Systematic Review

# Efficacy of Removal of Calcium Hydroxide Medicament from Root Canals by Endoactivator and Endovac Irrigation Techniques: A Systematic Review of *In vitro* Studies


## Abstract

**Introduction:** The aim of this systematic review was to systematically evaluate and summarize the outcomes of *in vitro* studies comparing Endoactivator irrigation and Endovac irrigation techniques for removing calcium hydroxide ($Ca[OH]_2$) medicament from the root canals. **Materials and Methods:** The research question was developed according to the population, intervention, comparison, and outcome strategy. A computerized literature search was conducted in Medline, PubMed, Google Scholar, and Embase. A hand search of the reference lists of identified articles was performed to separate relevant articles. Two reviewers critically assessed the studies that fulfilled the inclusion criteria and processed. Evaluation of the risk of bias of the studies was performed independently by the two reviewers. **Results:** After study selection, 61 were assessed for eligibility. Of these, 13 met the inclusion criteria and were included in the systematic review. Since significant heterogeneity was found in the methodologies, it was not possible to conduct a meta-analysis. **Conclusions:** On the basis of available evidence, we determined that Endoactivator irrigation technique showed better performance in removing $Ca(OH)_2$ intracanal medicaments from middle third and coronal third area of the root canals and Endovac irrigation technique showed better performance from the apical third area of the root canals. Due to the limitations, small sample sizes, and low number of included studies, further research is needed to confirm our results.


**Keywords:** *Calcium hydroxide removal, Endoactivator, Endovac, irrigation technique, root canals*


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## Introduction

### Rationale

The occurrence of microorganisms into the root canal system plays a major role for the development of pulpal and periapical diseases of the tooth, so the elimination or removal of this microorganisms from root canal systems is considered one of the main goal of endodontic treatments.[1] The elimination of all microorganisms from the root canal system is accomplished by mechanical instrumentation supported by various irrigating solutions and placement of the different intracanal medicaments.[2] Although cleaning and shaping of root canal by means of mechanical instrumentation have been shown to significantly reduce the number of bacteria in infected canals, complete disinfection of the root canal is difficult to achieve.[3]

Calcium hydroxide ($Ca(OH)_2$) has been widely used in endodontic treatment as an intracanal medicament, due to its antimicrobial properties against the most of the endodontic microorganisms and its biological effects and also for their capacity to inactivate bacterial endotoxins.[4] Removal of $Ca(OH)_2$ medicament from root canals are necessary because the remnant of $Ca(OH)_2$ on the canal walls will influence dentine bond strength and also harmfully affect the quality of root filling material.[2] Therefore, it has to be completely removed before obturation of the root canals is suggested.[5]

If $Ca(OH)_2$ medicament is not removed from root canal, residues of $Ca(OH)_2$ medicament can hamper the sealing ability of endodontic sealers which will obstruct the diffusion of root canal sealers into dentinal tubules.[6] Different irrigation techniques have been in use to determine this problem. Clinically, most commonly used technique for removal of ($Ca[OH]_2$) medicament is master apical file combined with numerous irrigation



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solutions.[6] It has been reported that irrigation of root canals with sodium hypochlorite (NaOCl) irrigating solution and ethylenediaminetetraacetic acid (EDTA) irrigating solution achieved better results in removal of ($Ca[OH]_2$) than NaOCl used alone.[7] Numerous studies have also confirmed that it is difficult to remove ($Ca[OH]_2$) completely from root canals using different irrigation solutions alone. Hence, to overcome this, new irrigation devices such as Endoactivator and Endovac were introduced.[8]

The Endoactivator system (Dentsply Tulsa Dental Specialties, Tulsa, OK) was introduced as new sonically driven canal irrigation system comprises a portable handpiece and three types of disposable flexible polymer tips with different sizes. These different sized tips do not cut root dentin.[1] Its design allows safe activation and the production of vigorous intracanal fluid agitation.[3]

The Endovac system (Discus Dental, Culver City, CA) is one of the true apical negative pressure irrigation devices which are designed to deliver irrigation solutions to the apical end portion of the root canal systems and to suction out debris from the root canals.[4] This system consists of a master suction tip, a macrocannula, and a microcannula that are connected to a vacuum line. Using this system, irrigation solutions are delivered into the pulp chamber with master suction tip.[9]

### Objectives

#### *Need of the review*

The evaluation of Endoactivator and Endovac irrigation technique in the removal of $Ca(OH)_2$ intracanal medicament from the root canals is essential to establish evidence-based guideline to improve clinical outcomes in endodontics. Previous studies have pointed out the removal efficacy of Endoactivator and Endovac irrigation technique individually. A systematic review has several purposes when the related articles had contradictory results to answer the questions that are not solved by the individual studies. However, no systematic review comparing the effectiveness of removal of $Ca(OH)_2$ medicament from root canals by Endoactivator and Endovac as an irrigation technique has been conducted.

