The effectiveness of different auxiliary methods in disinfecting root canals - Integrative review

A eficácia de diferentes métodos auxiliares na desinfecção dos canais radiculares - Revisão integrativa

La efectividad de diferentes métodos auxiliares en la desinfección de los conductos radiculares - Revisión integradora

Ismênia Figueiredo Carvalho[1], Matheus da Silva Ribeiro[2], Waldécio dos Santos Vita[3], Laerte Oliveira Barreto Neto[4], Misael Silva Ferreira Costa[5], Joana Dourado Martins Cerqueira[6]

How to cite: Carvalho IF, Ribeiro MS, Vita WS, Barreto Neto LO, Costa MSF, Cerqueira JDM. The effectiveness of different auxiliary methods in disinfecting root canals - Integrative review. REVISA. 2020; 9(3): 539-50. Doi: https://doi.org/10.36239/revisa.v9.n3.p539a550

1. Unidade de Ensino Superior de Feira de Santana, Department of Dentistry. Feira de Santana, Bahia, Brazil. https://orcid.org/0000-0003-0364-4584

2. Unidade de Ensino Superior de Feira de Santana, Department of Dentistry. Feira de Santana, Bahia, Brazil. https://orcid.org/0000-0001-8232-1112

3. Unidade de Ensino Superior de Feira de Santana, Department of Dentistry. Feira de Santana, Bahia, Brazil. https://orcid.org/0000-0002-2893-1689

4. Unidade de Ensino Superior de Feira de Santana, Departamento de Odontologia. Feira de Santana, Bahia, Brazil. https://orcid.org/0000-0001-9090-9063

5. Unidade de Ensino Superior de Feira de Santana, Department of Dentistry. Feira de Santana, Bahia, Brazil. https://orcid.org/0000-0001-8042-2489

6. Unidade de Ensino Superior de Feira de Santana, Department of Dentistry. Feira de Santana, Bahia, Brazil. https://orcid.org/0000-0001-8606-0220

Received: 12/04/2020
Accepted: 19/06/2020

RESUMO

Objetivo: realizar uma revisão integrativa da literatura sobre os diferentes métodos que potencializam a desinfecção dos canais radiculares. **Método:** Trata-se de uma revisão integrativa, onde foram selecionados artigos nas bases de dados Pubmed e Scielo, utilizando os decritores Desinfecção", "Endodontia" e "Enterococcus Faecalis" e seus respectivos termos em inglês: "Disinfection", "Endodontics" e "Enterococcus Faecalis", publicados nos últimos 10 anos. **Resultados:** Foram selecionados 09 artigos que foram lidos e seus achados sumarizados em formato de tabela, desses 06 estudos avaliaram a Irrigação Ultrassônica Passiva (PUI), apresentando os melhores resultados em 03 desses estudos**. Conclusão:** A desinfecção do canal radicular na presença dos métodos auxiliares foi superior em todos os estudos a limpeza promovida somente através dos instrumentos endodônticos, sejam eles manuais ou automatizados associado à solução irrigadora. Dentre os métodos estudados a PUI foi a mais utilizada, apresentando ainda resultados controversos, assim, torna-se necessário mais pesquisas acerca da temática.

Descritores: Enterococcus faecalis; Desinfecção; Endodontia

ABSTRACT

Objective: to carry out an integrative literature review on the different methods that enhance the disinfection of root canals. **Method**: This is an integrative review, in which articles were selected from the Pubmed and Scielo databases, using the descriptors "Desinfecção", "Endodontia" and "Enterococcus Faecalis" and their respective English terms: "Disinfection", "Endodontics" and "Enterococcus Faecalis", published in the last 10 years. **Results:** 09 articles were selected that were read and their findings summarized in table format, of these 06 studies evaluated Passive Ultrasonic Irrigation (PUI), presenting the best results in 03 of these studies. **Conclusion:** Disinfection of the root canal in the presence of auxiliary methods was superior in all studies, the cleaning promoted only through endodontic instruments, whether manual or automated, associated with the irrigation solution. Among the studied methods, the PUI was the most used, still presenting controversial results, thus, it is necessary more research on the theme.

