Efficacy of irrigation techniques in removing calcium hydroxide: a literature review

Eficacia de técnicas de irrigación en la remoción de hidróxido de calcio: revisión bibliográfica

Eficácia das técnicas de irrigação na remoção do hidróxido de cálcio: revisão bibliográfica

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Abstract

Objective: To conduct a literature review on and describe the most effective irrigation techniques in removing calcium hydroxide as an intracanal medicament.

Materials and methods: Literature review conducted in PubMed, Scopus, and Web of Science. Thirty-two articles published between 2015 and 2020 were selected.

Results: Ultrasonic irrigation—the most widely studied technique—does not achieve the highest levels of efficacy. Laser-activated irrigation was the most effective way to remove medication in the three thirds of the canals. The most frequently used irrigants were sodium hypochlorite and ethylenediaminetetraacetic acid.

Conclusion: The most effective techniques are laser-activated irrigation and passive ultrasonic irrigation. The evidence indicates that sodium hypochlorite and ethylenediaminetetraacetic acid should be used sequentially and not exclusively as irrigants.

Keywords: endodontics, techniques, efficacy, therapeutic irrigation, removal, calcium hydroxide.

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Resumen

Objetivo: Caracterizar en base a una revisión bibliográfica las técnicas de irrigación con mayor eficacia en la remoción de hidróxido de calcio como medicación intraconducto. **Materiales y métodos:** Revisión bibliográfica realizada en las bases de datos electrónicas PubMed, Scopus y Web of Science. Se seleccionaron 32 artículos contenidos entre los años 2015 y 2020. **Resultados:** La técnica más estudiada es la irrigación ultrasónica, no logrando tener los niveles más altos de eficacia. La irrigación activada por láser resultó ser la más eficaz en la remoción de medicación en los tres tercios de los conductos. Los irrigantes utilizados con mayor frecuencia fueron el hipoclorito de sodio y el ácido etilendiaminotetraacético. **Conclusión:** Las técnicas con mayor eficacia son irrigación activada por láser, seguida de irrigación ultrasónica pasiva. La evidencia sustenta que hipoclorito de sodio y ácido etilendiaminotetraacético deben ser los irrigantes utilizados, ambos de manera secuencial y no de uso excluyente.

Palabras clave: endodoncia, técnicas, eficacia, irrigación terapéutica, remoción, hidróxido de calcio.

Resumo

Objetivo: Caracterizar, com base em revisão bibliográfica, as técnicas de irrigação com maior eficiência na remoção do hidróxido de cálcio como medicamento intracanal. **Materiais e métodos:** Revisão bibliográfica realizada nas bases de dados eletrônicas PubMed, Scopus e Web of Science. Foram selecionados 32 artigos contidos entre os anos de 2015 e 2020. **Resultados:** A técnica mais estudada é a irrigação ultrassônica, não alcançando os níveis mais altos de eficácia. A irrigação ativada por laser foi considerada a mais eficaz na remoção de medicamentos em três terços dos canais. Os irrigantes usados com mais frequência foram hipoclorito de sódio e ácido etilenodiaminotetracético. **Conclusão:** As técnicas mais eficazes são a irrigação ativada por laser, seguida da irrigação ultrassônica passiva. A evidência apóia que o hipoclorito de sódio e o ácido etilenodiaminotetracético devem ser os irrigantes usados, tanto sequencialmente quanto não exclusivamente.

Palavras-chave: endodontia, técnicas, eficácia, irrigação terapêutica, remoção, hidróxido de cálcio.