Therefore, in the present review, the aim is to systematically evaluate the effectiveness of $Ca(OH)_2$ medicament removal from root canals by Endoactivator and Endovac irrigation techniques.

This systematic review was conducted in accordance with the guidelines of preferred items for systematic reviews and meta-analysis statement.[10]

The research question was the following:

"'Does Endoactivator irrigation technique remove more intracanal $Ca(OH)_2$ medicament than Endovac irrigation technique from the root canals?"'

The population, intervention, comparison, and outcome (PICO) strategy was used for the structured review question is depicted in Table 1.

## Materials and Methods

### Eligibility criteria

#### *Inclusion criteria for studies*

Studies were selected for inclusion if they fulfilled all of the following criteria:

1. Full-text articles
2. Articles in English language
3. *In vitro* studies performed on extracted fully formed (mature) human teeth
4. Studies assessing the removal of $Ca(OH)_2$ materials placed as an intracanal medicament and evaluating the efficacy of removal of $Ca(OH)_2$ medicament from root canals by an irrigation device
5. Studies comparing Endoactivator irrigation technique with Endovac irrigation technique or studies comparing one of this two irrigation technique with any another irrigation techniques.

#### *Exclusion criteria for studies*

1. Studies which are failing to meet any of these inclusion criteria were excluded
2. Literature reviews
3. Studies which are similar in different search engines (Duplicate studies)
4. Articles in language other than English
5. Studies which are not relevant to the research question like studies which are assessed for smear layer removal from root canals or any other parameter (Irrelevant studies)
6. Studies which are assessed for other aspect than the $Ca(OH)_2$ removal.

### Information sources

#### *Literature search*

A computerized literature search was conducted in Medline, PubMed and Google Scholar, and Embase for data published till March 2017 using the keywords such

**Table 1: The population, intervention, comparison, and outcome strategy for the structured review question**

| Research question | Example |
|---|---|
| The population | Extracted fully formed (mature) human teeth |
| The intervention | Endoactivator irrigation technique |
| The comparison | Endovac irrigation technique |
| The outcome | Removal of $Ca(OH)_2$ used as an intracanal medicament from root canals |
| The study design | *In vitro* studies examining the effects of Endoactivator irrigation by comparing it with Endovac irrigation technique |

$Ca(OH)_2$: Calcium hydroxide

as $Ca(OH)_2$ removal, Endo-activator, Endovac, irrigation technique, root canals.

### *Data sources*

Related articles, literature reviews that appeared in various search engines were evaluated and hand search of the reference lists of appropriate articles was also performed to identify relevant articles.

### *Search*

The search strategy was the same for each electronic database. The search strategy used is depicted in Table 2.

### *Criteria for considering studies for this review*

This systematic review included various studies that assessed the Endoactivator and Endovac irrigation techniques in terms of removal of $Ca(OH)_2$ medicament from root canals. The two reviewers assessed all of the full-text articles. Types of studies, types of populations, types of intervention, and types of outcome were specified as inclusion criteria using the PICO strategy, which enables an evidence-based approach.[11]

### *Study selection*

The articles were initially evaluated for relevance, on the basis of their titles and abstracts, by an observer independently. Possibly relevant studies were submitted to full-text evaluation. The full texts of the studies were obtained and reviewed for suitability.

### *Data collection process*

Studies that fulfilled the inclusion criteria were processed for data extraction. The focus of this review was the Endoactivator and Endovac irrigation technique used for removal of $Ca(OH)_2$ intracanal medicament from root canals. The appraisal step was performed in a standardized manner using quality assessment checklists (PRISMA Guidelines, 2009) that included items such as study design and analysis and identified the deficiencies that might arise from bias.[12] This step was performed by two independent reviewers for better reliability of the results. Any disagreements between the reviewers were resolved by discussion.

