Sonic/manual	Minimum 30
4	5% Sodium thiosulfate	Neutralize NaOCl	Sonic/manual	1
5	2% Chlorhexidine	Before filling	No	1

Discussion

Endodontic treatment success is directly linked to control of intraradicular microbiota in order to provide conditions for periapical tissue repair. Over the years, the great importance given to shaping has been observed. By definition and due to anatomical complexity, it ends up being performed only in the main canal while other areas, often infected, are left without instrument action. Such fact may directly influence therapy because once these microorganisms have access to nutrients, they may reach enough count to perpetuate endodontic infection. In this sense, in more recent studies, the literature has demonstrated the importance of effective irrigation that is able to reach areas that, in turn are inaccessible to instruments, besides the need for choosing bactericidal solutions capable of controlling infection and leading to success.[27]

The literature considers that irrigation of cervical and middle thirds is more effective in comparison to the apical third. Some factors may be related, as smaller caliber of the main canal or complex morphology of the apical third.[21,22,28] In general, there is a limited number of studies evaluating irrigation in the apical third, such as those assessing the influence of irrigant volume used or penetration depth of the needle. This deficiency may be related to difficulties with anatomy or methodology, especially in curved canals.

Additionally, there is certain lack of longitudinal clinical studies in the literature which seek to compare the action of solutions over microorganisms or the inorganic part of waste, either in isolation or in associations. Such fact may be explained by the complexity of carrying out such studies due to difficulty controlling the different variables capable of influencing treatment outcomes. In relation to in vitro studies, the literature reports several protocols of final irrigation, as it justifies that the association would be beneficial to gather effects of different solutions, especially with respect to antimicrobial action.[2-7,13,21,22,28]

The most common substances indicated as final solutions are: 2% CHX, 0.2% CTR, citric acid, and 17% EDTA,but different associations have been reported, which hampers the choice of a single clinical protocol. The association of an antimicrobial agent with a chelating agent (EDTA or citric acid) is certainly the combination of substances with greater evidence of success by associating the antimicrobial action of NaOCl with increased dentin permeability promoted by the chelating agent.[2,4,6-7,19,21-24]

CHX is indicated by several authors due to its antimicrobial effect and substantivity.[6,15,13,23,24] On the other hand, one must be careful when using them after NaOCl, since these two substances react, forming a precipitate that may reduce dentinal permeability and

cause staining of chemical dentin. Thus, intermediate irrigation is indicated with distilled water or saline solution, so as to remove residues of the former.[21]

Cetramine is also indicated due to presenting antibiofilm and antimicrobial effect against *Enterococcus faecalis*. When associated with CHX, it seems to promote prolonged antimicrobial action.[6,7] EDTA and citric acid are chelating substances that act on the inorganic part of smear layer and should be used as means to increase dentin permeability, as maintenance of this layer may influence the treatment.[2] The association of EDTA with NaOCl seems to be beneficial by reducing microbial count in root canal.[3,6,7] EDTA used alone does not have antimicrobial action, but favors removal of smear layer, exposing dentinal tubules, and allowing NaOCl input.[6]

MTAD is a substance that has shown antimicrobial efficacy in root canal apical region, besides promoting an increase in dentin permeability by presenting citric acid in its composition. This solution should be used as root canal final irrigant after preparation.[16,18,19,20,24] Despite signs of success, MTAD is not able to reduce microbiological count. There were no significative differences in comparison with the isolated use of NaOCl.[10,17]

The association of solutions with a method of agitation is considered a prerequisite for successful endodontic treatment.[29] The use of manual, sonic or ultrasonic techniques seems to increase disinfection by promoting greater removal of debris and favoring penetration of solutions in dentinal tubules.[9,12,30] Among the different agitation methods described in the literature, it has been reported there is no significative difference,[9] which differs from other findings[11,26] stating that ultrasonic agitation presented better results, especially in the apical third. Satisfactory results were also found when using sonic methods for agitation of chelating substances.[12,30,31]

Auxiliary devices to irrigation, such as EndoVac, Max-I probe, EndoSonic, and EndoActivator, are also mentioned to enhance irrigation.[11-13,25,26] The one which seems to present the highest success rate is EndoVac, may be due to negative pressure generated in root canal.[32,33] Nevertheless, these methods still need further studies to prove the benefits of their use.

Final Considerations

The reviewed literature reveals that several are the solutions employed as final irrigation and that associations between solutions is advantageous due to a sum of properties. However, caution is required, since certain combinations may result in undesirable products. Based on the analysis of studies involved in this review, the association with the highest success rate is the use of 2.5% NaOCl as irrigant during instrumentation of root canals due to its antimicrobial activity and tissue solvent capacity, combined with 17% EDTA or MTAD to remove smear layer and increase dentin permeability. Among the possible final solutions, 2% chlorhexidine was the solution with the highest success rate. The use of agitation methods is important due to an increase in efficiency in removing smear layer.

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