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Effectiveness of laser and ultrasonic irrigant activation on penetration of AH sealer – A Systematic review

Ms. Saaransh Handa¹

Ms. Riya Kukreja²

Ms. Sakshi Runwal³

Ms. Shruti Nahar⁴

Ms. Mannat Kaur⁵

¹ Intern, Undergraduate Student, Bharati Vidyapeeth Deemed University Dental College and Hospital, Pune, Maharashtra, India

Email address: saaranshhanda7@gmail.com

Bharati Vidyapeeth Educational Complex, Pune-Satara Road, Katraj- Dhankawadi,
Pune-411043, Maharashtra, India

² Intern Undergraduate Student, Bharati Vidyapeeth Deemed University Dental College and Hospital, Pune, Maharashtra, India

Email address: riyakukreja2699@gmail.com

Bharati Vidyapeeth Educational Complex, Pune-Satara Road, Katraj- Dhankawadi,
Pune-411043, Maharashtra, India

³ Intern Undergraduate Student, Bharati Vidyapeeth Deemed University Dental College and Hospital, Pune, Maharashtra, India

Email address: sakshirunwal2916@gmail.com

Bharati Vidyapeeth Educational Complex, Pune-Satara Road, Katraj- Dhankawadi,
Pune-411043, Maharashtra, India

⁴ Intern Undergraduate Student, Bharati Vidyapeeth Deemed University Dental College and Hospital, Pune, Maharashtra, India

Email address: shrutinahar7@gmail.com

Bharati Vidyapeeth Educational Complex, Pune-Satara Road, Katraj- Dhankawadi,
Pune-411043, Maharashtra, India

⁵ Intern Undergraduate Student, Bharati Vidyapeeth Deemed University Dental College and Hospital, Pune, Maharashtra, India

Email address: mannatk928@gmail.com

Bharati Vidyapeeth Educational Complex, Pune-Satara Road, Katraj- Dhankawadi,
Pune-411043, Maharashtra, India

Corresponding author:

Name: Ms. Saaransh Handa

Mobile number: +91 8178555077

Email address: saaranshhanda7@gmail.com

ABSTRACT

Aim: Evaluating the effectiveness of laser assisted and ultrasonic irrigant (UI) activation on the depth of penetration of AH PLUS sealer

Methods: Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines were followed during the review process. Databases were searched from January 2000 to December 2023 for studies evaluating the effectiveness of laser assisted and ultrasonic irrigant (UI) activation on the depth of penetration of AH PLUS sealer. Quality assessment was evaluated using Cochrane risk of bias (ROB) -2 tool for randomized controlled trials (RCT) through its domains using Review manager (RevMan) software version 5.3. With a random effect model ($p < 0.05$), the standardized mean difference (SMD) was employed as the summary statistic measure.

Results: Six studies were used in the qualitative synthesis. The quality assessment found a moderate to low level of bias. The various activation techniques assessed were conventional syringe-based irrigation (CSI), endo activator (EA), ethylene dioxide triacetate (EDTA), passive ultrasonic irrigation (PUI) and the use of lasers like photon-initiated photoacoustic streaming (PIPS), erbium-doped yttrium aluminium garnet laser (Er:YAG) and shockwave-enhanced emission of photoacoustic streaming (SWEEPS). The laser activation group was subdivided into PIPS and Er:YAG laser compared with UI. It was found that the laser group showed superiority to other agitation techniques in sealer penetration.

Conclusion: lasers provided highest and better penetration compared to other irrigation activation techniques at all the portions of tooth. However, furthermore standardized studies should be carried out to validate and provide a better evidence among all activation techniques which will help clinicians in improving the outcome of an endodontic procedure.