Descriptors: Enterococcus faecalis; Disinfection; Endodontics

RESUMEN

Objetivo: llevar a cabo una revisión integral de la literatura sobre los diferentes métodos que mejoran la desinfección de los conductos radiculares**. Método:** Esta es una revisión integradora, en la cual los artículos fueron seleccionados de las bases de datos Pubmed y Scielo, utilizando los descriptores "Desinfecção", "Endodontia" y "Enterococcus Faecalis" y sus respectivos términos en inglés: "Desinfección", "Endodoncia" y "Enterococcus Faecalis", publicado en los últimos 10 años. **Resultados:** se seleccionaron 09 artículos que fueron leídos y sus hallazgos resumidos en formato de tabla, de estos 06 estudios evaluaron la Irrigación Ultrasónica Pasiva (PUI), presentando los mejores resultados en 03 de estos estudios**. Conclusión:** la desinfección del conducto radicular en presencia de métodos auxiliares fue superior en todos los estudios, la limpieza se promueve sólo a través de instrumentos endodónticos, ya sean manuales o automáticos, asociados con la solución de riego. Entre los métodos estudiados, el PUI fue el más utilizado, aún presenta resultados controvertidos, por lo tanto, se necesita más investigación sobre el tema.

Descriptores: Enterococcus faecalis; Desinfección; Endodoncia.

REVIEW

Introduction

Biomechanical preparation during endodontic treatment aims at root canals asepsis, subsequently allowing them to be sealed in an airtight manner with an inert material.[1-2] This treatment success depends on the removal of inflamed pulp tissue or necrotic debris within a complex root canal system, thus being related to bacterial removal and its products, added to dentin debris.[3-6]

During endodontic therapy, most of these microorganisms are eliminated by endodontic instruments and irrigators, however, the difficulty of reaching areas of isthmus or regions of the apical delta, can lead to an unsatisfactory prognosis of treatment.[7-9] Among the microorganisms present in endodontic infections and in difficult access regions, Enterococcus Faecalis has been the target of many studies for being resistant to conventional endodontic treatment[10-11] and being frequently isolated from persistent endodontic infections.[11-13]

When considering the high anatomical complexity and the microbiota existing in the canal system, it is possible to see that the classic instrumentation and irrigation in isolation are not sufficient to promote adequate asepsis of the channels. This incapacity is mainly due to the high resistance capacity and the persistence of microorganisms, requiring new studies and technologies in order to facilitate endodontic therapy, making it safer, more effective and faster.[7]

Automated systems have been one of the greatest technological advances in Endodontics during the last decades. However, despite the numerous benefits, instrumentation even with the advent of reciprocating movement is still not sufficient to remove all microorganisms, since it reaches only the main channel.[14-15] Studies show that up to 79% of the surface area of the conduits remains untouched, regardless of the system used.16-17 This deficiency in cleaning makes mechanical biofilm removal impossible even in channels with less complex anatomy.[18]

Thus, for there to be an effective protocol in the removal of bacterial biofilm, it is necessary to activate the irrigating solutions within the root canal system, in order to obtain a greater dispersion in regions not reached during the instrumentation, penetrating the branches and isthmus.[18-19]

The mechanical agitation of the irrigating fluid is the factor of great relevance in the dissolution capacity of organic tissues present in the channel systems.[20-21] Therefore, new devices and strategies are needed to assist in this disinfection, by stirring solutions inside the root canal, such as Passive Ultrasonic Irrigation, EasyClean®, XP-Endo Finisher and also through other auxiliary methods such as Therapy Photodynamics (PDT).[22]

Thus, the present study aims to conduct an integrative review of the literature on the different methods that enhance the disinfection of root canals.

Method

This is an integrative review of the literature made using articles obtained from the databases of the International Literature in Health and Biomedical Sciences (PubMed / MEDLINE) and Online Electronic Scientific Library (SciELO) as a database.

For searching the selected articles, strategies were used respecting the specificities of each database, using the descriptors:"Desinfecção", "Endodontia"

and "Enterococcus Faecalis" and their respective terms in English: "Disinfection", "Endodontics" and " Enterococcus Faecalis ", who were previously consulted in Medical Subject Headings (MeSH) and Health Sciences Descriptors (DeCS). The search was carried out in April and May 2020.

The inclusion criteria used were: articles published in Portuguese or English, which were fully available online, published in the last 10 years and whose adopted methodology allowed to obtain potential evidence from experimental studies.

Results

In this study, 1,378 articles were initially found. 453 articles were excluded because they are not directly related to the topic, thus leaving 915 studies. Of these, 137 were selected because they have a specific relationship with the theme. Then 102 were excluded for not meeting the inclusion criteria. The 35 pre-selected articles were read in full, however, only 09 articles were selected to compose this review, as they evaluated the performance of different auxiliary methods of disinfecting the root canals.

Regarding the type of methodology applied in the articles studied in this work, it was noticed that seven articles are in-vitro studies and two are randomized clinical trials.