## Results

### Study selection

The combined search through the electronic databases and hand searching resulted in a total of 104 articles. Out of which, 61 articles were eligible for inclusion on the basis of their titles and abstracts. The other 43 articles were rejected as they were found to be irrelevant to the topic or they did not fulfill the inclusion criteria. Out of 61 articles, 48 articles were excluded as they did not fulfill the inclusion criteria and a total of 13 articles submitted to full-text evaluation fulfilled the inclusion criteria and articles were finally selected for the review. The PRISMA checklist flow diagrams of the included studies are presented as flowchart form [Figure 1].

### Study characteristics

The authors of all studies that are included in this review reported random assignment in their study reports. No standardization was found among the studies regarding the irrigation methods used for the outcome measurements. For example, researchers in some studies used 10 ml 2.5% NaOCl[2,5,7,13,14], whereas few other researchers used 1 ml 0.5% NaOCl[1] and 10 ml 0.5% NaOCl.[4] In several other studies, the authors have also used 2 ml 3% NaOCl, 5 ml 5.25% NaOCl,[3,15] 2 ml 1% NaOCl[16] and 5 ml 3% NaOCl.[9] In some studies, the researchers used 3 ml 18% EDTA[1] and 1 ml 17% EDTA[7] whereas other studies used 5 ml 17% EDTA.[3,5,8,9,15,16] In addition, differences were also found in irrigation times for the removal of $Ca(OH)_2$ medicaments from the root canals. Researchers in 8 studies evaluated outcomes using scanning electron microscopy,[1-4,6,13-15] whereas researchers in 5 studies evaluated outcomes under a stereomicroscope.[5,7-9,16]

### Risk of bias in included studies

In 6 studies,[2,4,9,14-16] the evaluator assessing the outcomes was blinded to the allocation groups. The sample sizes of the included studies were varied, with a range of 10–25 teeth in each experimental group. The overall risk of bias of the included studies was moderate. Two studies had a low methodological quality score of 3[7,8] and another had a low methodological quality score of 4.[2] Five studies had a moderate methodological quality score of 5;[1,3,5,6,13] the rest of the studies had a moderate methodological quality score

**Table 2: Example of the search strategy (Medline, PubMed, Google Scholar, Embase databases)**

| Search strategy | Results |
|---|---|
| Example of the search strategy for PubMed database | |
| Endoactivator | 77 |
| "therapeutic irrigation" OR "therapeutic" AND "irrigation" OR "therapeutic irrigation" OR "irrigation" | 33,211 |
| Endovac | 109 |
| "calcium hydroxide" OR "calcium" AND "hydroxide" OR "calcium hydroxide | 6789 |
| #1 AND#2 AND#3 AND#4 | 5 |
| Example of the search strategy for Google Scholar, Medline , Embase databases | |
| Endoactivator, Endovac, irrigation technique, calcium hydroxide removal, root canals | 99 |

Filter: Publication date till 2017

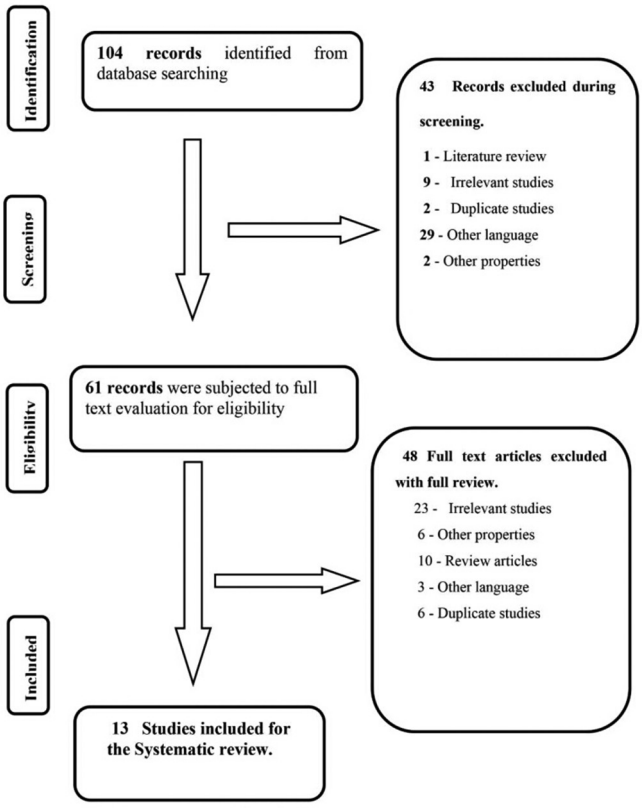


**Figure 1: A flowchart of the systematic review process**

of 6 [Table 3].[4,9,14-16] Blinding of the participants was not possible because of the nature of the studies.