Keywords: bio-ceramic sealer, laser activated irrigation, resin sealer, systematic review, ultrasonic irrigation

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INTRODUCTION

Pulp sealers are useful in minimizing endodontic infections and enhancing the long-term outcomes of root canal treatment [1][2]. Their adherence to the dentin wall in the root canal prevents microleakage and the implantation of residual bacteria into the complicated structure of the root canal and dentinal tubules. [1]. However, the results are dependent on the features of the dentin surface and the physical and chemical qualities of the sealant [3].

There is growing evidence that irrigation and static pressure in the canal play a crucial role in the disinfection of the root canal, including dental disease [4]. The air gauge in the apical third restricts the amount of fluid that can be delivered to the apical area, and standard syringes only deliver fluid 1 mm deeper than the needle [5]. Due to the acoustic microflow signature, passive ultrasonic irrigation has been demonstrated to offer superior root canal drainage than syringes at the apical 3 mm level [6]. It has been found recently that laser energy Er:YAG can remove the smear layer or sealer entering the dental canal [7].

In endodontic treatment, dental lasers are utilized for debridement and root canal cleaning. When photodynamic treatment (PDT) is applied in a root canal, the laser wavelength interacts with the biofilm, planktonic bacteria, smear layer, and dentin tissue to produce photosensitivity [8]. The dentin surface experiences morphological and chemical alterations as a result [9]. The filling material's adherence to the root canal wall may be impacted by these modifications [10].

Increased dislocation resistance of resin-based sealants following root canal therapy with diode or Er:YAG lasers has been documented by numerous authors [11][12]. The efficacy of Er:YAG laser irrigation in opening dental canals and enhancing permeability by eliminating the smear layer [13].

PIPS is a novel laser technology that activates the irrigant in the root canal using a low-power Er:YAG laser [14]. PIPS can inhibit tooth decay by enabling a deeper flow to enter the dental canal [15]. Research indicates that PIPS is more effective than syringe irrigation and ultrasonic stimulation at removing smear layers and debris [12][13]. PIPS uses only a single internal laser fibre to enter the cavity, eliminating the risk of thermal damage to teeth and tissues [10].

Utilizing biocompatible materials to create tight closure and a three-dimensional root canal volume is another crucial objective of root canal therapy [6]. The use of root canal sealer for transverse and apical sealing facilitates exchange between vessels and root canal walls [7]. This can be achieved by penetrating the sealer into the root canal, thereby improving the sealing ability and improving the sealability of the root canal [12]. Additionally, antibacterial action of the sealer can stop bacteria from colonizing and reinfected the root canal by allowing it to penetrate the dentine tubules [13]. The "gold standard" in endodontic research is the extensively utilized epoxy sealant-based resin known as AH-Plus root canal sealer. It is highly biocompatible, dimensionally stable, and has outstanding dental tubule permeability and adaptability [1].

Based on available data, no study has offered a thorough, quantitative, and comparative evaluation of the effects of ultrasonic irrigant activation and laser assistance on the AH PLUS sealer's penetration depth. In order to provide an updated systematic review of the literature involving studies that evaluated the effectiveness of laser assisted and ultrasonic irrigant activation on the depth of penetration of AH PLUS sealer, we updated our research for related studies and conducted a systematic review.

METHODOLOGY

Protocol development

This review was done in accordance to the Preferred Reporting Items for Systematic review and Meta-analysis (PRISMA) statement [16].

Study design

The research question “Is there any difference in the effectiveness of laser assisted and ultrasonic irrigant activation on the penetration depth of AH PLUS sealer?” was put out in the Participants (P), Intervention (I), Comparison (C) and Outcome (O) framework.