We noted that there are a lot of comparative studies between different methods. Of the selected studies, 08 evaluated Passive Ultrasonic Irrigation, 04 evaluated the effects of Photodynamic Therapy, 01 evaluated the results of the XP-endo Finisher and 01 evaluated the EasyClean device, and in the same study more than one method could be evaluated.

Table 1 - Relationship between endodontic infection control and the different mechanisms available.

Author- Year	Devices	Methodology	Main Findings
Saber; Hasbem, 2011	Passive Irrigation (PI), EndoVac (ANP), Manual Dynamic Activation (MDA) and Passive Ultrasonic Irrigation (PUI)	40 human lower premolars with single root decorated with a standard length of 16 mm. They were cleaned and modeled using the ProTaper system for size F4 and NaOCl 2.5%. The specimens were divided into 4 equal groups (n = 10) according to the final irrigation technique for activating information: - Group 1, passive irrigation (PI); - Group 2, apical negative pressure (ANP) (EndoVac); - Group 3, manual dynamic activation (MDA); - Group 4, passive ultrasonic irrigation (PUI). The samples were divided longitudinally and examined under scanning electron microscope for the presence of smear layer.	PI and PUI showed the highest amounts of smear layer in the smear, with no significant differences between them. This was followed by the MDA and, finally, the ANP, which showed low statistical significance (P <0.05). In the apical and coronal thirds, PI and PUI had higher smear scores, with no significant differences between them. MDA and ANP recorded the lowest smear scores, with no significant differences between them.
Muhammad et al., 2014	Photo-activation (LED) Aseptim Plus, PhotoDynamic Therapy (PDT) and Passive	30 extracted teeth were prepared and then divided into three groups. All samples were infected with an artificial biofilm formed by Enterococcus faecalis, Streptococcus salivarius, Porphyromonas gingivalis and Prevotella intermedia.	There was no statistically significant difference between the results obtained in the groups treated with Aseptim Plus® and Diode Laser (P <0.6267). In the cultures of both groups there was

	Ultrasonic Irrigation (PUI)	- Group 1 was treated with the Aseptim Plus® photo-activated disinfection system (LED); - Group 2 650 nm diode laser and toluidine blue as photosensitizer; - Group 3 as control by ultrasound irrigation (PUI) using 17% EDTA and 2.6% NaOCl solutions. The working time for all three groups was set at 3 min. The presence or absence of biofilm was assessed by and anaerobic cultures.	a maximum bacterial growth. The group treated with ultrasonic irrigation and NaOCI and EDTA solutions obtained the best results ($p < 0.0001$), there was a statistically significant reduction in bacterial load and destruction of microbial biofilm.
Tennert et al., 2015	ProTaper System and PhotoDynamic Therapy (PDT) Passive Ultrasonic Irrigation (PUI)	270 human teeth extracted with a root canal were instrumented using the ProTaper system, autoclaved, infected with E. faecalis T9 for 72 hours and divided into different groups: - Irrigation with 3% sodium hypochlorite (NaOCl), - 20% ethylendiaminetetraacetic acid (EDTA) or 20% citric acid, - PDT without irrigation, - PDT accompanied by irrigation with NaOCl, EDTA or citric acid, - PDT using an EDTA-based photosensitizer or a citric acid-based photosensitizer - PDT with ultrasonic activation of the photosensitizer. Toluidine blue at 15 mg / ml Sterile paper tips were used to evaluate the root canal sampling and dentin shavings for remaining contamination after treatment. The samples were cultured on blood agar plates and the colony forming units were quantified.	The antibacterial effects were increased by combining irrigation with NaOCl and EDTA or citric acid and PDT compared to irrigation alone. Over 99% of E. faecalis were killed using PDT with the modified photosensitizers and ultrasonic activation.
Hoedke et al., 2018	PhotoDynamic Therapy (PDT)	160 extracted human teeth were divided into four groups (n = 40). - In group G1, root canals were instrumented up to instrument 60 (control group); - In groups G2 to G4, the channels were increased to size 40. All root canals were inoculated with several species present in the biofilm (Enterococcus faecalis, Streptococcus oralis, Prevotella intermedia) for five days. In G2 to G4, instrumentation up to size 60 was performed with: (G2) 0.9% sodium chloride (NaCl) (G3) sodium hypochlorite (NaOCl) 1% (G4) 1% NaOCl and final irrigation with 2% chlorhexidine (CHX) In all groups, half of the samples received adjuvant PDT using phenothiazine chloride as a photosensitizer and diode laser (wavelength 660 nm). Colony formation unit (CFU) counts in each group were analyzed separately for planktonic and dentin-adherent bacteria immediately after therapy (T1) (n = 80) and after 5 days of additional incubation (T2) (n = 80) .	The reduction of planktonic bacteria was significantly affected by protocol irrigation at T1 and T2 ($p < 0.0001$), but PDT significantly reduced CFUs only at T2 ($p = 0.01$). Irrigation with NaOCl, CHX and adjuvant PDT significantly reduced CFU in T2 ($p < 0.0001$) compared to the control group.

