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Title

Outcome and effectiveness of ultrasonically activated irrigation on root canal disinfection and periapical healing. A systematic review.

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Abstract

Introduction:

Irrigation is an essential part of root canal treatment because it improves the debridement and disinfection of areas that tools are unable to thoroughly clean. Remote parts of the root canal system are frequently difficult to clean using irrigation that is mostly done with a syringe and a needle. As a result, various more complex techniques have been introduced. Ultrasonic irrigant activation is probably the most widely used adjunct method, and it has been compared with syringe irrigation in multiple studies. However, very few attempts have been made to summarize the available evidence.

Aim: The purpose of this study was to compare the effectiveness of ultrasonic irrigant activation during primary root canal treatment of mature permanent teeth to syringe irrigation in terms of cleansing and disinfecting root canals and healing of apical periodontitis.

Methods: An electronic search was conducted of the Cochrane Library, Embase, PubMed, Web of science and Scopus databases using both free-text key words and controlled vocabulary. Additional studies were sought through hand searching of endodontic journals and textbooks.

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The retrieved studies were screened by 2 reviewers according to predefined criteria. The included studies were critically appraised, and the extracted data were arranged in tables.
Results: The manual and automated searches turned up 957 titles, out of which 8 articles were selected for the systematic review. This evaluation comprised of randomized trials and in vitro research. In comparison to syringe irrigation, ultrasonic activation did not speed up the healing of apical periodontitis in teeth having a single root canal. The in vitro microbiological research reported a range of contradictory findings. Ultrasonic activation was superior to syringe irrigation in the removal of pulp tissue fragments and hard tissue debris.
Conclusion: As a result of inadequate evidence that was provided, no firm clinical recommendations could be made although ultrasonic activation does provide an alternate debridement mode in curved root canals.
Key Words- cleaning, disinfection Apical periodontitis, irrigation, root canal, ultrasonic activation

INTRODUCTION

The use of ultrasonics to enhance debridement and disinfection of canals has a long history (Martin 1976). Irrigation is an essential part of root canal treatment because it enhances the debridement and disinfection of areas insufficiently cleaned by instruments (1,2). Irrigation mainly performed by a syringe and a needle is often unable to clean remote areas of the root canal system (3). Thus, several more elaborate methods have been developed.

Despite recent improvements in endodontics, cleaning the root canal remains a difficult task. Teeth with periapical lesions have a 50% lower likelihood of success than teeth without periapical lesions, even though endodontic therapy has a success rate between 80 and 95%. This is because periapical injuries, which are caused by bacterial infections in the root canal, are an inflammation in the apical region. (4).

Numerous studies have examined the efficacy of passive ultrasonic irrigation. While some research suggests that churning the irrigating fluid produces better outcomes than traditional irrigation, other research revealed no differences between the methods. (5-8) Given the significance of irrigation in the effectiveness of endodontic therapy, it is necessary to understand which technique guarantees greater root canal disinfection and a higher treatment success rate.

The most popular adjunct technique is undoubtedly ultrasonic irrigant activation, which has been contrasted with syringe irrigation in numerous trials. However, there haven't been many attempts to compile the existing data. A more recent systematic review concentrated primarily on the ultrasonic activation in in vitro antibacterial activity against Enterococcus faecalis in comparison to all other irrigation methods, and several of the included studies made use of questionable experimental designs.

The purpose of this study was to compare the effectiveness of ultrasonic irrigant activation during primary root canal treatment of mature permanent teeth to syringe irrigation in terms of cleansing and disinfecting root canals as well as curing apical periodontitis.

Materials and Methods

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement. PICO question is-Does ultrasonic irrigant activation (I) in comparison to syringe irrigation (C) lead to better healing of apical periodontitis (primary outcome), a stronger antimicrobial effect, or better removal of pulp tissue remnants or hard tissue debris (secondary outcomes) from the root canal system in adult patients with fully formed permanent teeth in need of primary endodontic treatment (P)

Inclusion and exclusion criteria

Inclusion criteria

Studies were included if they utilized a microbiological culture approach, compared the antibacterial impact of UAI with at least one other irrigation technique, and conducted the research on extracted permanent human teeth with fully developed apices (colony forming units). For this review, only English-language articles were included.

Exclusion criteria

Studies that were conducted in vivo, on animals, or in bovine teeth were disregarded. Studies utilizing techniques other than colony forming units (microbiological culture) were excluded. Additionally, case studies and review articles were not included.