Introduction

The presence of microorganisms in the root canal system (RCS) is crucial for developing pulp and periapical pathologies. Therefore, eliminating microorganisms is one of the main objectives of endodontic therapy.[1,2] To this end, mechanical instrumentation is necessary, followed by irrigation and intracanal medicaments. Calcium hydroxide ($Ca(OH)_2$) is one of the most widely used intracanal medicaments due to its antimicrobial and biological action, ability to dissolve organic tissues, anti-inflammatory effects, and osteoclastic inhibition. It also enhances tissue repair.[3] However, residual $Ca(OH)_2$ in root canals significantly affects bond strength and dentin resistance. It also hinders the penetration of endodontic sealants into the dentin tubules, increasing the possibility of apical microleakage.[4,5] In this regard, several methods have been introduced to increase removal efficacy in the RCS: conventional irrigation, mechanized irrigation, sonic irrigation (SI), ultrasonic irrigation (USI), passive ultrasonic irrigation (PUI), negative pressure irrigation (NPI), and laser-activated irrigation (LAI).[6] Clinically, the technique most commonly used to remove the drug is conventional irrigation with syringes, needles of various diameters, and master apical files (MAF) in combination with irrigation solutions, such as sodium hypochlorite (NaOCl) and ethylenediaminetetraacetic acid (EDTA). However, EndoVac (NPI), EndoActivator (SI), PUI, or LAI have shown greater efficacy in removing $Ca(OH)_2$ with statistically significant differences.[7]

However, the available evidence shows controversy among the published results, as their presentations vary, and there are differences in the structuring and execution of the irrigation techniques. Therefore, there is no evidence grouping the great diversity of methods available according to their types and the characteristics of the most effective removal techniques. The most effective strategy should be the one that removes the greatest amount of intracanal $Ca(OH)_2$.

Therefore, this study aims to conduct a literature review to describe the most effective irrigation techniques in removing $Ca(OH)_2$ as an intracanal medicament. We evaluated the sample type, type of $Ca(OH)_2$, irrigants used, and type of device or instruments used in the most effective techniques.

Materials and methods

The literature review was conducted between October and November 2020 in electronic databases PubMed, Scopus, and Web of Science (WOS). Before the search, branches were structured according to the topic addressed and used to structure the search keys. (Table 1).

Table 1: Branch number, topic, and keywords.

Branch	Topic	Keywords
#1	Calcium hydroxide as an intracanal medicament	Calcium hydroxide, medicament, calcium hydroxide medicament, calcium hydroxide intracanal, calcium hydroxide intracanal medicament.
#2	Calcium hydroxide removal or elimination	Calcium hydroxide removal, calcium hydroxide elimination, intracanal calcium hydroxide removal, intracanal calcium hydroxide elimination, elimination, removal.
#3	Technique or devices used for removing calcium hydroxide as an intracanal medicament.	Technique, irrigation technique, irrigation system, EndoActivator system, EndoVac, passive ultrasonic irrigation, sonic irrigation, PUI, RinsEndo, ultrasound, K file, file, mechanical instrumentation, hand file, rotary file, XP-endo finisher files, laser, laser-activated irrigation, root canal, root canal irrigation, sonic irrigation, TRUShape 3D, canal brush, activation techniques, NaviTip FX.

In addition, a manual search was performed by evaluating similar references in each database during the keyword search. This QR code includes details of the searches in each database and the corresponding keywords (fig. 1).

Figure 1: QR code:
Databases consulted

The researchers simultaneously analyzed and preselected the studies after reading their titles and abstracts. Then, each article was read in full. The eligibility criteria for the analysis, selection, and exclusion process were as follows:

Inclusion criteria:

- Experimental in vitro studies in English and Spanish published between 2015 and 2020.
- Use of $Ca(OH)_2$ as the sole medication.
- Use of at least NaOCl and/or EDTA as irrigating agents.
- Comparison of at least two irrigation techniques for $Ca(OH)_2$ removal.
- Studies that used permanent human teeth with a closed apex and artificial grooves in the main root canal.

