Journal of Chemical Health Risks

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JCHR (2025) 15(3), 617-626 | ISSN:2251-6727

Comparing the Removal of Intracanal Medicament from Root Canal System using Four Different Irrigation Techniques: A Systematic Review

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(Received: 16 March 2025 Revised: 20 April 2025 Accepted: 01 May2025)

KEYWORDS

Calcium hydroxide · EDDY · Needle irrigation · Passive ultrasonic irrigation · SWEEPS

ABSTRACT:

Introduction: To eliminate intracanal calcium hydroxide (Ca[OH]2) medication from root canal, this systematic review compared the results of in vitro experiments using needle irrigation, ultrasonic irrigation, sonic irrigation, and laser activated irrigation techniques.

Methods: The population, intervention, comparison, and outcome strategies were taken into consideration when developing the research question. Cochrane, PubMed, Google Scholar, Ebsco, and Embase were searched for relevant material using a computer. To find pertinent articles, a random search of the identified papers' reference lists was done. The studies that meeting the inclusion criteria were evaluated critically by two reviewers. Both reviewers conducted separate assessments of the studies' risk of bias. A manual search using online resources was also carried out. To find further publications that satisfied the study's eligibility requirements, cross-reference lists of the selected studies were examined.

Results: Following study selection, 4093 publications were found using a database search; 161 full-text articles were assessed for eligibility. After fulfilling the inclusion requirements, eight of them were added to the systematic review. Because of the significant variation in the methods, a meta-analysis was not practical. The screening process was conducted by two reviewers. The first step was evaluating the publications based on their titles and abstracts. After that, full-text papers were obtained for further assessment to ensure they met the study's specifications.

Conclusions: We came to the conclusion that it did not have any statistically significant difference between the root canal and the removal of the CH based on the available data (P>0.05). The capacity

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JCHR (2025) 15(3), 617-626 | ISSN:2251-6727

to remove intracanal medicines was highest with SWEEPS and lowest with syringe-needle irrigation ($P<0.05$). The intracanal medicament could not be entirely removed using any method. SWEEPS technology fared better than the sonic and ultrasonic systems in terms of removing intracanal medicines. Due to the limitations, small number of studies, and sample sizes, findings are needed additionally.

1. Introduction

The main cause of dental infections is microorganisms found in the root canal system, and the main objective of endodontic therapies is to eradicate them [1] Irrigating fluids, intracanal medications, and mechanical equipment are used to accomplish this. [2] Although mechanical instrumentation greatly lowers microorganisms, it is still difficult to fully clean the root canal. As a result, strong antibacterial intracanal medications and efficient irrigation solutions are required. By eliminating biofilms and providing complete disinfection, these materials establish an environment that promotes regeneration.[3]

Despite drawbacks such cytotoxicity, staining, bacterial resistance, and weakened dentin bonding, calcium hydroxide (CH) is most frequently utilized as an intracanal medication in root canal therapy [4]. Current theories state that in regular endodontic procedures, calcium hydroxide is eliminated by syringe-needle irrigation (SNI) using an ethylene diamine tetra acetic acid (EDTA) solution. [5] Nevertheless, it has been shown that SNI may jeopardize the root canal space's ability to be effectively disinfected, and different irrigation techniques have been developed to enhance irrigation. [6] One of these is passive ultrasonic irrigation (PUI), which may be turned on between 25 and 30 kHz and concentrates on sending acoustic energy from a smooth wire or oscillating file to an irrigation solution in the root canal .[7] Another irrigation activation method used in endodontic operations involving the use of sonic radiation is called EDDY (VDW, Munich, Germany). [8] Its flexible polyamide tip causes sonic streaming and cavitation in the irrigation solution and has a frequency range of 5–6 kHz .[9]

To increase the effectiveness of watering and disinfection, laser-activated irrigation has been created. [10] Endodontics has recently employed shock wave–enhanced mission photo-acoustic streaming (SWEEPS, FOTONA, Ljubljana, Slovenia, EU) lasers to improve debridement efficiency. [11] Similar to PIPS, SWEEPS technology uses an erbium laser with ultra-short pulses to collapse laser-induced bubbles after inserting the fiber tip into the pulp chamber. [12]

No systematic review has examined the effectiveness of eliminating Ca(OH)2 medicine from root canals utilizing needle, ultrasonic, sonic, and laser-activated irrigation devices. Therefore, the purpose of the study was to assess the removal of CH from the root canal space using SNI, PUI, EDDY, and SWEEPS techniques.

The meta-analysis statement and the recommended items for systematic reviews criteria were followed in the conduct of this systematic review.

