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Evaluation of the Efficacy of Passive Ultrasonic Irrigation Versus Conventional Methods in Endodontic Therapy Outcomes: A Scoping Review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To map clinical passive ultrasonic irrigation protocols and their significance, or lack thereof, in the clinical success of endodontic treatment.
Study Design: Scoping review.
Place and Duration of Study: Independent systematic paired searches were conducted across six databases (Cochrane Library, IEEE Xplore, PubMed, ScienceDirect, Scielo, and the Virtual Health Library) in September 2024.
Methodology: The protocol for this study was registered in the Open Science Framework. Inclusion criteria encompassed randomised clinical trials, comparative in vivo and in vitro studies, and systematic reviews with or without meta-analysis. Studies were assessed for relevance and methodological quality. The risk of bias in clinical studies was evaluated using the Risk of Bias 2 tool in Review Manager 5.4.
Results: Out of 472 studies identified, 8 met the inclusion criteria. Among the 4 clinical studies, 2 demonstrated a moderate risk of bias, and 2 exhibited a high risk. Some studies reported that passive ultrasonic irrigation enhanced microbial reduction and debris removal; however, no significant differences in healing or clinical success were observed compared to conventional irrigation. In vitro studies suggested potential benefits in microbial control, but clinical evidence remained inconclusive due to limited sample sizes, short follow-up periods, and variations in protocols.
Conclusion: Current evidence does not support the routine use of passive ultrasonic irrigation to improve the clinical success of endodontic therapy. Further randomised clinical trials with larger sample sizes, extended follow-up durations, and standardised protocols are necessary to determine the true benefits of this technique in endodontic practice.

Keywords: Passive ultrasonic irrigation; endodontic treatment; root canal disinfection; irrigation protocols; clinical success.

1. INTRODUCTION

The role of bacteria and their by-products in the initiation and perpetuation of pulpal and periapical disease has been well established (Gomes et al., 2002). Most infecting bacteria, together with their principal substrate of necrotic pulp debris, may be removed by routine intra-canal procedures such as instrumentation and irrigation of the pulp space and the use of an intracanal medicament having antimicrobial activity. Nevertheless, this is not always fully achieved in clinical practice (Biffi and Rodrigues, 1989). The anatomical complexities of many root canals and consequent access limitations of instruments, irrigants and intracanal medicaments are well-recognized factors to eliminate the root infection (Biffi and Rodrigues, 1989; Gomes et al., 2002).

Moreover, despite the antimicrobial effect of chemomechanical preparation and intracanal medicaments, the elimination of microorganisms may not be uniform because of the vulnerability of the species involved (Gomes et al., 1996). Therefore, concern exists as to the fate and consequences of the remaining microorganisms in the canal. They may multiply rapidly, in some cases, to almost the initial number in 2–4 days, if the canal is left empty (Byström and Sundqvist, 1981).

A variety of irrigant solutions have been utilised in endodontics, including sodium hypochlorite, chlorhexidine, ethylenediaminetetraacetic acid (EDTA), citric acid, and saline, among others. Recently, the agitation of irrigant solutions, particularly sodium hypochlorite and EDTA, has been advocated to enhance their antimicrobial effectiveness and reach areas not accessible by instruments (Aveiro et al., 2020).

The concept of passive irrigation of the irrigant solution was initially proposed by Weller et al. (1980). According to the researchers, this practice aims to increase the antimicrobial power of the irrigant and facilitate access to areas untouched by endodontic instruments, such as isthmuses and lateral canals, as well as enhance the penetration of the irrigant into the depths of the dentinal tubules (Azim et al., 2016; Bao et al., 2017; Nabeshima et al., 2024).

In vitro studies strongly support the hypothesis that agitation can increase the antimicrobial capacity of the solution and improve the cleaning of canal walls compared to conventional irrigation methods (Nabeshima et al., 2024). However, there are few randomised clinical trials that support such protocols, which does not justify an increase in success rates with the incorporation of this systematic approach in clinical practice. Therefore, this scoping review aims to map the clinical irrigation protocols and their significance, or lack thereof, in the clinical success of endodontic treatment.

2. METHODS

The protocol for this study was registered on the Open Science Framework (OSF), where it was assigned the following identification code https://doi.org/10.17605/OSF.IO/38QM5.