Bao et al., 2017	Passive Ultrasonic Irrigation (PUI), Conventional Needle Irrigation (CNI) and XP-endo Finisher (XPF)	54 extracted single-root human premolars were selected. Each tooth was divided longitudinally into 2 halves, with a groove made in the apical segment of the canal wall. After cultivating mixed bacteria biofilm for 4 weeks, the divided halves were reassembled and instrumented using Vortex Blue files for size 40 / .06. The instrumented teeth were randomly divided into 6 groups (n = 8), according to the final irrigation protocol. Three different techniques (CNI, PUI and XPF) were performed, each with continuous irrigation or irrigation in three stages. Microscopic electronic scanning images were performed to assess the amount of residual biofilm inside and outside the groove.	Robust biofilm growth was observed in each control channel after 4 weeks. XPF showed the best biofilm removal efficiency inside and outside the groove, followed by PUI and CNI (P <0.05). The XPF 2 group using the three-step protocol showed better efficiency of the antibiofilm than the XPF 1 group with continuous irrigation inside the furrow (P <0.05).
Pourhajibagher et al., 2018	Photodynamic Therapy (PDT)	E. faecalis was used. Experimental procedures included PDT with curcumin (CUR) and green indocyanine (ICG) as photosensitizers, irrigation with 5.25% NaOCl, 0.2% CHX solutions and 2.0% as traditional endodontic irrigation solutions and the group control. The antibacterial and anti-biofilm potentials were evaluated by counting the colony-forming units and also by the violet crystal test, respectively.	According to the results, the biofilm of E. faecalis was interrupted in 65.3%, 81.0% and 92.6%, using 0.2% CHX, 2.0% CHX and 5.25% NaOCl, respectively (P <0.05). In addition, aPDT mediated by CUR and ICG showed a significant reduction in the count of E. faecalis (90.2% and 82.5%, respectively) and in its biofilm (83.6% and 75.2%, respectively) compared to the control group (P <0.05)
Choi et al., 2019	Passive Ultrasonic Activation (PUI) and GentleWave System.	47 recently extracted human molars were inoculated with Enterococcus faecalis and cultured for 05 weeks to establish the biofilm. 08 molars were tested to confirm infection. 04 of the 08 teeth were not inoculated to provide a negative control. The remaining 39 inoculated molars were randomly separated into three treatment groups (n = 13 per group): - Group 1 - without treatment, - Group 2 - conventional rotary instrumentation and passive ultrasonic activation - Group 3 - minimal instrumentation and GentleWave System treatment. The roots were subsequently prepared by standard histological tissue processing procedures. The sections stained with modified Brown and Brenn and the sections stained with hematoxylin and eosin were visualized at 4 × and 13.5 × magnification using a stereomicroscope. The sections were scored and blindly analyzed by two independent evaluators, including a histopathologist to assess the presence of biofilm on the canal wall.	A significant difference was found between Group 2 and Group 3 in the apical and middle regions (p = 0.001) of the mesial roots of the lower molars and mesiobuccal roots of the upper molars. Group 3 revealed significantly less biofilm than controls (p = 0.003). The GentleWave system demonstrated a significantly greater reduction in biofilm in the mesial roots of the lower molars and in the mesiobuccal roots of the upper molars than those treated with conventional rotary instrumentation and the PUI protocol.