Exclusion criteria:

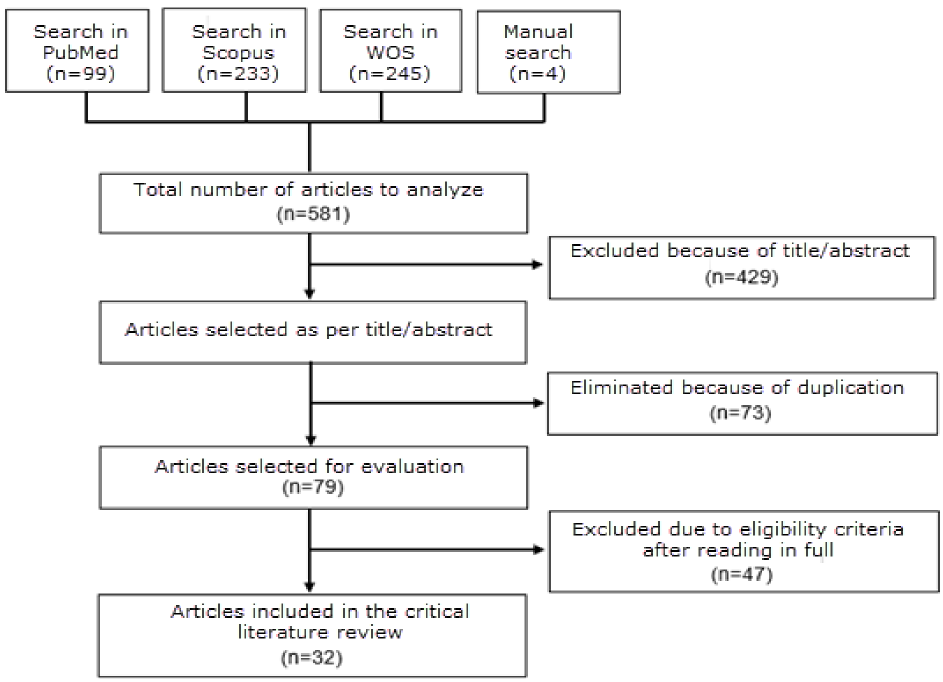
- Systematic literature reviews with or without meta-analysis.
- Studies that use temporary teeth, endodontic acrylic cubes simulating root anatomy, or permanent human teeth with interventions that seek to recreate root immaturity or root pathologies, such as rhizolysis.

The study variables to be analyzed in the articles were author, year of publication, the sample used, type of $Ca(OH)_2$, irrigants used, and the technique(s) with the greatest efficacy in $Ca(OH)_2$ removal.

Results

A total of 581 articles were obtained from the search, of which 32 articles were selected according to the eligibility criteria and the analysis conducted by the researchers: 32 in English and 1 in Spanish (Fig. 2).

Figure 2: Flowchart: Search strategy results.



Evaluation of residual $Ca(OH)_2$ in artificial canal grooves

We analyzed nine studies where artificial grooves were made in the main canal to simulate retention areas (Table 2). Approximately 55.5% of the authors conclude that PUI is the most effective option for $Ca(OH)_2$ removal, followed by LAI with 33% and USI with 22.2%.

Evaluation of residual $Ca(OH)_2$ using microscopy or chemical titration

We evaluated 12 studies where residual medicament was analyzed using microscopy or chemical titration (Table 3). A total of 33.3% of the studies showed that SI is the most effective option for $Ca(OH)_2$ removal, followed by PUI with 25% and NPI with 16.6%.

Evaluation of residual $Ca(OH)_2$ through imaging studies

We analyzed 11 studies where residual medicament was evaluated using imaging technology, 73% of which were assessed with Computed Microtomography (MicroCT) (Table 4). Approximately 36.3% of the studies indicated that PUI is the most effective $Ca(OH)_2$ removal method, followed by USI with 27.2% and LAI with 18%.

NaOCl and EDTA were the most commonly used irrigation solutions in the 32 studies analyzed to establish $Ca(OH)_2$ removal efficacy, with a relative frequency of 93.75% and 68.75%, respectively. Etidronic acid was used less frequently (6.25%). Other studies used Qmix 2in1 (EDTA and CHX, Dentsply), peracetic acid, and Savlon ™ (CHX and Cetramide) at a 3.13% concentration.

Table 2: Experimental in vitro studies on the efficacy of $Ca(OH)_2$ removal techniques in canals with artificial grooves.