The research question for this study was formulated using the PICO strategy, where P represents the patients, I the intervention, C the comparison, and O the outcomes. In this context, P refers to patients undergoing root canal treatment, I to passive ultrasonic irrigation (PUI), C to conventional irrigation methods, and O to the assessment of post-procedural healing. Consequently, the following research question was developed: is PUI more effective than conventional methods in promoting healing and clinical success?

The following keywords were used: “passive ultrasonic irrigation”, “root canal treatment”, “healing”, and “success”, due to the absence of suitable Medical Subject Headings (MeSH) descriptors for the condition under investigation, combined by the Boolean operator “AND”: “passive ultrasonic irrigation” AND “root canal treatment” AND “healing” AND “success”. No restrictions, such as publication date, language, or other factors, were applied in order to capture the widest possible range of articles on the topic. In cases where discrepancies arose, a third researcher was consulted to resolve them.

Systematic searches conducted in September 2024 were performed in the following databases: Cochrane Library, IEEE Xplore, PubMed, ScienceDirect, Scielo, and the Virtual Health Library (VHL). These searches were performed in the advanced search interface during September 2024, independently and in pairs.

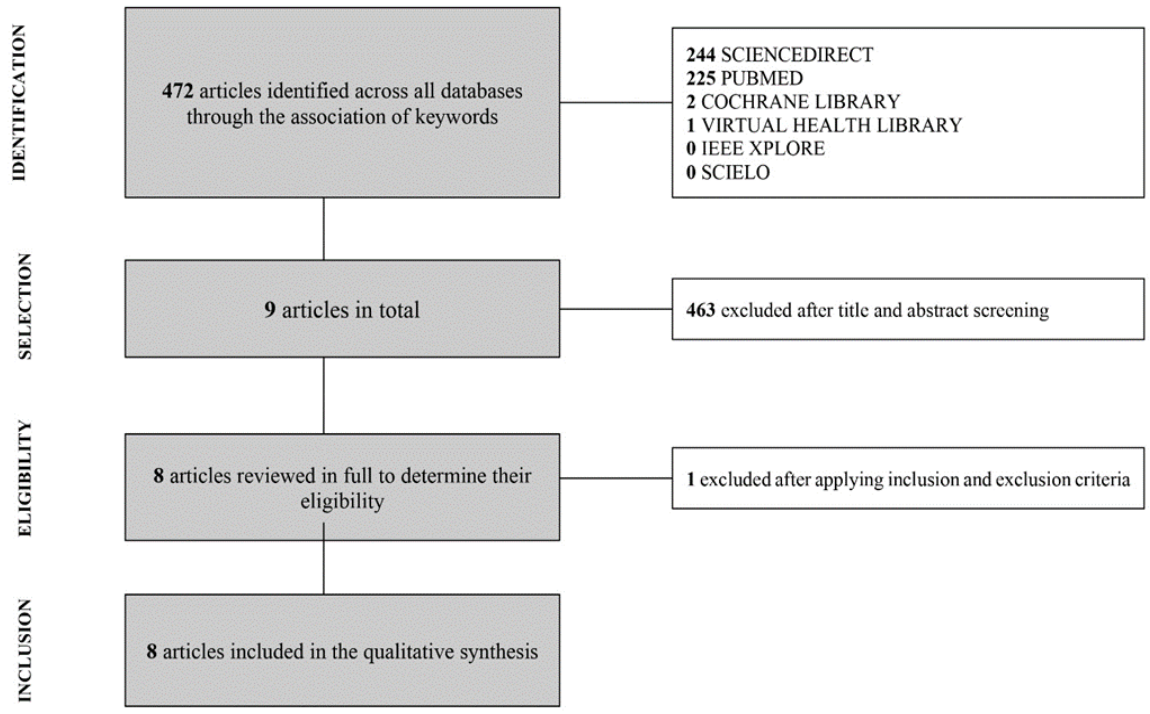

Fig. 1. Flowchart for identification and selection of studies.
Source: Authors (2024)

The inclusion criteria comprised randomised clinical trials, including double-blind studies, comparative in vivo and in vitro studies with a considerable sample size (n); systematic reviews, with or without meta-analyses; and any studies cited in the identified articles that met the inclusion criteria. Additionally, studies were included through manual selection when their relevance was meticulously verified against the predefined inclusion criteria. Exclusion criteria involved studies deemed tangential to the topic; isolated in vitro studies or those focusing exclusively on dentinal wall cleaning; other types of reviews, such as narrative or integrative reviews; and duplicate studies.

