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REVIEW ARTICLE

Passive ultrasonic irrigation in root canal: systematic review and meta-analysis

Rafaela Nogueira Moreira[a], Elizabete Bagordakis Pinto[b], Rodrigo Galo[a], Saulo Gabriel Moreira Falci[a] and Ana Terezinha Mesquita[a]

[a]Department of Dentistry, Federal University of Jequitinhonha e Mucuri Vallyes, Diamantina, Brazil; [b]Department of Oral Diagnosis, School of Dentistry, State University of Campinas, Piracicaba, Brazil

ABSTRACT

Objective: To investigate whether there are differences between the root canal disinfection, comparing the passive ultrasonic irrigation technique with the conventional technique.

Materials and methods: The following electronic databases were searched: Pubmed; VHL; Web of Sciences and OVID with no publication date restriction. The study's quality evaluation was carried out using the Handbook by Cochrane. The online research identified 5464 studies. From the nine studies selected for a full reading of the text, five were included in the present systematic review. Meta-analysis was performed in three articles, which evaluated the root canal's cleanness through microbiological analysis.

Results: Only one article concluded that the ultrasonic passive irrigation showed a better performance compared with the conventional irrigation. None of the articles analyzed presented a low risk of bias in all domains. According to the results of the meta-analysis, there was no statistical difference between the groups (OR = 0.34, IC 95%: 0.10–1.19).

Conclusions: The level of evidence comparing the two techniques is fragile since in all studies some type of bias was observed which may interfere in the results and conclusions.

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Endodontic irrigation; passive ultrasonic irrigation; conventional irrigation; bacterial reduction

Introduction

Despite recent advances in the endodontic area, the disinfection of the root canal is still a major challenge. Although the success rate of endodontic treatment ranges from 83 to 98% [1], teeth with periapical lesion have a 49% lower chance of success than teeth without periapical lesion [1]. This is because periapical injuries represent an inflammation in the apical region and occur as a result of a bacterial infection in the root canal [1].

Because of frequent anatomical variation of the teeth, a full mechanical preparation of the root canal system is rarely achieved [2]. Moreover, errors during the canal's shaping can lead to the presence of grooves and concave areas in its walls, allowing non-instrumented remaining regions throughout the length of the root canal, which can lead to endodontic treatment failures. Thus, taking into account the root canal anatomy's complexity and the limitations of mechanical preparation, instrumentation must be combined with adequate irrigation to complete the cleaning process and to reduce the number of microorganisms inside the root canal [3]. Therefore, the irrigation process has attracted attention from researchers.

The root canal final irrigation with an association of chemical products such as ethylenediaminetetraacetic acid (EDTA) and sodium hypochlorite (NaOCl) has been recently recommended, with the objective of removing organic and inorganic components of the smear layer [4]. In addition to the standard procedure of irrigation with a syringe, various techniques and mechanisms have been developed, such as the sonic and the passive ultrasonic irrigation [4]. The passive ultrasonic irrigation promotes an acoustic flow with forces that cause physical rupture of bacterial aggregations [5–9].

The effectiveness of passive ultrasonic irrigation has been the object of study of many researches [3,5–8,10–12]. Although studies have shown that the stirring of the irrigating solution offers superior results compared with conventional irrigation [5–8], other studies found no differences among the techniques [10,12]. Therefore, taking into account the importance of irrigation in the endodontic treatment success, there is a need for knowledge of which technique ensures a better disinfection of root canals and a higher treatment success rate. The objective of this systematic review with meta-analysis was to investigate whether there are differences in the disinfection of root canals, comparing conventional irrigation to the passive ultrasonic irrigation technique.

Materials and methods

This systematic review was conducted in accordance to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Guide (PRISMA) [13], and the PICO strategy (Population, Intervention/Exposure, Comparison, Outcome)

CONTACT Rafaela Nogueira Moreira rafismm.rm@gmail.com Department of Dentistry, Federal University of Jequitinhonha e Mucuri Vallyes, Rua da Glória 187, 39100-000 Diamantina, Brazil

Table 1. Description of the PICO strategy (Population, Intervention/Exposure, Comparison, Outcome) used to develop the research.