## Discussion

The findings confirm that the Endoactivator irrigation technique showed better performance in removing $Ca(OH)_2$ intracanal medicament from middle third and coronal third area and Endovac irrigation technique from apical-third area of the root canals. The most commonly used intracanal medicament is $Ca(OH)_2$ because it is effective against the majority of endodontic pathogens.[2] In included studies, various methods have been used to investigate the amount of $Ca(OH)_2$ residue on the root canal walls such as digital radiographs, conventional radiographs, stereomicroscope, and scanning electron microscopy. In this review, different researchers have discussed about which irrigation techniques to be used for complete removal of $Ca(OH)_2$ intracanal medicament from the root canals.

Out of 13 studies, 3 studies proposed that Endoactivator system is better than Endovac in removing $Ca(OH)_2$ medicament from the coronal and middle parts. Alturaiki *et al*. stated that Endoactivator system showed better results in removing $Ca(OH)_2$ medicament from the coronal, middle, and apical parts of root canals than the Endovac system. The efficiency in eliminating $Ca(OH)_2$ from root canals by the EndoActivator in combination with irrigation may be caused by its primary function, to produce vigorous intracanal fluid agitation through acoustic streaming and cavitations. It improves the penetration, circulation, and flow of irrigant into the more inaccessible sites of the root canals.[1] Further, Al-Garni *et al*. reported that agitation of Endoactivator system combined with NaOCl and EDTA irrigating solutions improved $Ca(OH)_2$ removal only in the coronal-third area.[3] Khaleel *et al*. concluded that Endoactivator irrigation technique was more effective in removing $Ca(OH)_2$ medicament from coronal third, middle third, and apical third of the root canals. The EndoActivator is performed in the coronal part but removed significantly more in the apical part. A possible explanation is that the oscillation amplitude of the sonically activated irrigation needle is higher at the tip than the attached end.[7]

While rest of the 3 studies concluded that Endovac system is better than Endoactivator in removing $Ca(OH)_2$ from apical third of the root canals. Turker *et al*. stated that Endovac system showed significantly better in removing $Ca(OH)_2$ from apical third of the root canals. The effectiveness of Endovac on removal of $Ca(OH)_2$ from apical third is related to its better mechanical flushing action and vacuum aspiration effect. Moreover, the orifices of the microcannula may provide a portal of exit for $Ca(OH)_2$, resulting in effective removal from apical third of the root canal.[2] Ahmetoglu *et al*. stated that Endovac system offers the safe and effective cleaning of $Ca(OH)_2$ in the apical area of the root canal.[4] Later, Yücel *et al*. concluded that Endovac irrigation systems improved removal of $Ca(OH)_2$ from the coronal third, middle third, and apical third resulting in cleaner root canal walls.[15]

Two of 13 studies proposed that Endoactivator and Endovac are comparable.[13,14] Dabhi *et al*. stated that Endoactivator and Endovac irrigation techniques performed better in removing $Ca(OH)_2$ medicaments from coronal third, middle third, and apical third of the root canals but more effective at the apical area due to the design and working properties of these systems like suction out debris and vigorous agitation of irrigant.[13] Later, Faria *et al*. in his study demonstrated that the rotary instrument combined with Endoactivator and Endovac were more efficiently remove $Ca(OH)_2$ from middle third and apical third of the root canals.[14] Summary of 13 studies evidence is summarized in Table 4.