Eligibility Criteria

a) Inclusion Criteria:

- 1) English language articles
- 2) Research based studies published between January 2000 – December 2023 and having relevant data on the effectiveness of laser assisted and ultrasonic irrigant activation on the depth of penetration of AH PLUS sealer
- 3) Studies reporting the data in terms of mean, standard deviation and frequency
- 4) Comparative studies, In vitro studies, Randomised controlled trials were included
- 5) Articles from open access journals

b) Exclusion Criteria:

- 1) Any studies conducted before January 2000
- 2) Articles in languages other than English language
- 3) Reviews, abstracts, letter to the editor, editorials as well as animal studies were excluded
- 4) Articles that are not from open access journals
- 5) Articles that fail to provide the mean and standard deviation of the study results

Screening Process

Two authors conducted the search and screening in two stages. First, the titles and abstracts were reviewed by two reviewers, and any publications that didn't meet the inclusion criteria were eliminated. In phase two, a small number of complete publications were independently screened and reviewed by the same reviewers. To resolve any disagreements, discussions were held. When two reviewers were unable to reach consensus on anything, a third reviewer was brought in to make the final decision. The corresponding author of the research was contacted via email when further information was required.

Search Strategy

An electronic search was conducted until December 2023 for research published within the last 23 years (from 2000 to 2023), using the English-language papers from PubMed, Google Scholar, and EBSCOhost databases.

The following keywords and their combinations were used to choose appropriate key words and Medical Subject Heading (MeSH) terms, which were then merged with Boolean operators like AND: The terms (MeSH term) AND “intracanal irrigation activation techniques” (MeSH term); “laser activated irrigation” (MeSH term) AND “ultrasonic irrigation” (MeSH term); “sonic irrigation” (MeSH term) AND “root canal disinfection” (MeSH term) AND dentinal tubules penetration (MeSH term); “penetration depth” (MeSH term) AND “endodontic infections and retreatment” (MeSH term) AND “irrigants” AND “randomized controlled trials” (MeSH term); “in vitro study” AND “comparative study”.

Data extraction

Two separate reviewing authors retrieved the demographic research characteristics for each of the included studies using a Microsoft Excel sheet, and the final analysis comprised the

following headings: author(s), study nation, study year, sample size, study design, outcome assessed, group assessed and conclusion.

Assessment of methodological quality

Using its different categories in Review Manager (RevMan) 5.3 software, the Cochrane Collaboration Risk of Bias (ROB) -2 tool [17] was used to assess the methodological quality of the included clinical trials or randomized controlled trials (RCT).

RESULTS

Study Selection

A total of 456 studies were identified after database search. After duplicates removal (n=256) and screening of records (n=162), a total of (n=41) studies were assessed for full text eligibility. The eligibility criteria was fulfilled by six studies and were included in qualitative synthesis as shown in **Figure 1**.

