

ENDODONTICS RETREATMENT AND SUCCESSFUL REMOVAL OF ENDODONTIC SEALERS USING LASERS: A SYSTEMATIC REVIEW

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ABSTRACT

The laser's potential to stimulate the irrigants inside the root canals has been the subject of several studies. Laser-activated irrigation (LAI) is a method that is more effective than conventional methods in cleaning the canal and removing the smear layer. Compared to more traditional forms of irrigant agitation, a laser's benefits are clear. A systematic literature review from 2010 to 2022 was performed using PubMed, Medline, and ScienceDirect databases. The keywords used were "endodontic retreatment," "sealer removal," and "lasers." In addition, the PRISMA flowchart was used to describe the selection process of searched articles. Four out of nine included studies did not show any significant difference in the removal of sealers with or without lasers. However, the other five studies did show significantly improved removal of sealer remains from the root canals. Lasers can be used effectively to remove a majority of the remaining sealing materials from the root canals.

Key words: Endodontics retreatment, Sealers, Lasers, Systematic review.

Introduction

In traditional endodontics, the irrigants are activated in various ways to improve cleaning and sealer penetration, ultimately leading to a successful treatment. Previous research has shown that tissue disintegration may be accelerated, and irrigation solution efficacy can be improved by agitating the irrigant. There are a variety of methods for agitating irrigants, including manual (Endobrush agitation, needle or cannula irrigation, and manual-dynamic agitation) and mechanical (continuous irrigation during rotary instrumentation, rotating brush agitation, ultrasonic, and sonic) methods [1].

The laser's potential to stimulate the irrigants inside the root canals has been the subject of several studies [2]. Laser-activated irrigation (LAI) is a method that is more effective than conventional methods in cleaning the canal and removing the smear layer. Compared to more traditional forms of irrigant agitation, a laser's benefits are clear. When used after obturation, it is an effective model for clearing debris, the smear layer, and other particles. In addition, it serves as a useful disinfecting activity. Photothermal, photochemical, photomechanical, and photoacoustic effects are all combined to describe the biological effects generated when different laser wavelengths interact with different targets (dentin, bacteria, and irrigants, respectively) [3, 4]. Inorganic residues, organic pulp tissue, odontoblastic processes, and microorganisms with metabolic products make up the amorphous smear layer. Intracanal disinfectants' ability

and sealer, permeate dentinal tubules is enhanced by the smear layer without affecting the root canal filling's seals integrity. The smear layer may persist in the dentin tubules to 40 μm. Studies have revealed that the smear layer must be removed to improve sealer adherence to the canal wall. That's why it's important to get rid of the smear layer in a certain way; doing so improves the prognosis for therapy [4, 5].

Researchers in the research community has recently emphasized innovative mechanisms for initiating irrigation systems. Dental lasers' photochemical, photothermal, and photoacoustic impacts are currently being studied. The primary motivation for using LAI was to improve the efficacy of irrigation systems. An innovative irrigant activation technique, photon-induced photoacoustic streaming (PIPS), is performed using an Er: YAG laser. The PIPS activation technique of irrigation can improve root canal cleansing and resin sealer adherence in endodontic therapy. This indicates that the binding strength of resin-based sealer is enhanced by activating the irrigant and creating the streaming. The AH Plus sealer's efficiency was boosted by the use of a laser [6].

Materials and Methods

A systematic literature review from 2010 to 2022 was performed using PubMed, Medline, and ScienceDirect databases. The keywords used were "endodontic retreatment," "sealer removal," and "lasers" (Table 1). In

addition, the PRISMA flowchart was used to describe the selection process of searched articles (**Figure 1**).

Table 1. Inclusion and exclusion criteria

| No | Inclusion criteria | Exclusion criteria |
|----|---|--|
| 1. | Case-control and randomized control studies | Systematic reviews or meta-analyses or expert opinions, or narrative reviews |
| 2. | Published between 2010 and 2022 | Out of the specified time range |
| 4. | English language of publication | Language other than English |
| 7. | In vivo (humans) | In vitro |