Search strategies

The PRISMA standards were followed in conducting the search strategy for this systematic review. For all studies published up until the end of August 2022, a thorough literature search was conducted utilizing the electronic databases PubMed, Ebsco Host, Embase, Cochrane Library, Science Direct, and Scopus. Figure 1 displays the search method, including the key phrase combinations used and the number of articles found. In addition, the Journal of Endodontics, International Endodontic Journal, Journal of Dentistry, and Australian Endodontic Journal were manually searched up until August 2022 for any potentially pertinent articles. Additional research was done on the chosen publications' references to find pertinent articles.

Quality assessment of included article

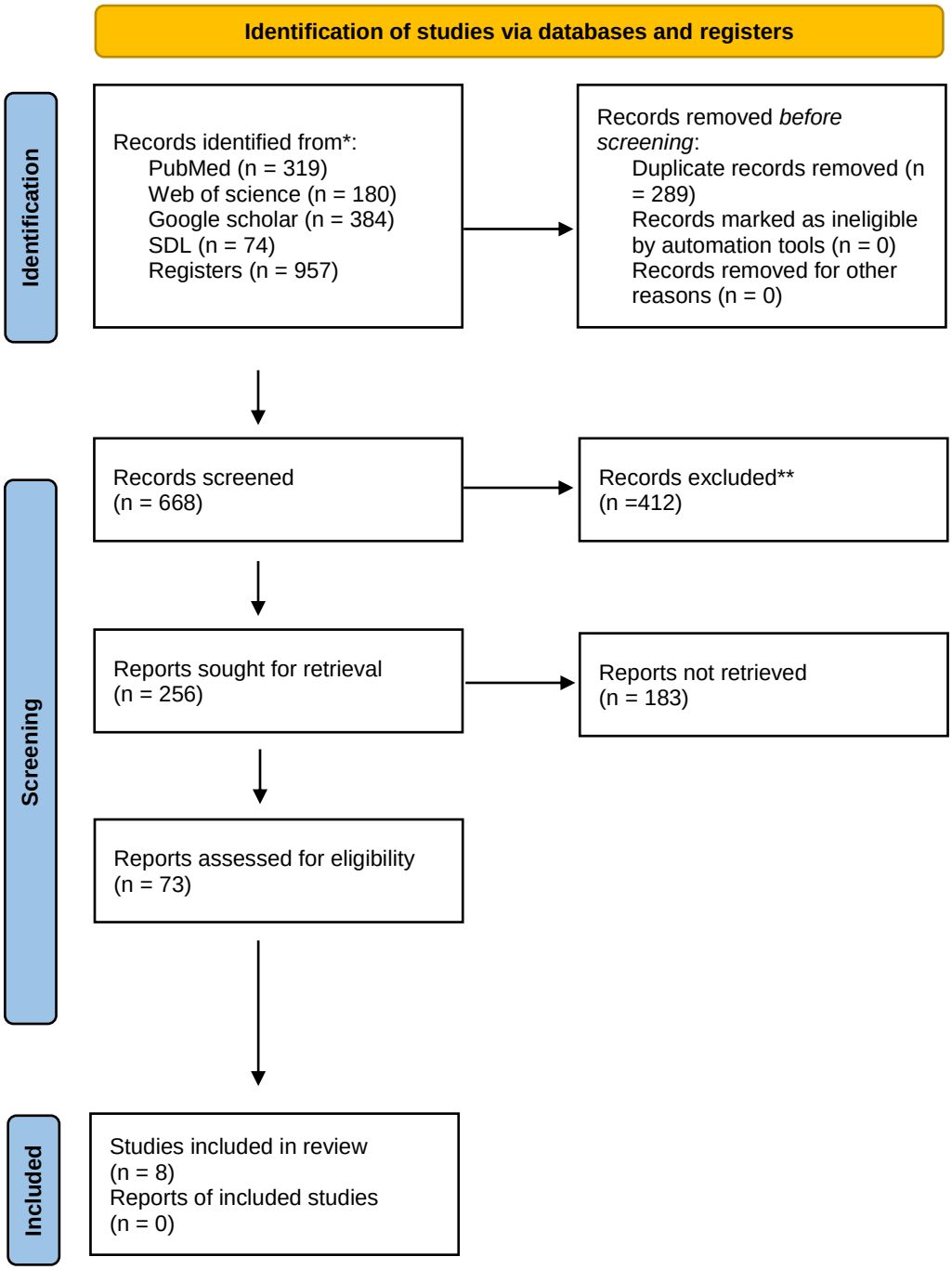
The clinical appraisal checklist for experimental studies by the Joanna Briggs Institute was carefully examined and modified to include all pertinent contents relating to the methodology based on the research question and PICO structure to evaluate the methodological quality of each article. Eight criteria were created as a result. The articles were rated independently by two authors, and in the event of a disagreement, a third author assisted in reaching a decision. Each article's degree of evidence was scored using the following points: low (score 0 to 4), moderate (score 5 to 8), and high (score 9 or higher) (score 9 to 12). Cohen's kappa coefficient was used to determine the initial level of agreement between the two examiners.