Author	Year	Sample used	Medicament used	Information about irrigation techniques with the highest efficacy for $Ca(OH)_2$ removal
Arslan H. et al. [8]	2015	48 mandibular PM	Powder $Ca(OH)_2$ (Kalsin) + distilled water	LAI Er:YAG (Fidelis AT) + 17% EDTA
Kustarci A. et al. [9]	2016	160 mandbular PM	Powder $Ca(OH)_2$ (Kalsin) + distilled water	LAI Er,Cr:YssG (Biolase) + Qmix 2in1
Gokturk H. et al. [10]	2017	105 maxillary I	$Ca(OH)_2$ paste (Ammdent)	PUI (IrriSafe) + NaOCl 2.5% LAI Er:Yag (Kavo Key Plus) + NaOCl 2.5%
Uygun A. et al. [11]	2017	32 mandibular PM	Powder Ca(OH)2 (Kalsin) + distilled water	USI (Various U files) + 17% EDTA
Wigler R. et al. [12]	2017	66 mandibular I	Powder $Ca(OH)_2$ + NaCl	PUI (IrriSafe) + 4% NaOCl XP-endo Finisher + 4% NaOCl
Kfir A. et al. [13]	2018	80 mandibular I	Powder $Ca(OH)_2$ (Sultan Healthcare) + NaCl	PUI (IrriSafe) + 4% NaOCl XP-endo Finisher + 4% NaOCl
Donnermeyer D. et al. [14]	2019	90 maxillary CI	$Ca(OH)_2$ in water suspension	PUI (IrriSafe) + 3% NaOCl SI (EDDY) + 3% NaOCl
Harzibartyan S. et al. [15]	2020	80 maxillary IC	Water-based $Ca(OH)_2$ (Procal R)	USI (VDW Ultra) + 1% NaOCl + etidronic acid
Turkaydin D. et al. [16]	2020	34 mandibular PM	Paste $Ca(OH)_2$ (Calcipast forte) Powder $Ca(OH)_2$ + iodoform	PUI + 2.5% NaOCl

$Ca(OH)_2$: calcium hydroxide, **EDTA:** ethylenediaminetetraacetic acid, **I:** incisor, **LAI:** laser-activated irrigation, **CI:** central incisor, **SI:** sonic irrigation, **PUI:** passive ultrasonic irrigation, **USI:** ultrasonic irrigation, **NaCl:** sodium chloride, **NaOCl:** sodium hypochlorite,
PM: premolar.

Table 3: Experimental in vitro studies on the efficacy of various techniques in removing $Ca(OH)_2$ from canals that evaluate residual medicament using microscopy or chemical titration.

Author	Year	Sample used	Medicament used	Information about irrigation techniques with the highest efficacy for $Ca(OH)_2$ removal
Alturaiki S. et al. [1]	2015	70 single-root teeth	Paste $Ca(OH)_2$ (Ultracal XS)	IS (EndoActivator) + 0.5% NaOCl + 18% EDTA
Phillips M. et al. [17]	2015	86 maxillary and mandibular C	Paste $Ca(OH)_2$ (Calasept)	PUI + 5.2% NaOCl + 17% EDTA
Romualdo F. et al. [18]	2016	22 single-root teeth	Powder $Ca(OH)_2$ + distilled water	ProTaper and NaviTip FX + 1% NaOCl + 17% EDTA
Kirar D. et al. [19]	2017	50 single-root teeth	Water-based $Ca(OH)_2$ (Prime Dent) Oil-based Ca(OH)2 (Metapex)	IS (EndoActivator) + 3% NaOCl + 17% EDTA
Hamdan R. et al. [20]	2017	68 mandibular I	$Ca(OH)_2$ (Produits Dentaires) and powder + distilled water.	XP-endo Finisher + 2.5% NaOCl
Agrawal P. et al. [21]	2018	75 mandibular PM	Powder $Ca(OH)_2$ + NaCl	NPI (EndoVac) + 5% NaOCl
Gokturk H. et al. [22]	2018	98 mandibular PM	Powder $Ca(OH)_2$ (Ammdent) + distilled water	LAI Er:YAG (Kavo KEY 3+) + 2.5% NaOCl
Chawla A et al. [23]	2018	40 single-root teeth	Powder $Ca(OH)_2$ + NaCl	NPI (EndoVac) + Savlon ™ SI (EndoActivator) + Savlon ™
Tamil S. et al. [24]	2019	30 single-root teeth	Powder $Ca(OH)_2$ + NaCl	PUI (U file) + 3% NaOCl + 17% EDTA
Falakaloglu S. et al. [25]	2019	36 mandibular M (mesial root)	Paste $Ca(OH)_2$ (Ultracal XS)	PUI + 2.5% NaOCl + 17% EDTA
Gupta R. et al. [26]	2020	30 mandibular PM	Paste $Ca(OH)_2$ (Ultracal XS	WaveOne + 5.25% NaOCl
Vega M. et al. [27]	2020	149 CI, LI, PM and M (lower distal root)	Paste $Ca(OH)_2$ (Ultracal XS)	USI (Mectron) + 5.25% NaOCl + 17% EDTA IS (EndoActivator) + 5.25% NaOCl + 17% EDTA