Aveiro et al., 2020	EasyClean and Irrisonic	24 root canals with pulp necrosis and periapical lesions were analyzed before and after the chemical-mechanical preparation of the canal. The teeth were randomly divided according to the activation protocol: - control group without activation (WA, n = 8), - alternating activation group using Easy Clean (EC, n = 8) - ultrasonic activation group using Irrisonic (US, n = 8). The microbiological samples were processed using a culture technique, and the composition of the microbiota was analyzed using the sparse rendering technique. The levels of Lipopolysaccharides (LPS) and Lipoic Acid (LTA) were quantified using Limulus Amebocyte Lysate (LAL) and Enzyme ImmunoAbsorption Assay (ELISA), respectively.	All the initial samples showed growth of viable bacteria, while only one case had this growth after the chemical-mechanical preparation of the canal. LPS and LTA were recovered in 100% of cases. The chemical-mechanical preparation significantly decreased the levels of LPS and ATL ($p < 0.05$), but no significant differences were found between groups ($p > 0.05$). The microorganisms most frequently identified were Prevotella nigrescens and Enterococcus hirae. After the chemical-mechanical preparation of the channel, many species were not detected in any of the three groups tested. There was a significant reduction in the US group, followed by the EC and WA groups.
Orozco et al., 2020	Activation Passive Ultrasonic (PUI) and Conventional Needle Irrigation (CNI)	20 root canals with Primary Endodontic Infection (PEI) and apical periodontitis. The root canals were instrumented and randomly divided into 2 groups, according to the irrigation method: PUI and conventional needle irrigation (CNI). Microbiological samples were collected before instrumentation (S1), after instrumentation (S2) and after irrigation with 17% EDTA (S3). The samples were submitted to the anaerobic culture technique and DNA-DNA checkered hybridization analysis.	A statistically significant difference was found between CNI (23.56%) and PUI (98.37%) in relation to the median percentage values for the reduction of cultivable bacteria ($p < 0.05$). In the initial samples, the most detected species were S. constellatus (50%), and after the root canal treatment was E. faecalis (50%).

Discussion

Sterilization of the root canal system is practically impossible to achieve, regardless of the system used, type of irrigation solution or irrigation techniques. However, what is sought in endodontic treatment is to reduce the bacterial load so that the periradicular tissue of the dental unit heals, since for disinfection, there are two major challenges: the variation of the root morphology of the canal system and the microbial resistance.[32-33]

The mechanical chemical preparation only decreases the microbial load in the root canal, but does not eliminate them completely. This difficulty in the total removal of bacteria is attributed to the reduction of their susceptibility when they are in the form of biofilm.[34] In this sense, different mechanisms have been proposed in the literature to control endodontic infection.[23-24,27,29-31]

When comparing the effectiveness of different methods that enhance the action of irrigating solutions in disinfecting root canal

systems, it was observed that the use of auxiliary methods in all studies favored greater disinfection of the canal system.[23-24,27,29-31] PUI was the most cited method, with better results in studies by Muhammad et al. in 2014, Aveiro et al. in 2020 and Orozco et al in 2020, and worse results in the studies of Saber; Hasbem in 2011, Bao et al. in 2017 and Choi in 2019.

Evidence shows that ultrasonic activation can result in better cleaning of accessory channels, especially in the apical third, and promotes greater penetration of irrigation solutions in dentinal tubules.[25,35] However, Saber; Hasbem, 2011 reported that Passive Irrigation (PI) and PUI showed higher smear layer amounts in the smear in the different thirds, with no significant differences between them, when compared to manual dynamic activation (MDA) and negative apical pressure (EndoVac). These results corroborate the findings by Bao et al. (2017) and Choi (2019).

Although in the literature, some authors have obtained negative results regarding PUI, Muhammad et al. (2014), concluded that the group treated with ultrasonic irrigation and NaOCl and EDTA solutions obtained the best results when compared to Photodynamic Therapy (PDT). Likewise, Orozco et al in 2020 observed that there was a high statistical difference between CNI (23.56%) and PUI (98.37%) in relation to the reduction of bacterial load. Similarly, Aveiro (2020) observed a significant reduction in microorganisms in the channels where PUI was used.

More recently, it has been proposed to use an irrigation solution agitation system, similar to ultrasound, acting in a controlled and efficient way, requiring the acquisition of a high cost equipment called GentleWave System 36. For Choi (2019) the GentleWave System revealed significantly less biofilm than controls and PUI, respectively.

For Muhammad et al. (2014), the PDT did not present positive results, promoting maximum bacterial growth, with no statistically significant difference between the results obtained in the groups treated with Aseptim Plus® and Diode Laser ($P < 0.6267$). However, for Tennert et al., 2015, more than 99% of E. faecalis were killed using PDT with the photosensitizer and ultrasonic activation. However, the conclusions of this study do not allow us to attribute this disinfection only considering the action of the PDT.

In vitro studies demonstrate the antimicrobial potential of PDT, mainly on Enterococcus faecalis in the most diverse parameters.[37-38] Research has also shown that diode lasers were more effective than the ultrasonic activation method or syringe irrigation to remove E. faecalis biofilms.[39] For Hoedke et al. (2017) the reduction of planktonic bacteria was significantly affected by the irrigation protocol in immediately after therapy and after five days of additional incubation ($p < 0.0001$), but the PDT significantly reduced CFUs only in T2 ($p = 0.01$).