RESULTS

A flowchart of the article searches, and selection process based on PRISMA 2020 guidelines is shown in Figure 1. All chosen publications are acceptable according to the JBI checklist. A total

of 957 related articles were retrieved from databases and eight articles were deemed suitable to be included in systematic review after quality assessment.

Fig 1-PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only



Discussion

There is widespread agreement that the removal of pulp tissue and dentin debris is more effective with passive ultrasonic irrigation than with traditional syringe and needle irrigation. This difference could be explained by the fact that ultrasound irrigation produces a higher speed and flow volume of the irrigant in the canal, which removes more debris, results in less apical packing, improves access of the chemical product to accessory canals, and even produces a flush effect that manual irrigation does not. The ultrasonic file can travel freely in the canal (10), preventing dentinal damage and the associated issues like perforations or form anomalies. Nevertheless, a PUI operation is required. The cumulative evidence regarding the removal of the smear layer shows that PUI using water as the irrigant does not completely remove the smear layer, while PUI using 3% NaOCl has been reported to completely remove the smear layer (11). These findings were supported by further research utilizing various NaOCl concentrations. The use of an efficient irrigant must therefore be supplemented with a method that facilitates access to the canal's challenging areas. Other research has produced less definite findings regarding the effectiveness of ultrasonic irrigation in eliminating the smear layer. Even though PUI was found to be significantly superior to needle irrigation, a study found that utilizing PUI with 1% NaOCl for 10 seconds did not entirely remove the smear layer (12). To improve smear layer removal when using sonically activated irrigation and PUI, EDTA has been modified (13,14). Numerous studies have demonstrated that the use of PUI, rather than needle and syringe irrigation, dramatically reduces the quantity of bacteria after manual and rotary instrumentation (15-17). These encouraging results may be the consequence of two primary things. First, high power ultrasound causes bacterial biofilms in the root canal to disaggregate due to the impact of the acoustic current. Bacterial biofilms are broken down, resulting in planktonic bacteria that are more vulnerable to the bactericidal effects of NaOCl. The transient weakening of the cell membrane caused by cavitation may also make the bacteria more permeable to NaOCl (18). However, other research indicates that while using ultrasonic activation reduces the number of surviving colonies, no method can guarantee total disinfection (19). Some writers think that the first stage of endodontic therapy, when the irrigant can be sprayed into the pulp chamber, is the ideal time to apply irrigants with PUI to increase flow activity. Using fine files, ultrasonography during this phase allows the irrigation media to flow toward the apical third. However, most authors claim that the final phase of irrigation, after shaping the root system, is the best time for ultrasound activation of the irrigant because this allows the needle to be introduced throughout the working length, increasing irrigation efficacy. As some authors have demonstrated, factors that favor irrigation include needle depth, the ratio of the root canal's radius to the irrigation needle, and the diameter to which the channel is prepared (20)

In a study conducted by Verma et al in 2020 on 69 patients, a significant difference was observed in the radiographic healing rates among three groups ($\chi 2=12.29$, $p=0.05$). On comparing the final outcome among the three groups (n=19), it was found that 2 (10.5%) cases of group I(Conventional Syringe irrigation), 7 (36.8%) cases of group II (Passive ultrasonic irrigation) and 8 (42.1%) cases of group III(Laser activated irrigation) were healed while under healing category

13 (68.4%) cases of group I, 12 (63.2%) cases of group II and 11 (57.9%) of group III were observed whereas 4 (21.1%) cases were categorised as diseased in group I only(21). A study conducted by Beus et al in 2012 on fifty patients were recruited with a posterior tooth requiring primary endodontic treatment of apical periodontitis, there was no statistical difference between irrigation methods. Each protocol resulted in a high frequency of negative cultures. This high frequency of negative cultures obtained in 1 visit is most likely related to an increased volume and depth of irrigation compared with previously reported protocols (22).