C: canine, **$Ca(OH)_2$**: calcium hydroxide, **EDTA:** ethylenediaminetetraacetic acid, **I:** incisor, **LAI:** laser-activated irrigation, **CI:** central incisor, **LI:** lateral incisor, **NPI**: negative pressure irrigation, **IS:** sonic irrigation, **PUI:** passive ultrasonic irrigation, **USI:** ultrasonic irrigation, **M:** molar, **NaCl**: sodium chloride, **NaOCl:** sodium hypochlorite, **PM:** premolar.

Table 4: Experimental in vitro studies on the efficacy of $Ca(OH)_2$ removal techniques that evaluate residual medicament using imaging.

Author	Year	Sample used	Medicament used	Information about irrigation techniques with the highest efficacy for $Ca(OH)_2$ removal
Ma J. et al. [28]	2015	34 mandibular M (C-Shape)	Paste $Ca(OH)_2$ (MetaBiomed)	USI + 5% NaOCl + 17% EDTA SI (EndoActivator) + 5% NaOCl + 17% EDTA
Ma J. et al. [29]	2015	30 mandibular M	$Ca(OH)_2$ with barium sulfate (Metapaste)	GentleWave + 3% NaOCl + 8% EDTA
Silva L. et al. [30]	2015	32 single-root teeth	Powder Ca(OH)2 (Maquira) + propylene glycol (Personale)	ProTaper Gold + 1% NaOCl + PUI + 17% EDTA
Li D. et al. [31]	2015	24 maxillary PM (isthmus)	$Ca(OH)_2$ with barium sulfate (Nordiska dental)	USI (EMS) + 3% NaOCl LAI Er:YAG (Fidelis AT) + 3% NaOCl
Lloyd A. et al. [32]	2015	30 mandibular M	Paste $Ca(OH)_2$ (Ultracal XS)	LAI Er:YAG + 8.25% NaOCl + 17% EDTA
Kumar P. et al. [33]	2017	42 mandibular PM	Paste $Ca(OH)_2$ (Metapex)	USI (Endo Ufile) + 5.25% NaOCl + 18% EDTA
Neelakantan P. et al. [34]	2017	128 mandibular PM	Paste Ca(OH)2 (Ultracal XS)	MAF + 3% NaOCl + 9% etidronic acid PUI (IrriSafe) + 3% NaOCl + 9% etidronic acid
Acharya N. et al. [35]	2018	40 mandibular PM	$Ca(OH)_2$ with barium sulfate (AvueCal RC protector)	SI (EndoActivator) + 3% NaOCl + 17% EDTA
de Oliveira R et al. [36]	2019	30 mandibular I	Powder $Ca(OH)_2$ + iodoform+ propylene glycol	Easy Clean + 2.5% NaOCl + 17% EDTA IUP (Helse) + 2.5% NaOCl + 17% EDTA
Murwakani N. et al. [37]	2019	32 mandibular PM	Paste $Ca(OH)_2$	IUP (IrriSafe) + 2.5% NaOCl + 17% EDTA
Denna J. et al. [38]	2020	16 maxillary PM	Paste $Ca(OH)_2$ (ApexCal)	XP-endo Finisher + 5.25% NaOCl PUI (IrriSafe) + 5.25% NaOCl