The articles were initially screened independently by two researchers based on their title and abstract, followed by a full-text review. Final selection was made after applying the inclusion and exclusion criteria (Fig. 1).

After the selection process, the studies were organised into a Google Sheets spreadsheet and categorised according to the following variables: author, year of publication, study location, study design, sample size, study summary, irrigant solution used, agitation protocol, and success rate as reported by the authors. Subsequently, the Clinical Studies were assessed for risk of bias using the Risk of Bias 2 (RoB 2) tool by a researcher experienced in the field of endodontics, and evaluations were conducted using Review Manager 5.4.

Finally, the present article was prepared following the guidelines outlined in the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) protocol.

3. RESULTS

The searches conducted in the selected databases yielded a total of 472 studies. Following title and abstract screening by two independent researchers, 9 articles were initially selected. One was excluded after full-text analysis and application of the eligibility criteria, leaving 8 articles to be included in this scoping review (Tables 1, 2, and 3). The bias risk assessment conducted using RoB 2 for the included clinical studies showed 2 with moderate risk and 2 with high risk (Figs. 2 and 3)

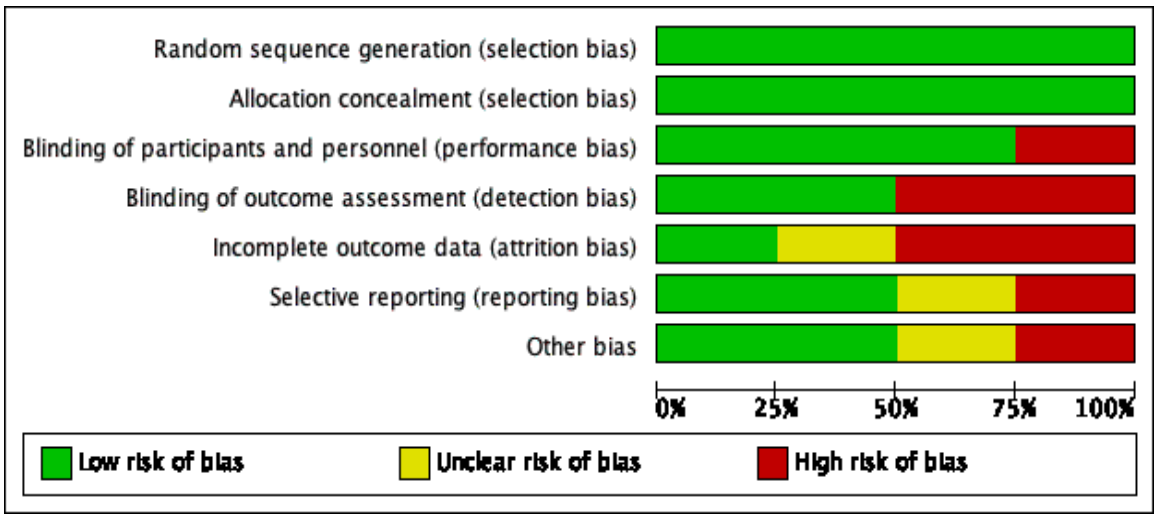

Fig. 2. Risk of bias assessment of Clinical Studies about each risk of bias item presented as percentages across all included studies

Source: Authors (2024)

Table 1. Clinical Studies Included in this Review

Authors, Year of Publication, and Country of Origin	Study Type	Irrigant Solution Used	Irrigation Technique Used	Total Sample Size	Vital or Lesioned Teeth	Lesion Regression Follow-up Period	Total Number of Re-examined Patients	Summary of Results
Liang et al., 2013, China	RCT	5.25% NaOCl	PUI	105	NPs and PLs	10-19 months	84	No significant difference between PUI and conventional irrigation.
Nakamura et al., 2018, Brazil	RCT	2.5% NaOCl	PUI	50	NPs and PLs	None	NA	Intracanal disinfection was higher with PUI, but root canals were not filled or followed radiographically.
Verma et al., 2020, India	RCT	3% NaOCl	PUI and Laser-activated Irrigation	69	NPs and PLs	6-12 months	57	Both PUI and Laser groups showed 100% success in lesion reduction and complete healing phases. Conventional irrigation group showed 78.9% success.
Doğan et al., 2024, Turkey	RCT	2.5% NaOCl and EDTA	PUI, Laser-activated irrigation, manual agitation, and manual agitation with gutta-percha	56	NPs and PLs	3, 6, 9, and 12 months	NA	No significant difference was found between the four groups.