Table 1. Summary of selected articles

Authors	Title	Research Design/ Year	Research Purpose	Subject	Result	Conclusion
Verma et al (21)	A randomized controlled trial of endodontic treatment using ultrasonic irrigation and laser activated irrigation to evaluate healing in chronic	Randimized trial/2020	Aim of this trial was to evaluate the combined clinical and radiographic success rate of endodontic treatment using passive ultrasonic irrigation (PUI) and laser activated irrigation (LAI) as compared to conventi	69 patients were randomly divided into three treatment groups (n=23) by allocation concealment method and irrigation was performed in accordance with the allocated group. Teeth were evaluated clinically and radiographically with CBCT after 6 months and 12 months of the treatment.	A significant difference was observed in the radiographic healing rates among three groups ($\chi 2=12.29$, $p=0.05$).	LAI and PUI can increase the predictability of the endodontic treatment success in cases of chronic apical periodontitis

	apical periodontitis		onal syringe irrigation.			
Beus et al (22)	Comparison of the Effect of Two Endodontic Irrigation Protocols on the Elimination of Bacteria from Root Canal System: A Prospective, Randomized Clinical Trial	Randimized trial/2012	The purpose of this prospective, randomized clinical study was to compare the results of a nonactivated single-irrigation protocol (NAI) that used only 1% NaOCl with a passive ultrasonic multi-irrigation protocol (PUI) that used 1%	Fifty patients were recruited with a posterior tooth requiring primary endodontic treatment of apical periodontitis. . Teeth were randomly treated with the NAI or PUI protocols in the first visit after complete instrumentation. Bacterial cultures were obtained at 4 periods during treatment from the canals: (1) before instrumentation, (2) after irrigation protocol, (3) after CaOH2 medication, and (4) before obturation. Statistical analysis was performed on data by using the Fisher exact test and multivariate analysis.	NAI and PUI rendered canals 80% and 84% bacteria free, respectively, at the end of the first visit. After CaOH2 medication the total sample (NAI + PUI) had increased to 87% bacteria free, and the second-visit instrumentation resulted in a total of 91% bacteria free. These differences were not significant (P > .05).	There was no statistical difference between irrigation methods. Each protocol resulted in a high frequency of negative cultures. This high frequency of negative cultures obtained in 1 visit is most likely related to an increased volume and depth of irrigation compared

			NaOCl, 17% ethylene diaminetetraacetic acid, and 2% chlorhexidine in rendering canals bacteria free. In addition, the effect of a second-visit instrumentation after intra-appointment calcium hydroxide (CaOH2) was also evaluated in bacterial elimination			with previously reported protocols.
Middha et al(23)	Effect of Continuous Ultrasonic	Randimized trial/2016	To evaluate via a randomized clinical	Seventy mandibular molars with non-vital pulps and apical periodontitis were treated endodontically using two different	No significant difference was observed in analgesic consumption between the groups (P > .05). Regression analysis	A significant difference was observed between

	Irrigation on Postoperative Pain in Mandibular Molars with Non-vital pulps: A Randomized Clinical Trial		trial the effect of continuous ultrasonic irrigation on postoperative pain in mandibular molars with non-vital pulps.	irrigation techniques. The patients were randomly allocated to one of two groups, continuous ultrasonic irrigation (CUI) (n=35) and syringe irrigation (SI) (n=35).	revealed a significant association of mean post-operative pain at 24 hours with the irrigant protocol (P = 0.017) and pre-operative pain (P = 0.000).	continuous ultrasonic irrigation and syringe irrigation on the first postoperative day following chemo-mechanical preparation. However, the benefit observed was not clinically relevant.
Haupt et al (24)	Effectiveness of different activated irrigation techniques on debris and smear layer removal from	Randomized trial/2019	This study evaluated the effectiveness of different activated irrigation techniques on removal of debris and smear layer from curved root	Ninety mandibular molars with a root canal curvature between 20 and 40 degrees were assigned to 4 groups (n = 20)	Activation of the irrigant significantly improved smear layer removal (P < 0.05). Regarding debris, only activation with EA and ED was significantly more effective than SI (P < 0.05).	No activation technique was able to eliminate debris and smear layer completely from curved root canals