Out of 5 studies, 2 studies reported that a significant problem in using the Endovac system is blockage of the holes of the microcannula. Thus, it may be a contributing factor for the failure to completely remove $Ca(OH)_2$.[9] Blockage of the holes of the microcannula may influence the sucking effect of the microcannula and result in insufficient $Ca(OH)_2$ removal.[5] While rest of the 3 studies concluded that Endoactivator did not clean the apical third or the isthmus areas successfully, even when their tips were placed close to the root apex. Trapped air in the apical area creates a vapor lock and block, which prevents fluid

**Table 3: Quality of the included studies**

| | Alturaiki S *et al.*, 2015 | Turker S *et al.*, 2013 | Al-Garni *et al.*, 2014 | Ahmetoglu F *et al.*, 2013 | Capar I *et al.*, 2014 | Li *et al.*, 2015 | Khaleel H *et al.*, 2013 | Arslan H *et al.*, 2014 | Topcuoglu H *et al.*, 2015 | Dabhi M *et al.*, 2016 | Faria G *et al.*, 2014 | Yucel A *et al.*, 2011 | Pabel AK *et al.*, 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Was the assignment to treatment groups truly random? | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Were participants blinded to treatment allocation? | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Was allocation to treatment groups concealed from the allocator? | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Were the outcomes of people who withdrew described and included in the analysis? | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Were those assessing the outcomes blind to the treatment allocation? | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 |
| Were control and treatment groups comparable at entry? | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Were groups treated identically other than for the named interventions? | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Were outcomes measured in the same way for all groups? | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| Were outcomes measured in a reliable way? | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| Was appropriate statistical analysis used? | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Total | 5 | 4 | 5 | 6 | 5 | 5 | 3 | 3 | 6 | 5 | 6 | 6 | 6 |

No and unclear: 0 point. Yes: 1 point (low methodologic quality: 1-2-3-4 points; moderate methodologic quality: 5-6-7 points; high methodologic quality: 8-9-10 points)[10]

**Table 4: Summaries of the characteristics of the studies**

| Study | Sample size (*n*) | Type of the teeth | Type of intervention | Type of calcium hydroxide | Placement method of calcium hydroxide score | Verification of calcium hydroxide placement | Irrigation method | Evaluation method |
|---|---|---|---|---|---|---|---|---|
| Alturaiki S *et al*., 2015 | 70 | Single-rooted teeth | Conventional irrigation<br>Endoactivator<br>Ultrasonic irrigation<br>Endovac | Paste form | Lentulospiral | Radiographs | 1 ml 0.5% NaOCl, 3 ml 18% EDTA | Scanning electron microscopy |
| Turker S *et al*., 2013 | 60 | Mandibular canine | Conventional irrigation<br>Canal brush irrigation<br>Endovac<br>Sonic agitation (SAF) | N/A | Lentulospiral | N/A | Conventional irrigation, Endovac, Sonic agitation (SAF)<br>10 ml of 2.5% NaOCl<br>Canal brush irrigation: 5 ml of 2.5% NaOCl | Scanning electron microscopy |
| Al-Garni *et al*., 2014 | 44 | Single-rooted mandibular premolars | Hand file irrigation<br>Endoactivator | Premixed solution | Lentulo spiral | Radiographs | 5 ml of 5.25% NaOCl, 5 ml of 17% EDTA | Scanning electron microscopy |
| Ahmetoglu F *et al*., 2013 | 30 | mandibular premolars | Endovac<br>PUI<br>Needle irrigation | Paste form | Master apical file | Radiographs | 10 ml of 5% NaOCl | Scanning electron microscopy |
| Capar I *et al*., 2014 | 88 | Single-rooted mandibular premolars | SAF<br>Endovac<br>PUI | N/A | N/A | Digital photograph | 10 ml of 2.5% NaOCl, 17% EDTA for 2 min | Stereomicroscope |
| Li *et al*., 2015 | 24 | Maxillary first premolars | Needle irrigation<br>Endoactivator<br>Ultrasonic irrigation<br>PIPS irrigation | Premixed injectable | Lentulo spiral | N/A | 2 ml of 3% NaOCl, for 60 s | Scanning electron microscopy |
| Khaleel H *et al*., 2013 | 45 | Single-rooted teeth | Needle irrigation<br>Protaper file<br>Endoactivator<br>Ultrasonic irrigation | Powder and distilled water | Lentulo spiral | Radiographs | 5 ml of 2.5% NaOCl, 1 ml of 17% EDTA | Stereomicroscope |
| Arslan H *et al*., 2014 | 48 | Single-rooted mandibular premolars | Needle irrigation<br>PIPS irrigation<br>Ultrasonic irrigation<br>Endoactivator | Powder and distilled water | N/A | N/A | 5 ml of 17% EDTA | Stereomicroscope |
| Topcuoglu H *et al*., 2015 | 100 | Single-rooted teeth | Conventional irrigation<br>Canal brush irrigation<br>PUI<br>SAF<br>Endoactivator<br>Endovac | Powder and distilled water | Lentulo spiral | N/A | 5 ml of 3% NaOCl, 5 ml of 17% EDTA for 2 min | Stereomicroscope |