Acronym	Description
Population	Patients submitted to endodontic treatment
Intervention/exposure	Conventional Irrigation
Comparison	Passive ultrasonic irrigation
Outcome	Bacterial infection

(Table 1). The methodology used in this systematic review includes a literature search strategy; selection criteria; screening and data extraction and a quality assessment.

Literature search strategy

The search strategy consisted of a search in the electronic databases and in the list of references of each article included and published by December 2017. The following electronic databases were searched: Pubmed; VHL; Web of Sciences and OVID, with no publication date restriction. A combination of key words was carried out for the databases search: (Ultrasonic irrigation OR ultrasound AND necrotic debris); (Ultrasonic irrigation OR ultrasound AND biofilm); (Ultrasonic irrigation OR ultrasound AND bacterial reduction); (Ultrasonic irrigation AND infection AND bacteria); (Ultrasound AND endodontic treatment AND biofilm); (Ultrasound AND endodontic treatment AND bacteria); (Root canal irrigation OR passive ultrasonic irrigation AND biofilm).

Selection criteria

Clinical trials that evaluated the disinfection of root canals using passive ultrasonic irrigation technique compared with the conventional irrigation technique were included and clinical trials that evaluated root canal cleansing through histological examination. The exclusion criteria were literature reviews, letters to the editor, editorials, case reports or case series, *in vitro* studies; and animal studies. There was no language restriction. The authors were contacted by e-mail when the studies could not be found.

Screening and data extraction

The electronic search identified a total of 5464 articles. The studies were transferred to Endnote Program **(**EndNote, Thomson Reuters, version x7), and the duplicates were removed. The list provided by EndNote was analyzed and the articles were selected based on their titles and abstracts by two independent reviewers (RNMG and EBP). Any disagreement was resolved by consensus with a third reviewer (SGMF). The reviewers conducted the extraction of information from the studies. They extracted data related to the year of publication; number of patients; tooth pulp condition (vitality or necrosis); presence or absence of periapical lesion; instrumentation technique used; irrigating solution used; irrigating solution's concentration, irrigation technique; root canal's infection evaluation method.

Quality assessment

After the articles selections, the reviewers assessed their scientific relevance, and in the case of divergence, the consensus technique was adopted. The evaluation of the studies quality was performed using the Cochrane Handbook, in which seven domains were evaluated: random sequence generation; allocation concealment; blinding of participants and personnel; blinding of outcome assessment; incomplete outcome data; selective reporting; eligibility criteria. Each of these areas was classified according to the risk of bias: low risk; obscure and high-risk.

Meta-analysis

Meta-analysis was carried out by the R statistics Program, after the activation of the 'meta' and 'metaphor' packages. The heterogeneity between the results was analyzed by the statistical I^2 test.

When the I^2 was equal to 0, the fixed-effects model was considered for the meta-analysis. When the I^2 >0, the random-effect model was considered. The meta-analysis searched variable was: the presence of bacteria in the root canal. For the category variables (presence of bacteria) the odds ratio (OR) was calculated, the mean differences (MD) were calculated. Forest plots were constructed for meta-analysis. The assessment of publication bias by Egger test [14] was not possible because there were less than 10 studies included in the analysis.

Results

The online search identified 5464 studies (Figure 1). After the removal of duplicate references, 3414 studies remained in the list provided by EndNote (EndNote, version x6, Boston, MA). After that, 3405 studies were excluded based on the title analysis and/or the abstracts by two reviewers (RNMF and EBP). From the nine studies selected for a full reading of the text, five were included in the present systematic review. For the accomplishment of the meta-analysis, the articles that made microbiological assessment were grouped and separated from the article that included a histological examination. Thus, a meta-analysis was performed of three articles that evaluated the presence of bacteria inside the root canals. Tables 2 and 3 show the studies' characteristics and each one's type of evaluation, whereas the Table 4 shows the results of the evaluation of the risk of bias.

According to the results of the meta-analysis, as observed in Figure 2, there was no statistically significant difference in the presence of bacteria between the passive ultrasonic irrigation and conventional irrigation, although a reduced quantity of bacteria has been found with the use of passive ultrasonic irrigation (OR = .34, IC 95%: .10–1.19; p = .1623).