2. Objectives

Need of the review: Establishing evidence-based guidelines to enhance clinical outcomes in endodontics requires evaluating different irrigation procedures for the elimination of Calcium hydroxide intracanal medication from the canals. When linked publications yield conflicting results, a systematic review can be used for a number of reasons to address issues that the individual research are unable to address. Prior research has demonstrated the effectiveness of several irrigation methods separately, but none of them have compared all of the methods for CH medication elimination.

The research question was the following: "'What is the efficacy of the removal of Ca(OH)2 from the root canal system using needle, ultrasonic, sonic and laser activated irrigation system?"'

The PICO framework was used for the prisma flowchart.

3. Methods

- **Protocol Registration:**

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standards and the 2019 Cochrane Handbook were carefully followed in the production of the review. January 10, 2024 was the start

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of the trial. The protocol was registered on the Open Science Framework (OSF) to ensure transparency and accountability in the review process. https://doi.org/10.17605/OSF.IO/UM9X4.

- **Focused Question:**

The focused question's specifics were as follows: 1. **Participants (P):** human teeth that had been removed but still had entire root canals. 2. **Intervention (I):** Elimination of intracanal calcium hydroxide medication. 3. **Comparison (C):** Standard techniques (both experimental and control groups from primary research will be included since this is a systematic review). 4.**Outcome(O):** A scoring system based on the amount of medication still in the root canal was used to assess the outcome of interest.

- **Information Sources and Search Strategy:**

Relevant literatures were searched independently by two authors up to **December 31st , 2023.** In all databases mentioned above, the following search strategy was used. **(((((((removal of intracanal medicaments) OR syringe needle irrigation) AND (ultrasonic irrigation)) AND (sonic irrigation)) AND (laser irrigation)) AND (PUI)) AND (EDDY)) AND (SWEEPS)) AND (Calcium hydroxide removal)) AND (double antibiotic paste removal)**

The following databases were searched:

PubMed, Ebsco, Embase, Cochrane, Google Scholar.

The search strategy used a combination of keywords related **"removal of intracanal medicaments", "irrigation techniques", " passive ultrasonic irrigation", "EDDY" "laser activated irrigation" were used.** To guarantee thorough coverage of the literature, pertinent search phrases were combined using boolean operators (AND, OR).

- **Selection Process:**

The study selection process involved full-text evaluation and screening of titles and abstracts. Two independent reviewers searched the titles and abstracts of the retrieved papers for possibly relevant studies. If an article met the inclusion criteria or required additional analysis, it was selected for full-text review.

Inclusion Criteria:

1. Research that has been published in journals with peer review.
2. Research such as systematic reviews, meta-analyses, clinical cases, and randomized control trials.
3. Extracted completely developed (mature) human teeth were used in vitro experiments.
4. Studies on the efficacy of employing an irrigation device to remove Ca(OH)2 medication from root canals and the removal of intracanally injected Ca(OH)2 materials.

5.Studies conducted on models undergone RCT.

6.Studies comparing various irrigation systems.

7.Studies for removal of intracanal medicament from root canal system.

8.Studies reporting relevant clinical outcomes, in the removal efficacy of various systems.

9.English language studies.

Exclusion Criteria:

1. Research that doesn't address the research question.
2. In vivo and animal research.
3. Research that did not satisfy any of these requirements for inclusion was not included.

4. Reviews of the literature.
5. Research that appears similarly in many search engines (duplicate studies)

6. Studies with inadequate sample size or insufficient data.

7. Studies in languages other than English.

8. Studies focusing on surgical intervention for removal of Ca(OH0)2 from the root canal.

- **Risk of Bias Assessment and Statistical Analysis:**

Using the Cochrane's risk-of-bias approach (RoB 2.0), the risk of bias generated by the following five domains was assessed: the randomization procedure, deviations from planned interventions, missing outcome data, outcome assessment, and choice of the reported result. Two writers separately assessed the risk of bias in each domain after a series of signaling questions. They then estimated each included trial's overall bias using the

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algorithm described in the RoB 2.0 recommendations. For a study to be considered low risk in all domains, it was considered to have a low risk of overall bias. If there were significant risks in any one of the domains, the study was considered to have a high risk of overall bias. If the experiment had minimal risk or some worries but no considerable risk in any one area, it was considered to have some issues overall. A senior author was consulted in order to resolve the discrepancies of two evaluators. The domains were categorized as "+" to suggest a low risk of bias (RoB) and as "-" to suggest a high RoB. Articles were classed as having a low RoB if they had six or more domains assessed as low (+); a moderate RoB if they had four or five low domains; and a high RoB if they had three or fewer low domains.