For Pourhajibagher et al. (2018), regarding PDT, it is still important to consider the type of irrigation solution used, according

to its results, the biofilm of E. faecalis was interrupted in 65.3%, 81.0% and 92.6 %, using 0.2% chlorhexidine, 2.0% chlorhexidine and 5.25% NaOCl, respectively (P <0.05). In addition, the type of photosensitizer can also interfere in the results, where the use of Curcumin and Green Indocyanine showed a significant reduction in the count of E. faecalis (90.2% and 82.5%, respectively) and in its biofilm (83 , 6% and 75.2%, respectively) compared to the control group (P <0.05). The use of NiTi rotary files to activate the irrigation solution and promote greater cleaning of the canal system has been proposed 40. In this study, Bao et al. (2017), found that the use of XP Endo Finisher had a better removal of biofilm compared to the results obtained in PUI and conventional irrigation.

The use of EasyClean has been growing in recent years, especially due to its ease of handling and, when used in low speed or endodontic engine, there is the potentialization of the removal of debris and a better contact of the irrigating solution with the walls of the complex channel system.[41] For Souza (2018), the protocol using EasyClean showed a quantitative reduction in bacterial load, although it was not statistically significant, as in the study by Aveiro et al (2020), where Irrisonic showed greater efficiency in disinfecting root canals, when compared to EasyClean.

Among the methodologies used to analyze root canal disinfection, five studies used Colony Forming Count (CFU / mL)[25-26,28,30-31,] two used Scanning Electron Microscopy (SEM)[23,27-29] and one study used both methods.[24] Andrade (2012), also performed radiographic images with contrast before and after using the PUI to assess its ability to clean the channels.

Conclusion

Based on the results obtained in this study, it can be concluded that different methods were studied, using different methodologies, which made it difficult to compare them. It was possible to observe that the disinfection of the root canal in the presence of auxiliary methods was superior in all studies to the cleaning promoted only through endodontic instruments, whether manual or automated, associated with the irrigation solution. Among the studied methods, the PUI was the most used, still presenting controversial results, thus, it is necessary more research on the theme.

References

1. Huang Y, Orhan K, Celikten B, Orhan AI, Tefenkci P, Sevimay S. Evaluation of the sealing ability of different root canal sealers: a combined SEM and micro-CT study. J Appl Oral Sci. 2018; 26:1-8.
2. Przesmycka A, Tomczyk J, Pogorzeelska A, Regulski P, Szopinski K. Detection of root canals in historical population from Radom (Poland). Folia Morphol. 2019; 78(4): 853-61.

3. Castelo-Baz P, Martín-Biedma B, Cantatore G, Ruíz-Piñón M, Bahillo J, Rivas-Mundiña B, Varela-Patiño P, *et al.* In vitro comparison of passive and continuous ultrasonic irrigation in simulated lateral canals of extracted teeth. J Endod. 2012; 38(5): 688-91.
4. Neves MA, Provenzano JC, Rôças IN, Siqueira Jr JF. Clinical antibacterial effectiveness of root canal preparation with reciprocating single-instrument or continuously rotating multi-instrument systems. J Endod. 2016; 42 (1):25-29.
5. Nunes KS, Feron L, Montagner F, de Melo, TA.F. Analysis of root canal organic tissue dissolution capacity according to the type of irrigation solution and agitation technique. Brazilian Journal of Oral Sciences. 2016; 15(1): 70-4.
6. Cesario F, Duarte MAH, Duque JA, Alcalde MP, de Andrade FB, So, MVR. et al. Comparisons by microcomputed tomography of the efficiency of different irrigation techniques for removing dentinal debris from artificial grooves. Journal of Conservative Dentistry, Mumbai, Medknow Publications and Media Pvt. 2018; 21(4): 383-7.
7. Rôças IN, Siqueira Jr JF. Identification of bacteria enduring endodontic treatment procedures by a combined reverse transcriptase-polymerase chain reaction and reverse-capture checkerboard approach. Journal of Endodontics. 2010; 36: 45-52.
8. Singla M, Aggarwal V, Logani A, Shah, N. Comparative evaluation of rotary ProTaper, profile, and conventional stepback technique on reduction in Enterococcus faecalis colony forming units and vertical root fracture resistance of root canals. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2010; 109(3): 105-10.
9. De-Deus G, Belladonna FG, Zuolo AS, Cavalcante DM, Carvalhal JCA, Simões-Carvalho M et al. XP-endo Finisher R instrument optimizes the removal of root filling remnants in oval-shaped canals. International Endodontic Journal. 2018; 52(6): 899-907.
10. Pinheiro SR, Alcalde MP, Vivacqua-Gomes N, Bramante CM, Vivan RR, Duarte MA et al. Evaluation of apical transportation and centring ability of five thermally treated NiTi rotary systems. International endodontic journal, 2018;51(6): 705-13.
11. Basmaci F, Oztan MD, Kiyan M. Ex vivo evaluation of various instrumentation techniques and irrigants in reducing E. faecalis within root canals. Int. Endodontic Journal. 2013; 46(9): 823-30.
12. Paqué F, Zehnder M, De-Deus, G. Microtomography-based comparison of reciprocating single-file F2 ProTaper technique versus rotary full sequence. J. Endod. 2011; 37(10): 1394-7.
13. Tennert C, Feldmann K, Haamann E, Al-Ahmad A, Follo M, Wrbas KT et al. Effect of photodynamic therapy (PDT) on Enterococcus faecalis biofilm in experimental primary and secondary endodontic infections. BMC Oral Health. 2014; 14(132): 1-19.
14. De-Deus G, Brandão MC, Barino B, Di Giorgi K, Fidel, RAS, Luna AS. Assessment of apically extruded debris produced by the single-