Discussion

The success of the endodontic treatment depends on the instrumentation technique along with the irrigation system's

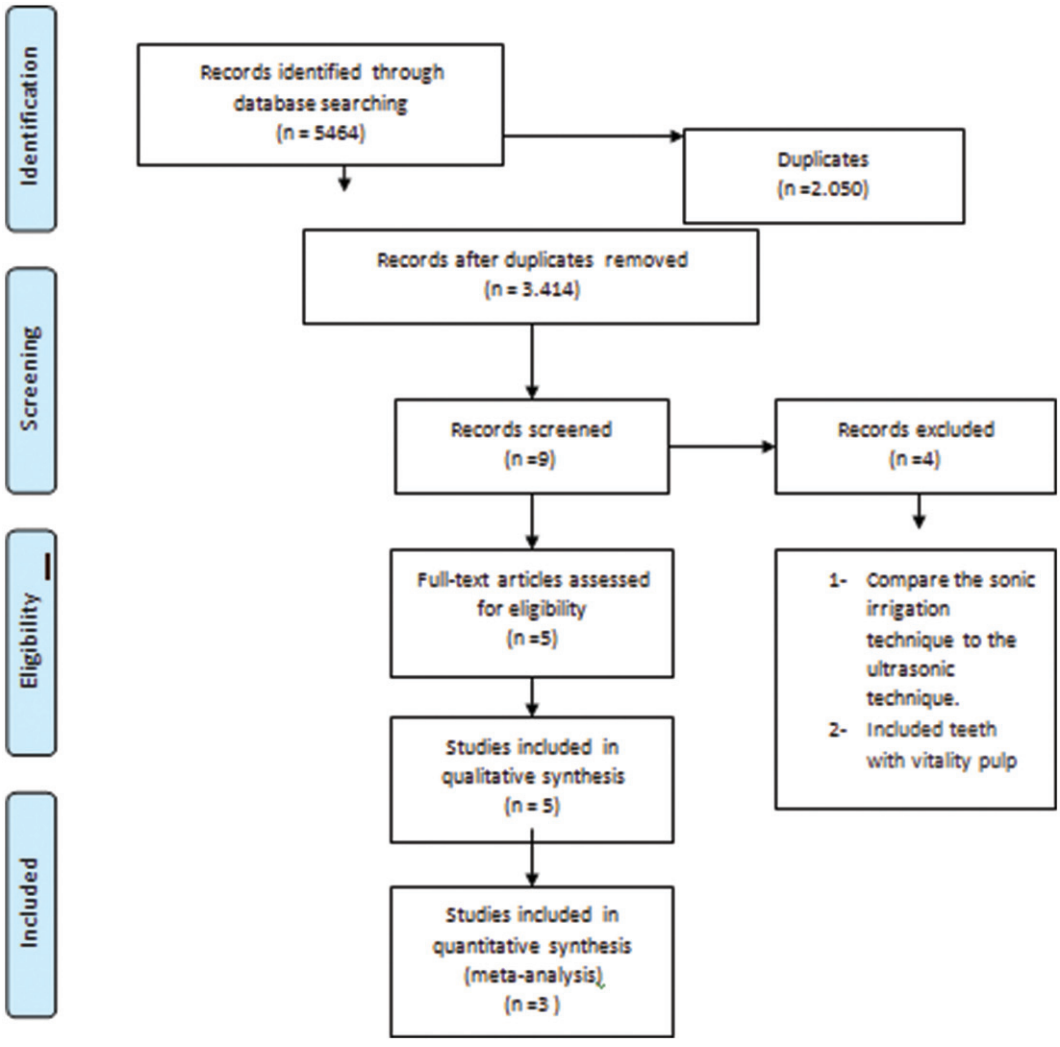

Figure 1. Studies screening.

Table 2. Characteristics of included studies.