Literature Screening and Data Extraction:

A standardized data extraction form was preferred for data extraction and quality assessment checklists (PRISMA Guidelines, 2009) were used for the appraisal step. These checklists covered topics like study design and analysis and pointed out any potential bias-related shortcomings. Two independent reviewers completed this stage to increase the results' dependability. Disagreements among the reviewers were settled through discussion.

- **Data Synthesis and Analysis:**

Because of the expected heterogeneity among the primary investigations, a narrative synthesis of the results from the included studies was conducted. For making comparison and understanding simple, the results were arranged and displayed in a tabular style.

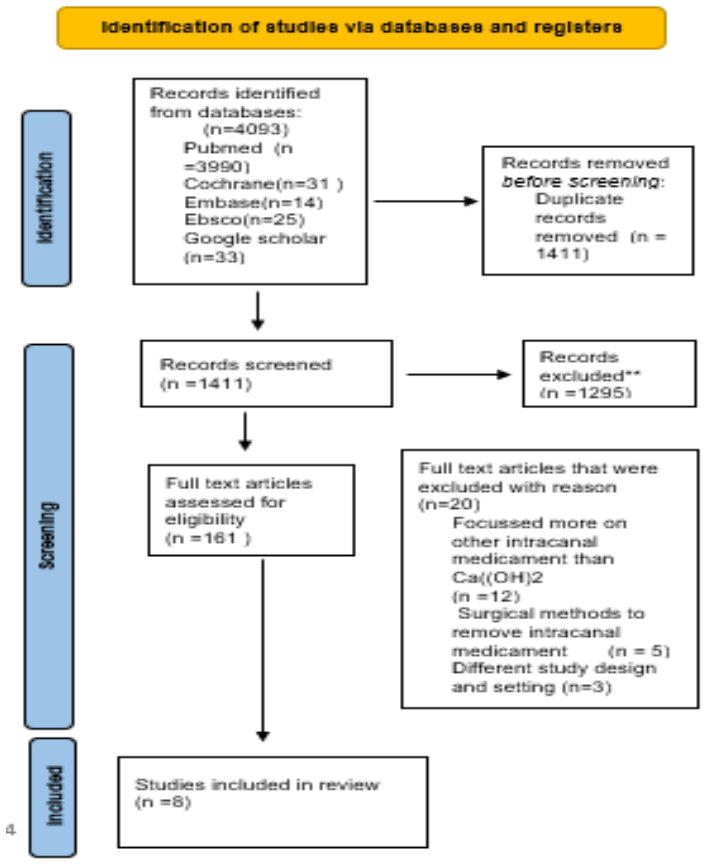
- **Ethics and Conflicts of Interest:**

Ethics approval was not necessary for this systematic review because it analyzed existing literature. Every possible conflict of interest was disclosed and handled in compliance with moral principles.

4. Results

STUDY SELECTION:

A PRISMA flowchart of the systematic review procedure is shown in Figure 1. Eight studies in all satisfied the requirements for inclusion.



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First Author and Year	Title of Study	Subjects of Study	Methods of assessment	Results
Sıla Nur Usta -2024	Comparison of the removal of intracanal medicaments used in regenerative endodontics from root canal system using needle, ultrasonic, sonic, and laser-activated irrigation systems – An in vitro study	Eighty teeth with closed apexes, single roots, and no caries were gathered.	stereomicroscope	While SNI was the less successful activation technique, SWEEPS technology eliminated noticeably more CH and DAP than the other activation technologies. In terms of their capacity to extract medications from root canal walls, PUI and EDDY had comparable efficacy.
Phu Yadanar -2024	Comparative Effectiveness of Different Er:YAG Laser-Activated Irrigation Systems on Removing Calcium Hydroxide from Simulated Internal Root Resorption Cavities at Different Root Levels	IRR cavities (1.6 mm in diameter) were created at the apical, middle, and coronal root levels in 60 mandibular premolars. The cavities were subsequently filled with a radiopaque CH paste.	Scanning electron microscopy and micro-computed tomography were used to measure the surface area and remaining CH volume in IRR cavities, respectively.	The LAI(P)-F and PIPS-T groups outperformed the others in terms of removing CH from simulated IRR cavities.
Pasupuleti Swathi-2023	Effectiveness of Laser-activated and Ultrasonic Irrigation Techniques in Removal of Calcium Hydroxide and Modified Triple Antibiotic Paste from the Root Canals: An *In Vitro* Evaluation	Eighty human permanent maxillary incisors were prepared from fresh extractions.	Using a 4-grade scoring system, intracanal medication residues were assessed under a stereomicroscope at 25× magnification.	It was discovered that laser-activated irrigation (LAI) was better than UI. With either irrigation method, Ca(OH)2 was more effectively eliminated than MTAP.
Roshni Arora-2022	Comparative evaluation of efficacy of different irrigation devices in removal of calcium hydroxide in teeth with simulated internal resorption cavities - An *in vitro* study	The ProTaper Gold file system was used to prepare and decoronate 120 single-rooted mandibular premolars up to F5. Resorption cavities were created by buccolingually sectioning the samples.	Internal resorption cavity images were captured using a digital DSLR camera with a 1:1 macro lens.	There was no discernible difference between the devices, with PUI and XP-endo removing more amount of CH than the others ($P < 0.05$).
Lu Shi – 2022	Efficacy of five irrigation techniques in removing calcium hydroxide from simulated S-shaped root canals	Eighty-four S-shaped root canals were made in resin blocks up to size #25/0.08 using Protaper Gold, and they were filled with Ca(OH)2.	The remaining Ca(OH)2 was measured using digital radiography.	Irrigation activation enhanced the elimination of Ca(OH)2 from the apical portion of the S-shaped root canal. Compared to SNI, all activation techniques were much more effective.