file ProTaper F2 technique under reciprocating movement. Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod. 2010;110(3): 390-4.
15. You SY, Kim HC, Bae KS, Baek SH, Kum KY, Lee W. Shaping ability of reciprocating motion in curved root canals: a comparative study with micro-computed tomography. J. Endod. 2011; 37(9): 1296-300.
16. Versiani MA, De-Deus G, Vera J, Souza E, Steier L, Pécora JD et al. 3D mapping of the irrigated areas of the root canal space using micro-computed tomography. Clinical Oral Investigations. 2015; 19(4): 859-66.
17. Lopes RMV, Marins FC, Belladonna FG, Souza EM, De-Deus G, Lopes RT, et al. Untouched canal areas and debris accumulation after root canal preparation with rotary and adaptive systems. Australian Endodontic Journal. 2017; 44(3): 260-6.
18. Lin J, Shen Y, Haapasalo M. A comparative study of biofilm removal with hand, rotary nickel-titanium, and self-adjusting file instrumentation using a novel in vitro biofilm model. Journal Endodontics. 2013; 39(5): 658-63.
19. Dioguardi M, Di Gioia G, Illuzzi G, Laneve E, Cocco A, Troiano G. Endodontic irrigants: Different methods to improve efficacy and related problems. European Journal of Dentistry. 2018; 12(3): 459-66.
20. Plotino G, Grande NM, Mercade M, Cortese T, Staffoli S, Gambarini G, et al. Efficacy of sonic and ultrasonic irrigation devices in the removal of debris from canal irregularities in artificial root canals. Journal of Applied Oral Science 2019; 27.
21. Rivera-Pena ME, Duarte MAH, Alcalde MP, Furlan RD, Só MVR, Vivan, RR. Ultrasonic tips as an auxiliary method for the instrumentation of oval-shaped root canals. Brazilian Oral Research. 2019; 33.
22. Teves A, Blanco D, Casaretto M, Torres J, Alvarado D, Jaramillo DE. Effectiveness of different disinfection techniques of the root canal in the elimination of a multi-species biofilm. Journal of clinical and experimental dentistry. 2019; 11(11): 978.
23. Saber SED, Hashem AAR. Efficacy of Different Final Irrigation Activation Techniques on Smear Layer Removal. Journal of Endodontics. 2011; 37(9): 1272-5.
24. Muhammad OH, Chevalier M, Rocca JP, Brulat-Bouchard N, Medioni E. Photodynamic therapy versus ultrasonic irrigation: Interaction with endodontic microbial biofilm, an ex vivo study, Photodiagnosis and Photodynamic Therapy. 2014;11(2): 171-81.
25. Tennert C, Drews AM, Walther V, Altenburger MJ, Karygianni L, Wrbas, KT, et al. Ultrasonic activation and chemical modification of photosensitizers enhances the effects of photodynamic therapy against Enterococcus faecalis root-canal isolate. Photodiagnosis and Photodynamic Therapy. 2015;12(2): 244-51.
26. Hoedke D, Enseleit C, Gruner D, Dommisch H, Schlafer S, Dige EU, Amargo K. Efeito da terapia fotodinâmica em combinação com vários protocolos de irrigação em um biofilme endodôntico de