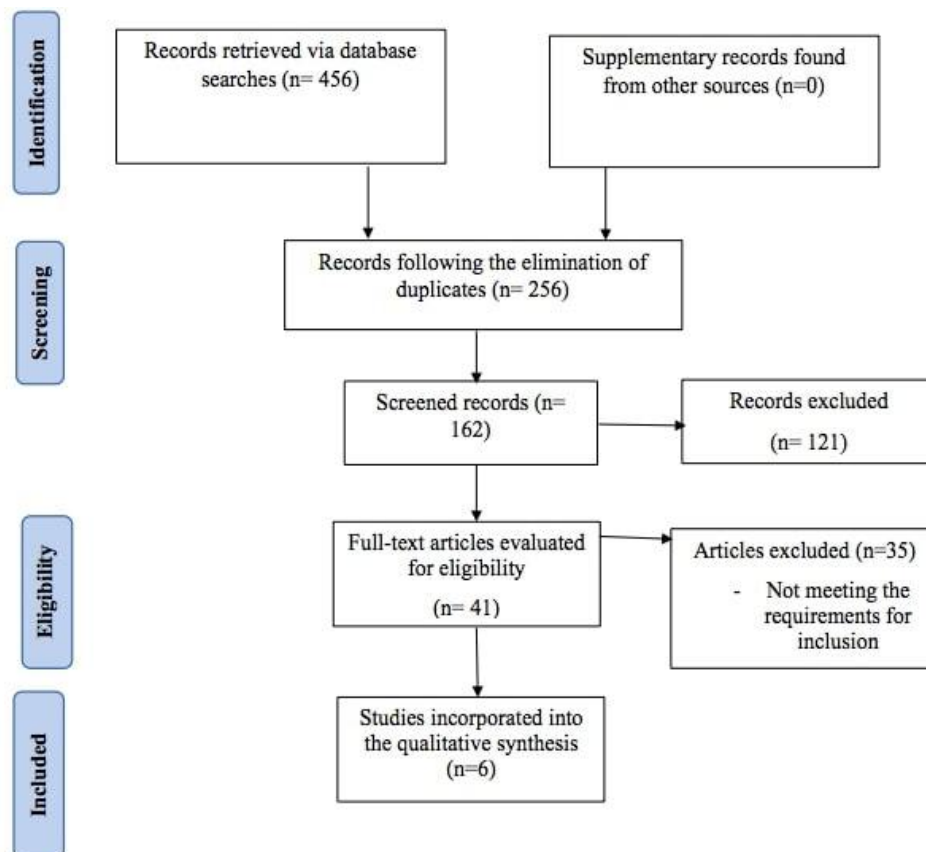


Figure 1- PRISMA Flow Diagram

Study Characteristics

As shown in **Table 1**, data was evaluated from six studies [18-23] from an aggregate of total of 335 teeth subjected to application of laser activated and ultrasonic irrigation activation on the better penetration of sealer into the coronal, middle and apical segments or portion of tooth. All the included studies had clinical trial study design. Among the included studies, two studies [18][23] was conducted in Turkey, one study in Korea [19] one study in China [20], Croatia [21] and India [22]. All the included studies assessed the outcome as the effect/ efficacy or effectiveness of various irrigation activation techniques in sealer penetration into dentin. The various activation techniques assessed were conventional syringe-based irrigation (CSI), endo activator (EA), ethylene dioxide triacetate (EDTA), passive ultrasonic irrigation (PUI) and the use of lasers PIPS in four studies [18-21], Er:YAG laser in two studies [22][23] and shockwave-enhanced emission of photoacoustic streaming (SWEEPS). It was found that the laser group showed superiority to other agitation techniques in sealer penetration.

Author, years of study	Country	Study design	Sample size	Outcome assessed	Groups assessed	Conclusion
Akcay et al. 2014 ¹⁸	Turkey	clinical study	72	Impact of different irrigation activation methods on dentin sealer penetration	Group A: CSI; Group B: PUI; Group C: PIPS; Group D: Sonic irrigation	Activation through laser followed by PIPS had a better sealer penetration
Gu et al. 2016 ¹⁹	Korea	clinical study	60	Evaluating the impact of five different intracanal agitation methods on the penetration of sealers and irrigants into dentinal tubules	Group 1: CSI; Group 2: Sonic agitation; Group 3: ultrasonic agitation; Group 4: V clean endodontic agitator; Group 5: Laser (Nd:YAP laser)	In terms of sealer and irrigant penetration, laser was superior than other agitation methods.

Yang et al. 2021 ²⁰	China	clinical study	36	Assessing efficacy of laser and ultrasonic activation techniques in sealer penetration	Group 1: CSI; Group 2: PUI; Group 3: PIPS	Compared to other agitation techniques, activation through PIPS greatly improved penetration
Bago et al. 2022 ²¹	Croatia	clinical study	50	Assessing efficacy of laser and ultrasonic activation techniques in sealer penetration	Group 1: CSI + NaOCl + EDTA; Group 2; PIPS + NaOCl + EDTA; Group 3: NaOCl + EDTA + diode laser; Group 4: NaOCl + EDTA + PDT; Group 5: CHX + NaOCl + EDTA;	PIPS group showed best penetration capacity
Talreja et al. 2023 ²²	India	clinical study	42	Assessing effectiveness of PUI and laser (Er:YAG) on solution and sealer penetration into dentinal tubules	Group A and B with AH and CS sealer as control; Group C: PUI; Group D: laser (Er:YAG)	Highest and better penetration was seen with laser at all the portions of tooth
Almasri et al. 2024 ²³	Turkey	clinical study	75	The ability of various irrigation activation methods to penetrate sealers	Group A: CSI; Group B: EA; Group C: PUI; Group D: Er: YAG laser; Group E: SWEEPS	Laser activation irrigation techniques had a better sealer penetration rate