$Ca(OH)_2$: calcium hydroxide, **EDTA:** ethylenediaminetetraacetic acid, **I:** incisor, **LAI:** laser-activated irrigation, **CI:** central incisor, **SI:** sonic irrigation, **PUI:** passive ultrasonic irrigation, **USI:** ultrasonic irrigation, **MAL:** master apical file, **M:** molar, **NaCl:** sodium chloride, **NaOCl:** sodium hypochlorite, **PM:** premolar.

Discussion

The most effective techniques require a minimum activation time of one minute for each irrigant, and the most used and recommended irrigation solutions are NaOCl and EDTA.[39] PUI and LAI have proven to be the most effective techniques in removing $Ca(OH)_2$. However, the EndoVac device, categorized as NPI, proved to be the most effective in removing residual medicament in the apical third.[40]

Various irrigants have been used for medication removal. The combined use of NaOCl and 17% EDTA is ineffective for full $Ca(OH)_2$ removal. However, this combination proves to be more effective in removing the medicament than the agents used separately.[41] The efficacy of other calcium chelators such as 10% citric acid and 7% maleic acid has been studied. It is suggested that their use would be effective in removing $Ca(OH)_2$ from root canals.[42] It has been shown that 30 seconds of irrigation is ineffective for complete $Ca(OH)_2$ removal. Uzunoglu et al.[43] suggest an irrigation time of approximately one minute for each irrigant used, regardless of the irrigation technique. Furthermore, efficacy is directly related to the volume of irrigant used, i.e., the greater the volume of irrigant, the greater the efficacy of irrigation.[44]

Of the publications analyzed, 37.5% studied PUI, making it one of the most effective options. Li et al. [31] observed that PUI was the most effective method for removing this medicament in the three thirds of the root canal compared to conventional irrigation. No significant differences were found between this type of activation and XP-endo Finisher in the coronal and middle thirds. Although the difference in the amount of irrigant extrusion outside the apex is minimal between SI and PUI, it is still higher in PUI.[45] This is explained by the difference between the powers at which acoustic currents and cavitations are generated, as they are higher in PUI.[46] Although LAI is the least studied technique, it has been shown to leave almost 0% residual $Ca(OH)_2$.[32]