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Abhinav K Singh-2021	*In Vitro* Assessment of Intracanal Calcium Hydroxide Removal Using Various Irrigation Systems: An SEM Study	90 mandibular premolar teeth with a single root.	Every sample tooth was inspected under a 1000x magnification under scanning electron microscope (SEM).	None of the irrigation methods were able to totally eliminate the Ca(OH)2 on the root canals. However, EndoVac apical negative pressure irrigation had a slightly higher likelihood of eliminating Ca(OH)2 from the root canals than Vibringe sonic irrigation and the NaviTip FX irrigation system.
Sevan Harzivartyan-2021	Evaluation of different irrigation solutions and activation methods on removing calcium hydroxide	On the apical third of the root canal surface, 80 maxillary central incisor teeth were sculpted and a standard groove was created.	After being divided in half, the teeth were examined at a 50× magnification using a light microscope. A digital microscope was used to take the pictures.	The elimination of Ca(OH)2 is unaffected by dual rinse HEDP. When using a NaOCl solution, PUI is more effective than both techniques.
Momina Anis Motiwala-2021	Comparison of Two Different Methods in the Removal of Oil-Based Calcium Hydroxide From Root Canal System: A Triple-Blinded Randomised Clinical Trial	60 patients with necrotic teeth were scheduled to receive intracanal medication (Metapex) based on silicon oil.	After placing the SOBCH, a periapical radiograph was done to ensure proper adaption.	For SOBCH, both rotary master apical file and ultrasonic file activation were equally successful in all three canal segments. Furthermore, none of the methods succeeded in getting rid of the SOBCH entirely.

5. Discussion:

One of the main goals of root canal disinfection is the removal of bacteria. [13]. Although previous study focused on improving the clearance of Ca(OH)2 during endodontic therapy, none of the methods can completely eliminate intracanal medicines from the root canals. [14] By altering the sucking motion and resulting in insufficient removal of Ca(OH)2, obstruction of the microcannula's openings may cause partial elimination. [15] Trapped air in the apical area creates a vapor lock, which prevents fluid exchange and circulation. [16] Overall success rates for endodontic procedures have been demonstrated to range from 50 to 98% thanks to advancements in the materials and techniques used. [17] However, due to serious disadvantages, the use of currently available intracanal medicines in endodontic treatments is restricted. [18] Thus, this study sought to examine the effect of different irrigation techniques on

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the removal of CH, given the understanding that the total elimination of intracanal medications is crucial.

Some of the techniques utilized in various studies to examine the leftover medication in the root canal include digital images, stereomicroscopy, SEM, and micro CT. [19] The amount of Ca (OH)2 that remained in the canal was determined by either the surface area of the residues on the canal walls or the volume percentage of residual Ca(OH)2 in the canal. [20] The optimal irrigation techniques to employ in order to fully remove the intracanal drug calcium hydroxide from the root canals have been the subject of numerous studies, which are reviewed in this study. However, it would be challenging to properly view them using micro-CT due to the radiopacity level of CH and the high cost and limited availability of three-dimensional imaging. [21]