RCT, Randomised Controlled Trial; EDTA, Ethylenediaminetetraacetic Acid; LP, Periapical Lesion; NaOCl, Sodium Hypochlorite; NA, Not applicable; NPs, Necrotic pulps; PUI, Passive Ultrasonic Irrigation.

Source: Authors (2024)

Table 2. *In Vitro* Studies Included in this Review

Authors, Year of Publication, and Country of Origin	Study Type	Irrigant Solution Used	Irrigation Technique Used	Total Sample Size	Summary of Results
Ahangari et al., 2021, Iran	*In Vitro*	5.25% NaOCl	PUI Laser-activated Irrigation, and PUI combined with Laser-activated Irrigation	50	No significant difference between conventional irrigation and PUI.
Nabeshima et al., 2024, Brazil	*In Vitro*	2.5% NaOCl and 17% EDTA	PUI, EasyClean agitation in reciprocating and rotating motions, XP-Endo Finisher agitation, XP Clean agitation, and conventional irrigation	72	No bacterial growth observed in any of the samples after preparation and 24 hours of incubation.

EDTA, Ethylenediaminetetraacetic Acid; NaOCl, Sodium Hypochlorite; PUI, Passive Ultrasonic Irrigation.
Source: Authors (2024)

Table 3. Systematic Reviews Included in this Review

Authors, Year of Publication, and Country of Origin	Study Type	Total Studies Without Duplicates	Total Included Studies	Statistical Evaluation	Summary of Results
Silva et al., 2019, Brazil	Systematic Review without Meta-analysis	346	3	Not applied.	No difference in healing outcomes observed with or without the use of PUI.
Gobbo et al., 2024, Brazil	Systematic Review with Meta-analysis	997	3	Dichotomous variables were analysed using Relative Risk (RR) as the effect estimate, with a 95% confidence interval (CI). Inter-study variation was assessed using tau-square, and heterogeneity magnitude was evaluated using I^2. Random-effects meta-analysis.	The effects of this technique were inconclusive, and the quality of evidence was rated as moderate.

Source: Authors (2024)

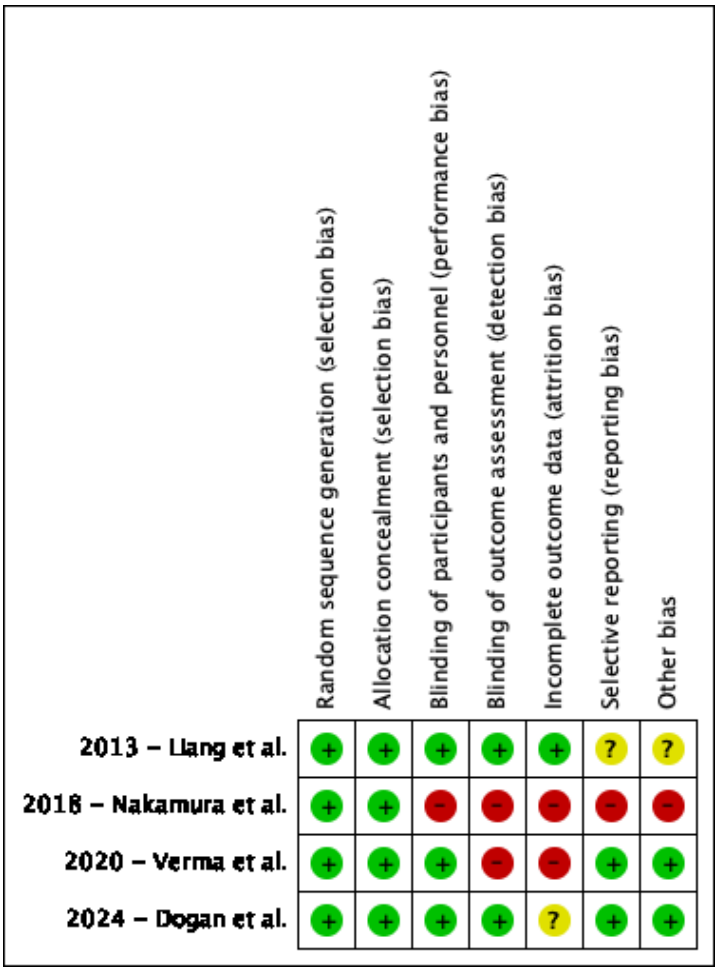

Fig. 3. Risk of bias assessment of Clinical Studies about each risk of bias item for each included study

Source: Authors (2024)

4. DISCUSSION

Over the past few decades, huge technological advancements have been made in the field of endodontists such as the ultrasonic activation of irrigation solutions. Despite such advancements, the question exists as to whether these technologies have improved the outcome of endodontic treatment and increased the likelihood of tooth survival (Fleming et al., 2010).