References	No Pat	Teeth	Pulp Condition	Periapical lesion	Inst. Tech.	Solution Concentration	Infection evaluation method	Results
Paiva et al. [15]	10	One canal	Necrosis	Absent	Rotary	2.5% NaOCl EDTA	Microbiological evaluation (qpcr; PCR DGGE; cloning and sequencing)	No statistical difference
Paiva et al. [16]	13	One canal	Necrosis	Absent	Rotary	2.5% NaOCl 17% EDTA	Microbiological evaluation (CFU)	No statistical difference
Beus et al.[10]	50	Posteriors	Necrosis	Present	Rotary	1% NaOCl 17% EDTA 2% Chlorhexidine	Microbiological evaluation (bacteria presence or absence)	No statistical difference
Burleson et al. [5]	48	Inferior molars	Necrosis	Present	Rotary	6% NaOCl	Histological evaluation	There was statistical difference
Carver et al. [6]	31	Inferior Molars	Necrosis	Present	Rotary	6% NaOCL	Microbiological Evaluation (CFU)	There was statistical difference

capacity to promote cleanliness of the root canal system, either of vital tissue, necrotic tissue or microorganisms and their sub-products [7]. The use of passive ultrasonic irrigation has been proposed as a possible solution to the problems concerning to remaining debris and microorganism in the root canal system, thus improving their cleaning and disinfection [6].

Hence, does ultrasonic passive irrigation promotes better disinfection of the root canal compared with conventional irrigation? Some studies claim that the ultrasonic passive

Table 3. Selected studies and their types of data evaluation and extraction of the presence of bacteria analysis.

	Presence of bacteria (%)			CFU			Culture-dependent methods		
References	IC	PUI	*p* Values	IC (average/ DP)	PUI (average/DP)	*p* Values	IC	PUI	*p* Values
Paiva et al. [15]							2.01×10^4	1.65×10^4	.67
Paiva et al. [16]	5/13 (38.5%) +	3/13 (23%)+	> .05				9 (69%) +	7 (54%) +	> .05
Beus et al. [10]	5/25 (20%) +	4/25 (16%)+	> .05						
Burleson et al. [5][a]									
Carver et al. [6]	11/15 (73%) +	3/15 (20%) +	.0047	5.6/4.0	1.2/2.6	.0006			

[a]Histological study.

Table 4. Studies' risk of bias assessment according to the Cochrane Collaboration Handbook.

References	Random sequence generate	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome data	Selective report	Inclusion and exclusion criteria
Paiva et al. [15]	Uncertain	Uncertain	Uncertain	Uncertain	Low	Low	Low
Paiva et al. [16]	Uncertain	Uncertain	Uncertain	Uncertain	Low	Low	Low
Beus et al. [10]	Uncertain	Uncertain	Low	Uncertain	Low	Low	Low
Burleson et al. [5]	Low	High	Low	Low	Low	Low	Low
Carver et al. [6]	Low	High	Low	Low	Low	Low	Low

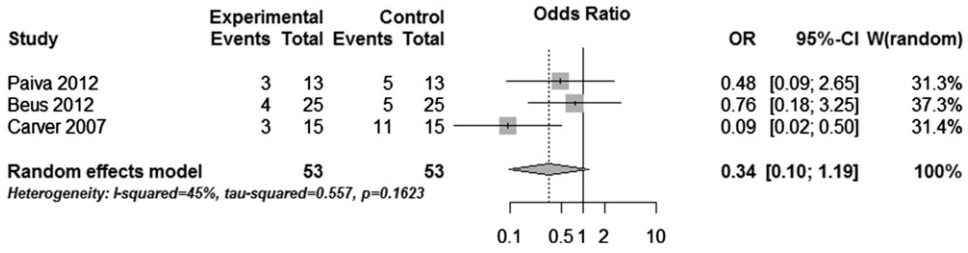

Figure 2. Results of the meta-analysis of microbiological studies.

irrigation improves the performance of irrigating solutions in removing organic and inorganic debris from root canals [9]. One possible explanation for the greater penetration of the irrigating solution in non-sclerotic tubules of the root canal's wall may be a larger stream flow and an increase in the solution's volume, associated with ultrasonic agitation [11]. However, from an initial search of 5464 articles, only eight articles were selected for this study, which yet reports a small number of studies to possibly produce a high level of evidence to answer this question.

The articles selected in this review were evaluated for quality using the Guide to the contents of the Cochrane protocol and review. In studies by Paiva et al. [15], Paiva et al. [16], from the seven domains assessed, four presented an uncertain risk of bias, as it was not possible to obtain enough information to classify them as low-risk or high risk. Thus, the degree of evidence in these studies should be analyzed with caution. In contrast, studies by Carver et al. [6], Burleson et al. [5] and Gutarts et al. [7], showed a high risk of bias in the sample allocation concealment domain, as they used an open randomization process (random list of numbers). Therefore, the intervention's allocation may have been foreseen before the recruitment of participants and may have influenced the results. It is also important to note that these same studies showed a low risk of bias in most of the other areas. However, none of the eight analyzed articles presented a low risk of bias in all areas, showing that there is still poor evidence on this subject.