*Contd...*

**Table 4: Contd...**

| Study | Sample size (*n*) | Type of the teeth | Type of intervention | Type of calcium hydroxide | Placement method of calcium hydroxide score | Verification of calcium hydroxide placement | Irrigation method | Evaluation method |
|---|---|---|---|---|---|---|---|---|
| Dabhi M *et al*., 2016 | 60 | Maxillary anteriors | Side-vented needle<br>Endoactivator<br>Endovac | Premixed injectable (metapex) | N/A | N/A | 5 ml of 2.5% NaOCl for 30 s | Scanning electron microscopy |
| Faria G *et al*., 2014 | 66 | Canines | Conventional irrigation<br>PUI<br>Endovac<br>Endoactivator | Paste form | Lentulo spiral | Radiographs | 5 ml of 2.5% NaOCl for 30 s | Scanning electron microscopy |
| Yucel A *et al*., 2011 | 47 | Single-rooted teeth | Side-vented needle<br>Endovac<br>Proultra piezoflow | Powder and saline solution | Lentulo spiral | Radiographs | 5 ml of 5.25% NaOCl, 5 ml of 17% EDTA for 90 s, 30 s, 1 min | Scanning electron microscopy |
| Pabel AK *et al*., 2017 | 110 | Single-rooted teeth<br>Central and lateral maxillary incisors, canines, premolars | PUI<br>RinsEndo<br>Endoactivator<br>Motor-driven plastic brush (CanalBrush)<br>Manual irrigation with syringe | Premixed injectable (calxyl) | N/A | Digital photograph | 2 ml 1% NaOCl, 5 ml 17% EDTA | Stereomicroscope |

EDTA: Ethylenediaminetetraacetic acid; SAF: Self-adjusting file; NaOCl: sodium hypochlorite; PUI: Passive ultrasonic irrigation; PIPS: Photon-induced photoacoustic streaming; N/A: Not available

movement and exchange. It cannot create adequate fluid movement to suck air from the apical region. Furthermore, the needle delivers irrigants no further than 1 mm beyond the needle tip, and therefore, the apical third is inaccessible for flushing. It also delivers insufficient volume of irrigants to the apical area and lacking cavitation, resulted in low efficiency of $Ca(OH)_2$ removal.[6] The ineffectiveness of it could result from its inability to create cavitation.[8] A potential benefit could be its noninvasive mode of action but it is not effectively remove $Ca(OH)_2$ medicament from coronal and apical groove of root canals when compared to other irrigation techniques.[16]

### Limitations

This review had certain limitations. In that, the first limitation was the complexities of the different methodologies used in the different studies assessed. Different types of $Ca(OH)_2$, irrigation times, irrigation solutions, and their concentration and outcome measurements were used in the studies assessed. Hence, it was not possible to conduct a meta-analysis. The second limitation was that the results of the included studies were derived from *in vitro* studies. But, however, the clinical trials such as randomized controlled trials give more accurate results.

The third limitation was that all of the included studies described randomized allocation of all groups but none of the studies described the randomization methods. Furthermore, some of the studies performed blinding and some studies not performed blinding. Hence, this has increased the risk of bias.

The different evaluation methodologies used in the included studies made comparisons difficult amongst the studies because of a lack of uniformity in the evaluative criteria for the assessment of removal of $Ca(OH)_2$ from root canals. There was no standardization of placement of $Ca(OH)_2$, removal of $Ca(OH)_2$, or evaluation methods. The fourth limitation of the review was the small size of the studies evaluated. Studies with larger sample sizes would have led to results that are more accurate.

## Conclusions

The review did not find enough evidence for the superiority of Endoactivator and Endovac irrigation techniques investigated because of conflicted, limited, and methodological differences between the studies evaluated. These differences may have led to conflicting evidence in some comparisons. Due to the methodological differences between the studies evaluated, further research is required to produce definitive results. Within the limitation of this systematic review, the current evidence indicates that Endoactivator irrigation technique showed better performance in removing $Ca(OH)_2$ intracanal medicament

from middle third and coronal third area of the root canals and Endovac irrigation technique from the apical third area of the root canals. However, none of the irrigation techniques removed $Ca(OH)_2$ intracanal medicament completely from the root canals.