Although ultrasonic activation improves both the mechanical and chemical aspects of the irrigation procedure in *in vitro* research, it did not influence the endodontic outcome of root canal treatment and the researchers suggest that PUI can be ineffective in significantly improving disinfection of the main root canal after chemo mechanical procedures (Ng et al., 2011; Paiva et al., 2013; Nabeshima et al., 2024). This can be related to a variety of reasons, including the statistical power of the studies, the clinical relevance of the *in vitro* models, and the fact that improved cleaning does not automatically result in a better outcome. Furthermore, other complicating factors such as the details of the root canal anatomy (apical delta and dentinal tubules), the structure of the biofilm, the external biofilm around the root apex, root filling, or the effect of instrumentation could have been more influential than the irrigation procedures used associated or not with passive ultrasonic irrigation (Haapasalo et al., 2008; Liang et al., 2013).

On the other hand Verna et al. (2020) when comparing the final outcomes among the three groups (n=19), the success rate for treatment of group I (Conventional Syringe irrigation) was 78.9%, while groups II (Laser-Activated Irrigation) and III (Passive Ultrasonic Irrigation) both achieved a success rate of 100% with a significant difference in the radiographic healing

rates among the three groups (χ^2=12.29, p=0.05). The 100% success achieved in groups II and III may be related to the short follow-up period and the lack of identification of the causes of failure in the group with conventional irrigation. Another important consideration is the sample size and the limited follow-up time after endodontic treatment. A longer follow-up period could lead to a better balance between success and failure across the groups, as the 100% success rate observed in groups II and III is not consistent with the indices typically seen for endodontic treatment (Ng et al., 2011).

The most important randomised clinical study with the largest number of patients selected in the literature search of the present study was conducted by Liang et al. (2013), who compared the radiographic healing of eighty-six single-rooted teeth with radiographic evidence of periapical bone loss, which were randomly assigned to two treatment groups. In both groups, syringe irrigation was performed, and in one group, the irrigant was also activated by passive ultrasonic activation. Ten to 19 months after treatment, the teeth were examined using periapical radiography (PA) and cone-beam computed tomography. In both irrigation groups, the percentage of absence and reduction of radiolucency was high: 95.1% for the ultrasonic group and 88.4% for the syringe group with no significant difference between the results of the two groups (P = .470) what supports the hypothesis of the present study is that there is no significant difference between the use and non-use of ultrasonic agitation.

Ng et al. (2011) showed that some conditions were found to improve periapical healing significantly: the preoperative absence of a periapical lesion (P = 0.003); the absence of a preoperative sinus tract (P = 0.001); achievement of patency at the canal terminus (P = 0.001); extension of canal cleaning as close as possible to its apical terminus (P = 0.001); absence of root-filling extrusion and filling with no voids (P £ 0.001) and presence of a satisfactory coronal restoration (P £ 0.001) what supports the results observed in the present study is the evidence suggesting that while ultrasonic agitation may enhance the effectiveness of irrigation, but it does not consistently correlate with improved outcomes in endodontic therapy.

There is literature that supports PUI's use and suggests several benefits that could lead to more favourable outcomes in root canal treatment. These benefits include reduced microbial load (Nagendrababu et al., 2018), increased hard tissue debris removal (Barbosa et al., 2021), increased efficacy in the removal of the vapor-lock phenomenon (Dioguardi et al., 2019), increased efficacy on the removal of interappointment calcium hydroxide dressings (Jamali et al., 2020). However all their studies were made *in vitro* which made the clinical relevance doubt.

Nabeshima et al. (2024) showed that the root canal lumen had no bacterial growth after root canal preparation and final irrigation with 2.5% sodium hypochlorite throughout the 24 hours of incubation when compared the ultrasonic irrigation and conventional irrigation. The root canal cementum is of greater importance in isolating patent dentinal tubules on the periodontal side, preventing residual bacteria from reaching exit portals to the periodontal space, except in larger lateral canals. Thus, when the cementum is present, residual bacteria inside dentinal tubules will not survive with-out nutrients and space for their growth (Haapasalo and Orstavik, 1987; Safavi et al., 1990). The cementum was confirmed by Berutti et al. (1997). to be a barrier against the penetration of bacteria.