	curved root canals: a SEM evaluation		canals			
Kamaci et al (25)	The effect of ultrasonically activated irrigation and laser based root canal irrigation methods on debris removal	In vitro/2018	To test the efficacy of debris removal of 5 in vitro irrigation protocols: conventional irrigation, irrigation activated by ultrasound, Er:YAG laser with photon-induced photoacoustic streaming (PIPS) tip, and 2 diode laser techniques.	The root canals of 75 extracted human canine teeth were enlarged and bisected longitudinally. Standardized grooves were prepared	Ultrasonically activated irrigation removed significantly more dentinal debris than conventional irrigation ($p = 0.016$), but there were no significant differences between the other groups.	Ultrasonically activated irrigation was more effective than conventional irrigation in the removal of apically placed dentine debris.

Filho et al(26)	Intermittent or continuous ultrasonically activated irrigation: micro-computed tomographic evaluation of root canal system cleaning	In vitro/2015	s The aim of this study was to evaluate the efficacy of two passive ultrasonic irrigation (PUI) methods and conventional manual irrigation (CMI) in root canal system (RCS) cleaning.	Artificial single-rooted teeth were used. Four lateral canals were made 2 and 7 mm short from the apex	There was no difference among PUI1, PUI2, and CMI1 regarding the contrast solution removal from RCS ($p > 0.05$)	PUI with intermittent or continuous flushing and CMI with the needle placed 1 mm from the working length were efficient in cleaning the main and lateral root canals.
Rodig et al(27)	Micro-CT evaluation of sonically and ultrasonically activated irrigation on	In vitro/2019	To evaluate the efficacy of sonically and ultrasonically activated irrigation on removal of	Forty mesial roots of mandibular molars with two independent canals joint apically by an isthmus (	A significant reduction of AHTD was achieved after final irrigation in all groups ($P < 0.05$), ranging from 44.1%-66.8%. The vol% of debris after irrigation was 3.7 ± 1.9% for EA, 3.3 ± 2.3 % for ED, 2.1 ± 1.6 % for UAI, and 4.4 ± 2.3 % for MI, with no significant difference	None of the final irrigation protocols completely removed AHTD from mesial root canals systems. Sonically and ultrasonica

	the removal of hard-tissue debris from isthmus-containing mesial root canal systems of mandibular molars		accumulated hard-tissue debris (AHTD) in mesial root canal systems of mandibular molars using micro-computed tomographic (micro-CT) analysis		between groups (P > 0.05).	lly activated irrigation performed no better compared to manual irrigation.
Hoedke et al (28)	Reduction of dual-species biofilm after sonic- or ultrasonicactivated irrigation protocols: A	In vitro/2021	To evaluate the antibacterial effect of sonic- and ultrasonic-activated irrigation on bacterial reduction of a dual-species	Two hundred and forty extracted human single-rooted maxillary anterior teeth were divided into two main groups	Sonic activation resulted in significantly higher LRFs than ultrasonic activation	In this laboratory study on extracted maxillary anterior teeth highfrequency sonic activation resulted in a greater bacterialreduction compared to ultrasonic activation

	labora tory study		biofilm in root canals compare d to nonactiv ated irrigation in a laborator y study			in groups receiving solely irrigation/ activation protocols

Conclusion

After thoroughly preparing the root canal system, intermittent passive ultrasonic irrigation should be used as the final step of root canal preparation to augment the initial phase of traditional syringe irrigation. Combining traditional irrigation with ultrasonic irrigation streamlines the process and enhances the removal of germs and the smear layer throughout the canal system, contributing to improved endodontic treatment success rates.

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Author contribution

1) Dr Suhael Ahmed conceptualized the study
2) Sultan Khalid Alsuayri, Ohoud Hamoud Alshammari, Mohammed Abdallah Almana, Shouq Mohammed Aljohani and Sultan Ismail Alshammari gathered the data from databases.
3) Renad Mohammed Alasmari, Suhael Ahmed and wrote the manuscript.
4) Farhan Jassam AlShammary and Aljowhara Allaboon prepared the summary of the selected articles.

Conflict Of Interest

'Conflict of interest declared none'

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