The articles included in this review used NaOCl in different concentrations as the irrigating solution. Only one study compared a final irrigation with chlorhexidine addition to comparing passive ultrasonic irrigation to conventional irrigation [16]. Most likely, the NaOCl concentration's variations among the studies did not influence the results, once it has been reported that the concentration of sodium hypochlorite does not affect the antibacterial efficacy [17]. In contrast, these differences in the treatment's method may have increased the heterogeneity among the studies' results which reinforce the need for methodology standardization to achieve an appropriate level of evidence on the subject.

As for the evaluation method of root canals' disinfection, one study [5] used the histological evaluation after extraction of the endodontically treated tooth and four studies [6,7,15,16] conducted the microbiological evaluation. Among the studies that conducted the microbiological evaluation, two performed bacterial culture [15,16]. Carver et al. [6] evaluated the presence of bacteria by counting colony forming units (CFU) on culture plates. Beus et al. [10] only evaluated the presence or absence of bacteria in cultures carried out with the samples obtained. Studies using cultures have shown a correlation between negative cultures and favorable prognosis [18]. However, it is important to highlight that the bacterial diversity and bacterial counts usually are underrepresented by culture analysis [19].

The two studies by Paiva et al. [15,16] evaluated the bacterial cultures obtained from their samples through the

endpoint PCR [16], and qPCR and PCR-DGGE [15]. This approach culture dependent is more reliable in detecting viable bacteria, especially when samples are taken immediately after antimicrobial treatment when viability cannot be determined by the majority of independent culture methods [19]. Moreover, because of limitations on the sampling procedures, on the low sensitivity of culture techniques and the presence of bacteria, even if non-cultivable, a negative culture does not imply sterility [20]. From the four articles that underwent microbiological evaluation [6,10,15,16], only the article by Carver et al. [6], concluded that the passive ultrasonic irrigation showed better performance compared with conventional irrigation. In this study, from the four articles that underwent microbiological analysis, only three were included in the meta-analysis, as the results of the study by Paiva et al. [15] used qPCR and PCR-DGGE, which values could not be compared to other studies. There was no statistically significant difference between the groups, likely due to the small sample size used in the three articles or due to the fact that only the main canal was evaluated.

One of the challenges of contemporary endodontic is to achieve complete cleaning and disinfection of the root canal system [21]. Taking into account that 5.25% sodium hypochlorite represents the gold standard among irrigating solutions, morphological and microbiological studies and randomized clinical trials studies should be performed with the aim of to evaluate the cleaning and disinfection pattern using NaOCl-based protocols combined with different techniques and including also the cleaning of the lateral canals and dentinal tubules. Lateral canals and dentinal tubules are more difficult areas to reach, so the cleaning of these areas can vary according to the irrigation protocol.

Clinically, the conventional irrigation methods make irrigation solution flow more difficult in the apical third due to its atresic configuration. However, it is possible to establish an irrigant flow in this region using fine caliber needles. Moreover, the apical third presents a lower density of dentinal tubules but, on the other hand, there is a high frequency of secondary and accessory canals. Taking into account that the passive ultrasonic irrigation by generating vibration waves improves the penetration potential of the irrigant in the lateral canals [11], strategically an adequate combination of irrigating solutions [21] coupled to the technologic use of passive ultrasonic vibration could provide superior cleaning of areas previously considered inaccessible to biomechanical preparation.

To date, the level of evidence comparing passive ultrasonic irrigation technique to conventional irrigation technique is weak, as in all studies there is a presence of some type of bias that might interfere with the results and conclusions. Although two studies analyzed in this review point out better results for passive ultrasonic irrigation, according to the results of our meta-analysis there was no difference between passive ultrasonic irrigation and conventional irrigation. There is a necessity of more randomized clinical trials comparing the two techniques to confirm the superiority of ultrasonic passive irrigation.

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Disclosure statement

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References

[1] Ng YL, Mann V, Gulabivala K. A prospective study of the factors affecting outcomes of nonsurgical root canal treatment: part 1: periapical health. Int Endod J. 2011;44:583–609.