múltiplas espécies ex vivo . International Endodontic Journal. 2018; 51: 23-34.
27. Bao P *et al*. Eficácia *in vitro* do finalizador XP-endo com 2 protocolos diferentes na remoção de biofilme de canais radiculares apicais. Journal of Endodontics. 2017; 43(2): 321-25.
28. Pourhajibagher M, Chiniforush N, Shahabi S, Palizvani M, Bahador A. Eficácia antibacteriana e anti biofilme da terapia fotodinâmica antimicrobiana contra Enterococcus faecalis intracanal : um estudo comparativo in vitro com soluções tradicionais de irrigação endodôntica. J Dent. 2018; 15(4): 197-2014.
29. Choi HW, Park SY, Kang MK, Shon WJ. Comparative Analysis of Biofilm Removal Efficacy by Multisonic Ultracleaning System and Passive Ultrasonic Activation. Materials. 2019; 12(21): 3492.
30. Aveiro E, Chiarelli-Neto VM , de-Jesus-Soares A, Zaia AA, Ferraz CCR, Almeida JFA, et al. Eficácia da ativação recíproca e ultrassônica do hipoclorito de sódio a 6% na redução do conteúdo microbiano e dos fatores de virulência em dentes com infecção endodôntica primária . International Endodontic Journal. 2020; 53: 604-18.
31. Orozco EIF, Toia CC, Cavalli D, Khoury RD, Cardoso FGDR, Bresciani E et al. Effect of passive ultrasonic activation on microorganisms in primary root canal infection: a randomized clinical trial. Journal of Applied Oral Science. 2020; *28*.
32. Kishen, A. Advanced therapeutic options for endodontic biofilms. Endodontic Topics. 2010; 22(1): 99-123.
33. Rôças IN, Provenzano JC, Neves MAS, Siqueira JF. Efeitos desinfetantes da instrumentação rotatória com hipoclorito de sódio a 2,5% ou clorexidina a 2% como principal irrigante: um estudo clínico randomizado. Jornal de Endodontia. 2016; 42:943-7.
34. Siqueira Jr Jf, Rôças I, Ricucci D. Biofilms in endodontic infection. Endod Topics. 2012; 22: 33-49.
35. Souza MA, Pazinatto B, Bischoff KF, Palhano HS, Cecchin D, de Figueiredo, JAP. Influence of ultrasonic activation over final irrigants in the removal of photo-sensitizer from root canal walls after photodynamic therapy, Photodiagnosis. Photodyn. Ther. 2017; 17: 216–20.
36. Molina B, Glickman G, Vandrangi P, Khakpour M. Evaluation of Root Canal Debridement of Human Molars Using the GentleWave System. *J Endod*. 2015;41(10):1701-5.
37. Silva EJ, Menaged K, Ajuz N, Monteiro MR, Coutinho-filho TS. Dor pós-operatória após aumento do forame em dentes anteriores com necrose e periodontite apical: ensaio clínico prospectivo e randomizado. J Endod. 2013; 39: 173–6.
38. Cruz Junior, JA. The effect of foraminal enlargement of necrotic teeth with the reciproc system on postoperative pain: A prospective and randomized clinical trial. J Endod. 2016; 42 (1): 8-11.
39. Neelakantan P, Romero M, Vera J, Daood U, Khan AU, Yan A, Cheung GSP. Biofilms in Endodontics-Current Status and Future Directions. Int. J. Mol. Sci. 2017; *18*: 1748.

40. Tietz, L. Avaliação com MEV de três protocolos de ativação da substância irrigadora na remoção de material obturador em áreas de complexidade anatômica simulada [Dissertação de Especialização]. Porto Alegre: Faculdade de Odontologia da Universidade Federal do Rio Grande do Sul. 2018.
41. Duque, JA, Duarte, MAH, Canali, LCF, Zancan, RF, Vivan, RR, Bernardes, RA, Bramante, CM. Comparative effectiveness of new mechanical irrigant agitating devices for debris removal from the canal and isthmus of mesial roots of mandibular molars. J Endod. 2017; 43(2): p. 326-31.

Correspondent Author
Joana Dourado Martins Cerqueira
Unidade de Ensino Superior de Feira de Santana
Luís Eduardo Magalhães Subaé Av. ZIP: 44079-002.
Aviário. Feira de Santana, Bahia, Brazil.
martinsjoana_1@hotmail.com