CHX: chlorhexidine; CSI: conventional syringe-based irrigation; EA: endo activator; EDTA: ethylene dioxide triacetate; Er:YAG laser: erbium-doped yttrium aluminium garnet laser; PDT: photodynamic therapy; PUI: passive ultrasonic irrigation; PIPS: photon-initiated photoacoustic streaming; SWEEPS: shockwave-enhanced emission of photoacoustic streaming

Table 1- Descriptive study details of included studies

Assessment of methodological Quality

The creation of random sequences yielded the highest ROB followed by blinding of participants and personnel. All of the included studies concluded moderate to lowest ROB. Domains of allocation concealment followed by blinding of outcome assessment, insufficient outcome data, selective reporting and other bias were given the lowest ROB as depicted in

Figure 2 and 3.

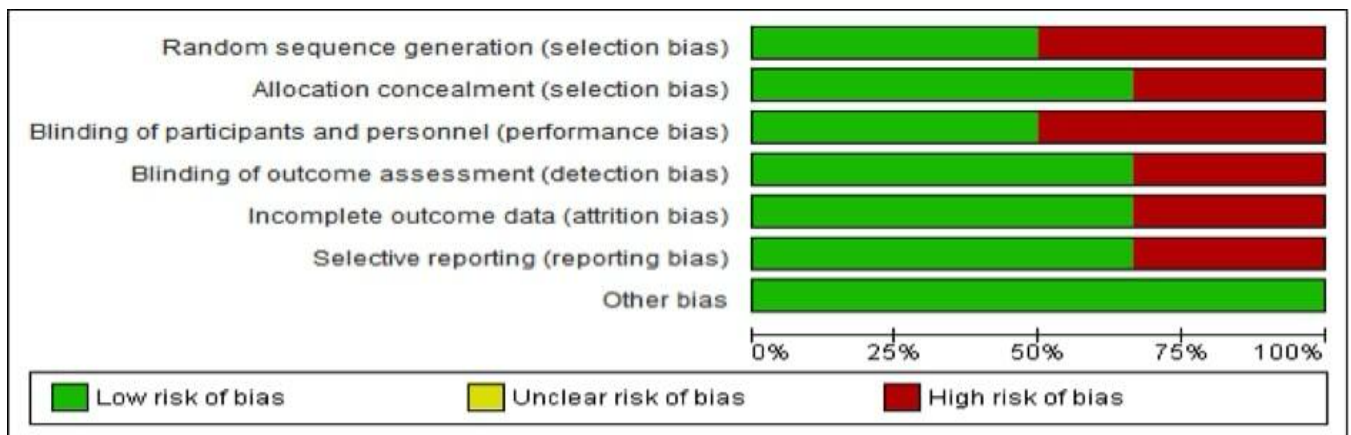


Figure 2: showing ROB graph: presented as percentages across all included studies.

Study	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Akcay et al. 2014	+	+	+	+	+	+	+
Almasri et al. 2024	+	-	+	-	+	-	+
Bago et al. 2022	-	+	-	+	-	+	+
Gu et al. 2016	+	+	-	-	+	-	+
Talreja et al. 2023	-	-	+	+	-	+	+
Yang et al. 2021	-	+	-	+	+	+	+

Figure 3: showing ROB summary: for each included study

DISCUSSION

Tan et al. [25] conducted a meta-analysis of RCTs to assess sealer penetration into dentinal tubules between sonic activation (SA) and conventional needle irrigation (CNI). Databases were searched till October 2022 for confocal laser scanning microscopy studies evaluating sealer penetration between SA and CNI. Nine studies fulfilled eligibility criteria and were considered in review and eight studies in meta-analysis. Pooled estimate through weighted mean difference (WMD) showed that SI provided greater sealer penetration in coronal (8.09, 2.78-13.40), middle (8.81, 5.76-11.87) and apical portion (4.73, 2.34-11.80) compared to CNI. It was concluded that SI had better filling ability than CNI during root canal treatments.