[2] De-Deus G, Barino B, Zamolyi RQ, et al. Suboptimal debridement quality produced by the singlefile F2 ProTaper technique in oval-shaped canals. J Endod. 2010;36:1897–1900.

[3] Castelo-Baz P, Martín-Biedma B, Cantatore G, et al. In vitro comparison of passive and continuous ultrasonic irrigation in simulated lateral canals of extracted teeth. J Endod. 2012;38:688–691.

[4] Plotino G, Cortese T, Grande NM, et al. New technologies to improve root canal disinfection. Braz Dent J. 2016;27:3–8.

[5] Burleson A, Nusstein J, Reader A, et al. The in vivo evaluation of hand/rotary/ultrasound instrumentation in necrotic, human mandibular molars. J Endod. 2007;33:782.

[6] Carver K, Nusstein J, Reader A, et al. In vivo antibacterial efficacy of ultrasound after hand and rotary instrumentation in human mandibular molars. J Endod. 2007;33:1038–1043.

[7] Gutarts R, Nusstein J, Reader A, et al. In vivo debridement efficacy of ultrasonic irrigation following hand-rotaryinstrumentation in human mandibular molars. J Endod. 2005;31:166–170.

[8] Munoz HR, Camacho-Cuadra K. In vivo efficacy of three different endodontic irrigation systems for irrigantdelivery to working length of mesial canals of mandibular molars. J Endod. 2012;38:445–448.

[9] Townsend C, Maki J. An in vitro comparison of new irrigation and agitation techniques to ultrasonic agitation in removing bacteria from a simulated root canal. J Endod. 2009;35:1040–1043.

[10] Beus C, Safavi K, Stratton J, et al. Comparison of the effect of two endodontic irrigation protocols on the elimination of bacteria from root canal system: a prospective, randomized clinical trial. J Endod. 2012;38:1479–1483.

[11] De Gregorio C, Estevez R, Cisneros R, et al. Efficacy of different irrigation and activation systems on the penetration of sodium hypochlorite into simulated lateral canals and up to working length: an in vitro study. J Endod. 2010;36:1216–1221.

[12] Huffaker SK, Safavi K, Spangberg LS, et al. Influence of a passive sonic irrigation system on the elimination of bacteria from root canal systems: a clinical study. J Endod. 2010;36:1315–1318.

[13] Moher D, Shamseer L, Clarke M, et al. Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) 2015 statement. Syst Rev. 2015; 4:41.

[14] Egger M, Davey Smith G, Schneider M, et al. Bias in meta-analysis detected by a simple, graphical test. BMJ. 1997;315:629–634.

[15] Paiva SS, Siqueira JF, Jr, Rôças IN, et al. Molecular microbiological evaluation of passive ultrasonic activation as a supplementary disinfecting step: a clinical study. J Endod. 2013;39:190–194.

[16] Paiva SS, Siqueira JF, Jr, Rôças IN, et al. Supplementing the antimicrobial effects of chemomechanical debridement with either passive ultrasonic irrigation or a final rinse with chlorhexidine: a clinical study. J Endod. 2012;38:1202–1206.

[17] Alves FR, Almeida BM, Neves MA, et al. Disinfecting oval-shaped root canals: effectiveness of different supplementary approaches. J Endod. 2011;37:496–501.

[18] Waltimo T, Trope M, Haapasalo M, et al. Clinical efficacy of treatment procedures in endodontic infection control and one year follow-up of periapical healing. J Endod. 2005;31:863–866.

[19] Siqueira JF, Jr, Rôças IN. Exploiting molecular methods to explore endodontic infections: part 1–current molecular technologies for microbiological diagnosis. J Endod. 2005;31:411–423.

[20] Siqueira JF, Jr, Rôças IN, Paiva SS, et al. Bacteriologic investigation of the effects of sodium hypochlorite and chlorhexidine during the endodontic treatment of teeth with apical periodontitis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2007;104:122–130.

[21] Soares JA, Roque de Carvalho MA, Cunha Santos SM, et al. Effectiveness of chemomechanical preparation with alternating use of sodium hypochlorite and EDTA in eliminating intracanal Enterococcus faecalis biofilm. J Endod. 2010;36:894–898.