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### Conflicts of interest

There are no conflicts of interest.

## References

1. Alturaiki S, Lamphon H, Edrees H, Ahlquist M. Efficacy of 3 different irrigation systems on removal of calcium hydroxide from the root canal: A scanning electron microscopic study. J Endod 2015;41:97-101.
2. Türker SA, Koçak MM, Koçak S, Sağlam BC. Comparison of calcium hydroxide removal by self-adjusting file, EndoVac, and CanalBrush agitation techniques: An *in vitro* study. J Conserv Dent 2013;16:439-43.
3. Al-Garni S, Al-Shahrani S, Al-Nazhan S, Al-Maflehi N. Evaluation of calcium hydroxide removal using EndoActivator system: An *in vitro* study. Saudi Endod J 2014;4:13-7.
4. Ahmetoglu F, Keles A, Simsek N. Effectiveness of the several irrigation techniques for removal of calcium hydroxide-based intracanal medication from an artificial standardized groove in the apical root canal. Marmara Dent J 2013;2:53-6.
5. Capar ID, Ozcan E, Arslan H, Ertas H, Aydinbelge HA. Effect of different final irrigation methods on the removal of calcium hydroxide from an artificial standardized groove in the apical third of root canals. J Endod 2014;40:451-4.
6. Li D, Jiang S, Yin X, Chang JW, Ke J, Zhang C, *et al.* Efficacy of needle, ultrasonic, and endoactivator irrigation and photon-induced photoacoustic streaming in removing calcium hydroxide from the main canal and isthmus: An *in vitro* micro-computed tomography and scanning electron microscopy study. Photomed Laser Surg 2015;33:330-7.
7. Khaleel HY, Al-Ashaw AJ, Yang Y, Pang AH, Ma JZ. Quantitative comparison of calcium hydroxide removal by EndoActivator, ultrasonic and ProTaper file agitation techniques: An *in vitro* study. J Huazhong Univ Sci Technolog Med Sci 2013;33:142-5.
8. Arslan H, Akcay M, Capar ID, Saygili G, Gok T, Ertas H, *et al.* An *in vitro* comparison of irrigation using photon-initiated photoacoustic streaming, ultrasonic, sonic and needle techniques in removing calcium hydroxide. Int Endod J 2015;48:246-51.
9. Topçuoğlu HS, Düzgün S, Ceyhanlı KT, Aktı A, Pala K, Kesim B, *et al.* Efficacy of different irrigation techniques in the removal of calcium hydroxide from a simulated internal root resorption cavity. Int Endod J 2015;48:309-16.
10. Aminoshariae A, Kulild J. Master apical file size – Smaller or larger: A systematic review of microbial reduction. Int Endod J 2015;48:1007-22.
11. Higgins JP, Green SP. Cochrane Handbook for Systematic Reviews of Interventions 5.1.0 (Updated March 2011) The Cochrane Library. Chichester, UK: John Wiley & Sons, Ltd; 2011.
12. Moher D, Liberati A, Tetzlaff J, Altman DG; PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. PLoS Med 2009;6:e1000097.
13. Dabhi M, Kishan KV, Parekh V, Rathore V. Comparative evaluation of 3 different irrigation system: 30 gauge blunt ended side vented needle, endoactivator & endovac in removal of $Ca(OH)_2$ from root canal system – Sem study. IOSR J Dent Med Sci 2016;15:84-9.
14. Faria G, Viola KS, Kuga MC, Garcia AJ, Daher VB, De Pasquali Leonardo MF, *et al.* Effect of rotary instrument associated with different irrigation techniques on removing calcium hydroxide dressing. Microsc Res Tech 2014;77:642-6.
15. Yücel AÇ, Gürel M, Güler E, Karabucak B. Comparison of final irrigation techniques in removal of calcium hydroxide. Aust Endod J 2013;39:116-21.
16. Pabel AK, Hülsmann M. Comparison of different techniques for removal of calcium hydroxide from straight root canals: An *in vitro* study. Odontology 2017;105:453-9.