Almadi et al. [26] carried out a comprehensive assessment to evaluate the impact of photodynamic therapy (PDT) on penetration of endodontic sealers (AH Plus and epoxy-based sealer). Databases were searched till September 2022, fetching 12 laboratory studies. From the results of review, it was concluded that PDT does not have any significant impact on the depth of penetration of sealers into the dentinal tubules.

Kaplan et al. [27] conducted a systematic review to examine the ability of two distinct endodontic sealers to penetrate the dentin tubules using various irrigation activation approaches. (AH-Plus and Totalfill-BC). 100 premolars were used in this study. Different irrigation activation techniques assessed were CSI, PUI, EndoVac and Er:YAG laser. It was observed that Er:YAG laser had maximum sealer penetration compared to other activation techniques.

This review was conducted to analyse the better effectiveness between laser and ultrasonic irrigation activation on the penetration depth of AH PLUS sealer. Databases were searched till December 2023. Six randomized controlled trials [18-23] were taken in review and five studies for meta-analysis. All the included studies assessed the outcome as the efficiency of several irrigation activation methods for penetrating sealers into dentin.

The various activation techniques assessed were conventional syringe- based irrigation (CSI), endo activator (EA), ethylene dioxide triacetate (EDTA), passive ultrasonic irrigation (PUI) and the use of lasers like photon-initiated photoacoustic streaming (PIPS), erbium-doped yttrium aluminium garnet laser (Er:YAG) and shockwave-enhanced emission of photoacoustic streaming (SWEEPS). From the results of review, it was found that laser group showed highest and better penetration was seen with laser at all the portions of tooth.

Although it was found that among two lasers analysed, Er:YAG was statistically and clinically superior to PIPS and UI, we could not compare between PIPS and Er:YAG due to data heterogeneity. Furthermore, standardized studies and trials should be conducted between other irrigation activation techniques with laser, also a comparative analysis should be carried out between different class of lasers with regards to sealer penetration into dentinal tubules so as to help the clinicians with an updated evidence which will help them improve the outcome of an endodontic treatment or re-treatment.

This systematic review is strengthened by its adherence to PRISMA guidelines, extensive unrestricted literature search, use of reliable methodology for the qualitative synthesis of data, and quality assessment of evidence using the Cochrane risk of bias tool for randomized controlled trials. All of the studies that were included in the quality evaluation had excellent overall quality, specifying lack of potential and inevitable sources of bias with limited variation and inadequate reporting.

A systematic review is a transparent and repeatable procedure for identifying, selecting and critically assessing published or unpublished data to address a well-defined research question. Meta-analyses, a statistical analysis that incorporates numerical data from related studies, are frequently paired with systematic reviews.

The best evidence is generally regarded as systematic reviews and meta-analyses. However, the calibre of the included studies has an impact on how strong the evidence is. In the present review, sufficient studies with a brief observation period and a known risk of bias were included. As a result, the presently available evidence is sufficient to make therapeutic recommendations in response to the current systematic review's focus question.

CONCLUSION

It was observed that lasers provided highest and better penetration compared to other irrigation activation techniques at all the portions of tooth. However, furthermore standardized studies should be carried out to validate and provide a better evidence among all activation techniques which will help clinicians in improving the outcome of an endodontic procedure.

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DATA AVAILABILITY

All the data analysed during this study are included in this published article.

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