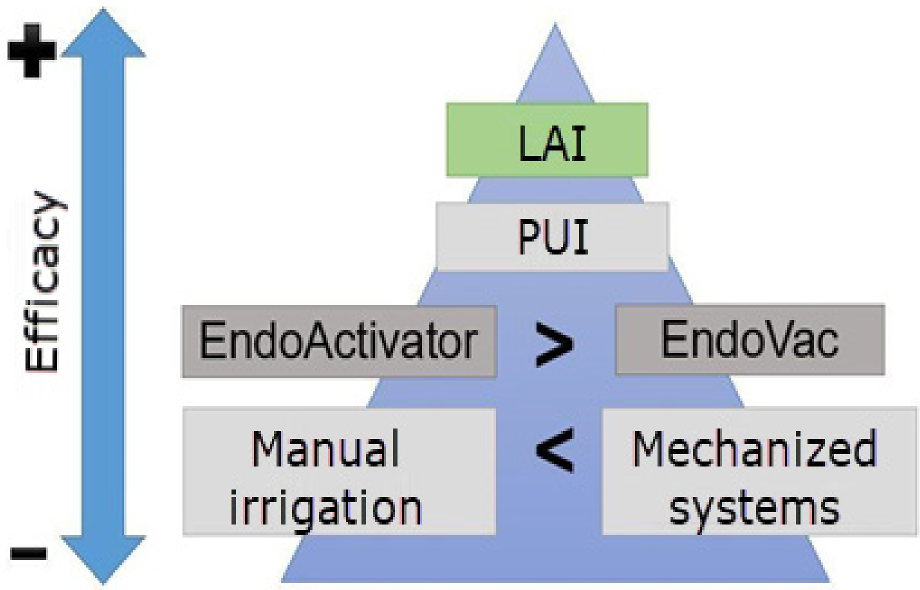
Sonic irrigation showed favorable results because this type of energy requires vigorous irrigant agitation in the canals through oscillatory movement and bubble cavitation.[46] Alturaiki et al.[1] found that EndoActivator was highly effective in removing medicament at the coronal, middle, and apical thirds of the canals compared to other techniques such as USI and NPI. However, NPI proved to be more effective at the apical third than SI because of the microcannula specially designed for this area.[47] A potential disadvantage of this system is the blockage of the microcannula orifices, which may contribute to failed $Ca(OH)_2$ removal. EndoVac has presented significant differences when removing residual medicament. The working length (WL), less than 1 mm, is considerably less than irrigation performed at 2 mm, under this system or another, such as conventional needle irrigation.[1]

It is necessary to rigorously consider the working length and the caliber of the apical conformation for appropriate biomechanical preparation. This guarantees case resolution and the integrity of the surrounding tissues. An extruded irrigation solution can cause inflammation and, in some cases, even tissue necrosis, resulting in severe perioperative and postoperative pain. In addition, this may compromise the healing of apical periodontitis.[48]

The studies analyzed showed significant variability in the use or non-use of radiopaque $Ca(OH)_2$, which challenges the correct assessment of the residual medicament. Therefore, radiopaque $Ca(OH)_2$ should be used to distinguish between medication and a smear layer and to evaluate and assess the case through imaging accurately. Furthermore, future studies should include sample units with more significant anatomical variability as this would be closer to applying these techniques in vivo. Similarly, further research should be conducted on the efficacy of GentleWave and Easy Clean devices, as they showed promising efficacy in $Ca(OH)_2$ removal, though the evidence

is currently limited.
Only in vitro experimental studies were conducted. We observed significant variability in the execution of irrigation techniques and presentation of the results by the authors, which makes it difficult to standardize systematic reviews with or without meta-analysis. Therefore, standardizing this type of research will provide a higher level of evidence to support clinical decision making.
Finally, the least effective technique is manual irrigation because there is no aid to the continuous delivery of the irrigant.[31] On the other hand, irrigation associated with mechanized systems is more effective due to the physical contact between the rotary instrument and the root canal walls. Furthermore, the EndoActivator system has a better hydrodynamic mechanism than EndoVac, allowing the irrigant to penetrate, circulate, and flow in the hard-to-reach areas of the RCS.[40] Passive ultrasonic irrigation had one of the best results. It is recommended because its activation is not interrupted. However, LAI was the most effective technique due to the emission of photons that create photoacoustic shock waves in the irrigant and, therefore, effectively cleans the root canals (Fig. 3).

Figure 3: Pyramid showing device efficacy as part of the irrigation technique to remove $Ca(OH)_2$.



LAI: Laser-activated irrigation, **PUI:** Passive ultrasonic irrigation.

Conclusions

The literature review shows that the best irrigant activation options to remove more residual $Ca(OH)_2$ in the three thirds of root canals are LAI and PUI. This proves that the most studied technique is not the most effective one. In addition, the irrigants used in each irrigation technique should be NaOCl and EDTA, sequentially and not exclusively, considering a minimum irrigant activation time of one minute.
Finally, a successful technique involves the combined use of several devices. Clinicians should identify the potential of each one of them in the three root segments, weighing the clinical variability that each case may have.

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Authorship contribution

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5. Drafting of the manuscript
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