In cases involving teeth with wide or open apices, it is advisable to keep shaping to a minimum. Furthermore, active irrigation should be avoided due to the risk of the irrigant extruding beyond the apex (Brown et al., 1995). The dynamics of irrigation play a crucial role in its effectiveness; the ability of the irrigant solution to come into contact with microorganisms and debris within the root canal is vital (Gao et al., 2009). For immature teeth or those with open apices, appropriate irrigant techniques are essential to reduce the risk of apical extrusion. Sodium hypochlorite (NaOCl), with its numerous beneficial properties, can be used in teeth with open apices, especially when coupled with passive ultrasonic irrigation (PUI), to enhance disinfection and cleaning of the root canal while minimising the risk of apical extrusion, provided it is applied with caution (Magni et al., 2021).

Currently, there exists a body of work striving to systematically review the subject in order to understand the primary effects of the technique. However, these reviews encounter common challenges, notably the limited number of rigorously conducted randomised controlled trials (RCTs) eligible for inclusion.

Silva et al. (2019) identified a considerable number of 346 studies during their initial search, excluding duplicates; however, only three were included as they met broad and non-specific inclusion criteria. This led to difficulties in analysing the included studies, as despite all investigating PUI in some capacity, the protocols varied and did not assess the same outcomes. Two studies focused on microbiological aspects, while the third evaluated clinical-radiographic control. The study acknowledges these limitations and emphasises the need for additional randomised controlled trials to achieve a more precise understanding of the technique.

The systematic review and meta-analysis conducted by Gobbo et al. (2024) similarly included only three studies, with stringent inclusion and exclusion criteria limited to randomised controlled trials. The statistical analysis suggests a positive impact of PUI on the periapical healing rate when compared to conventional irrigation; however, the certainty of this evidence remains moderate, and the overall impact of the technique is inconclusive, making it less than fully reliable, as these studies employed differing protocols and were conducted under varying conditions.

Both the evaluated reviews (Silva et al., 2019; Gobbo et al., 2024) reinforce the necessity for further research with larger sample sizes and extended follow-up periods. Nevertheless, the recommendation by Gobbo et al. (2024) for the inclusion of this technique in the routine clinical practice of endodontic treatments, alongside the development of clinical guidelines, cannot be considered at least for the time being, as there is still insufficient scientific evidence to justify such an approach.

Common limitations are apparent in the studies assessed and compared in this review. The findings were predominantly inconclusive, and the methodologies employed across these studies exhibited considerable variability. A significant shortcoming was the limited number of rigorous investigations, many of which suffered from small sample sizes and inadequate follow-up durations, with some lacking the necessary long-term follow-up to fully understand the effects. Furthermore, complicating factors such as the anatomy of the root canal and the structure of the biofilm must be taken into account when interpreting the results. Additionally, statistical uncertainty was noted, alongside recommendations that lacked justification, as there is presently insufficient evidence to substantiate them.

The execution of this scoping review also encountered limitations. Notably, there was a lack of a comprehensive descriptor that encompasses the PUI technique, which somewhat hampers the identification of studies that could have enriched the sample, even though the search was conducted meticulously. Furthermore, as previously discussed, the limited number of eligible studies, coupled with the predominance of *in vitro* investigations, many of which exhibit methodological biases, undermines the reliability of their findings.

5. CONCLUSION

Based on the literature mapped for this scoping review, the available evidence does not support the use of PUI to improve the success of endodontic therapy. Further randomised clinical trials with larger sample sizes, longer follow-up periods, and standardised protocols are needed to determine the real benefit of this practice in endodontic routine.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The authors declare that the AI technology, GPT-4o, was used fairly and solely for rewriting and editing this manuscript, with the specific purpose of correcting the English grammar of the translated text, which was originally written in Brazilian Portuguese. No additional information was inserted into the text; the AI's role was limited to verifying and refining the accuracy of the translation. Details of the AI usage are as follows:

1. The original manuscript, written in Brazilian Portuguese, was translated into English, and the AI was employed to ensure the final text adhered to the grammatical standards of academic English.
2. Specific prompts were designed to guide the AI in providing grammatical corrections and verifying the translation's alignment with academic conventions.

CONSENT

It’s not applicable.

ETHICAL APPROVAL

It’s not applicable.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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