Regardless of the irrigation methods employed, Berkhoff et al. demonstrated that CH was more successfully eliminated with no discernible difference between them. [22] Conversely, Eymirli et al. showed that a laser-activated system considerably increased the amount of CH left in the root canal, and they stated that the lesser size of particles allows CH to directly enter the dentinal tubules. [23] The retrievability of those medications using the SNI, PUI, EDDY, and SWEEPS systems did not differ statistically significantly. [24] This outcome is comparable to some research that compares the elimination of CH from the root canals in the literature. The various irrigation activation mechanisms, tooth morphologies, irrigation solutions, and other factors can all account for the disparate findings in the literature.[25]

Though their superiority over one another has not been demonstrated in accordance with other research in the literature, EDDY and PUI considerably remove more CH from root canals than SNI .[26] The greater amount of calcium hydroxide removal may be justified by the increased irrigation solution velocity brought on by PUI. [27] Higher intracanal medication clearance from root canal is also the result of improved irrigant fluid flow brought on by the EDDY system's increased frequency. [28] Similar to the PUI, the three-dimensional movement produced by EDDY causes cavitation and acoustic streaming; as a result, comparable efficacy of these irrigation activation methods in terms of medication elimination has been noted. [29]

Numerous clinical trials have shown how effective SWEEPS technology is at removing calcium hydroxide from the body, but little is known about how well it works for endodontic treatments. [30] Although there was no appreciable difference between the PIPS and SWEEPS groups, Kırmızı et al. demonstrated that SWEEPS significantly eliminated calcium hydroxide from the resorption cavities when compared to the sonic and ultrasonic irrigation activation methods. [31] Yang et al. also discovered that the SWEEPS group had fewer calcium hydroxide remains than the ultrasonic activation system, particularly in the cervical third of the root canal system. [32]

Although SWEEPS greatly enhanced CH elimination, no irrigation activation method was able to totally eradicate CH, according to the current study. The unique activation mechanism of SWEEPS, which accelerates the expansion of the second bubble created by the second laser pulse, explains this outcome. Increased pressure on the original bubble causes the primary bubble to violently collapse. [33] During the irrigation activation phase, this powerful shock wave produced by the secondary cavitation bubbles may be released from any root canal surface. [34] Its vertical flows and shear stress efficiently remove debris, biofilm, smear layer, and intracanal medications from the root canal surface. [35]

Of the eight studies, one found that SNI was the least effective way to remove CH from the root canals, three conclude that passive ultrasonic irrigation showed more effectiveness comparing to sonic irrigation at removing CH, and three found that SWEEPS was the most effective method. PUI and EDDY were found to be equally effective. However, none of the methods were able to get CH out of the root canal entirely.

Limitations:

One of the evaluation's drawbacks was the intricacy of the many approaches taken in the several research that were assessed. Numerous research used various Ca(OH)2 types, irrigation times, irrigation solutions, and their concentrations and results. Consequently, a meta-analysis was not feasible. Another drawback was that the included studies' findings were derived from in vitro research, whereas clinical trials like randomized controlled trials yield more precise outcomes. The third disadvantage was that none of the included papers explained the randomization procedures; instead, they

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only documented the randomized allocation of all groups. Additionally, some but not all of the investigations employed blinding. Prejudice has become more likely as a result.

Comparisons were challenging due to the disparate evaluation approaches employed in the included studies and the lack of consistency in the evaluation criteria for determining the extent of medicament removal from canals. Evaluation techniques, Calcium hydroxide placement, and Ca(OH)2 removal were not standardized. The review's fourth shortcoming was the small number of papers it examined. More accurate results would have been obtained from studies with bigger sample numbers.

Conclusion:

Because of the high level of evidence, previous protocol registration, and detailed eligibility criteria, the current study employed a thorough literature search method. More investigation is necessary to yield conclusive findings because of the methodological variations across the reviewed studies. The review offers conclusions that are supported by data and could develop a helpful clinical application guideline. While SNI was the less successful activation technique, the SWEEPS method eliminated noticeably more CH than the other activation systems. When it came to removing CH from root canal walls, PUI and EDDY performed similarly well.

Abbreviations:

1. CH - Calcium Hydroxide
2. SWEEPS – Shock Wave Enhanced Mission Photoacoustic Streaming
3. SNI – Syringe Needle Irrigation
4. PUI – Passive Ultrasonic Irrigation
5. EDDY – Endo Sterile Irrigation Tips
6. RET – Regenerative Endodontic Treatment
7. PIPS – Photon Induced Photoacoustic Streaming
8. EDTA – Ethylene Diamine Tetraacetic Acid
9. SOBCH - Silicon Oil-Based Calcium Hydroxide

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