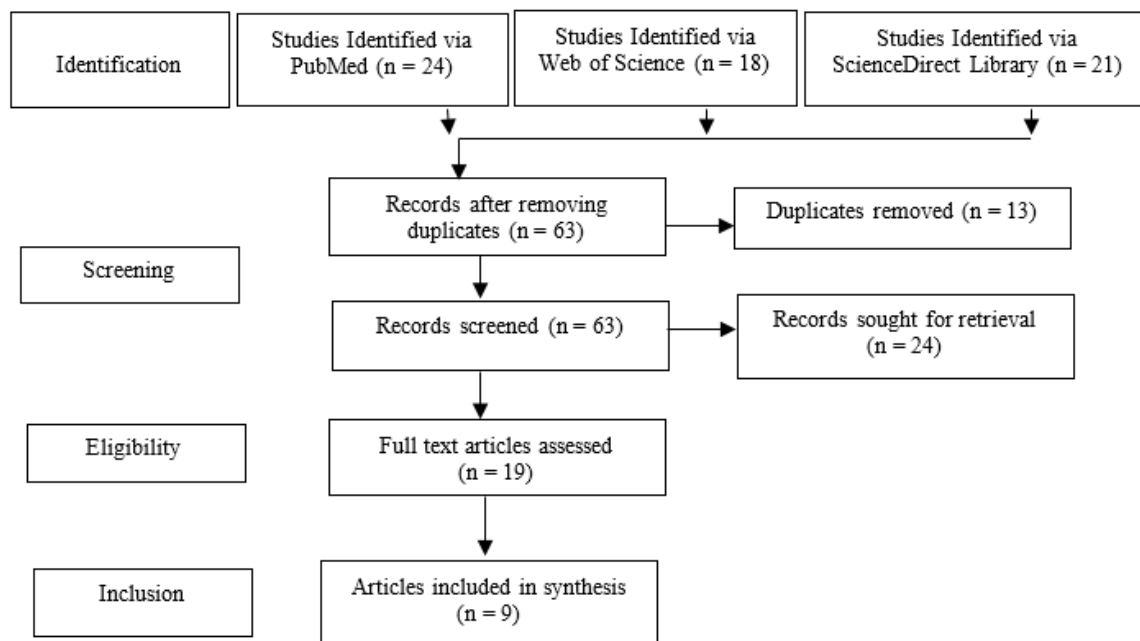


Figure 1. PRISMA Flow Diagram

Risk of bias assessment

The Cochrane risk of bias assessment method was used to assess the studies' quality (**Table 2**).

Table 2. Summary of Cochrane Risk of Bias Assessment

| Study | Selection Bias/Appropriate control selection/baseline characteristics similarity | Selection bias in randomization | Selection bias in allocation concealment | Performance-related bias in blinding | Reporting bias/Selective reporting of outcomes | Detection bias Blinding outcome assessors | Accounting for confounding bias |
|---------------------------------|--|---------------------------------|--|--------------------------------------|--|---|---------------------------------|
| Lloyd <i>et al.</i> , (2016) | + | + | - | + | + | + | - |
| ElShafei <i>et al.</i> , (2022) | + | + | + | + | + | + | - |
| Suk <i>et al.</i> , (2017) | + | + | + | + | + | - | + |
| Keleş <i>et al.</i> , (2015) | + | + | + | + | + | + | - |
| Nasher <i>et al.</i> , (2016) | + | - | + | + | + | - | + |

| | | | | | | | |
|-------------------------------|---|---|---|---|---|---|---|
| Eldeeb <i>et al.</i> , (2021) | + | + | + | - | + | + | + |
| Yang <i>et al.</i> , (2020) | + | + | - | + | + | + | + |
| Dönmez <i>et al.</i> , (2019) | + | + | + | + | + | + | - |
| Laky <i>et al.</i> , (2013) | + | + | - | + | + | + | + |

Results and Discussion

The study by Lloyd *et al.* (2016) compared the efficacy of three different irrigation techniques: Er: Passive ultrasonic irrigation (PUI) with EndoUltra, YAG laser-activated irrigation (PIPS), and standard needle irrigation (SNI) to remove calcium hydroxide [Ca(OH)₂] from the mesial roots of Weine Type II mandibular molars [7]. CT was used to observe mesial roots with complicated intra-canal architecture and a shared apical foramen in 30 mandibular molars. When comparing the middle and apical thirds to the coronal third, Ca(OH)₂ had a more significant mean volume in the coronal third before the removal ($p < 0.001$). The removal of Ca(OH)₂ from the upper and central thirds was comparable across the three approaches ($p > 0.05$). Ca(OH)₂ clearance in the apical third was significantly greater in PIPS (median 0%; IQR: 0-0) compared to PUI and SNI ($p < 0.001$).

The research by ElShafei *et al.* (2022) aimed to evaluate the efficacy of photoinduced photoacoustic streaming for push-out bond strength, sealer penetration, and smear layer removal utilizing a 2940 nm Er: YAG laser and a 980 nm diode laser [8]. Sixty permanent human teeth with one canal were obtained for this investigation. Concerning smear layer elimination, the findings revealed that the PIPS group had exposed dentinal tubules, followed by the diode laser group, and the Side vented needle group showed the least cleaning impact. There was a statistically significant difference between the three groups regarding sealing ability and dye penetration, with the Er: YAG laser (PIPS) being the most effective. There was no statistically significant difference in push-out bond strength between the diode and Er: YAG groups. However, there was a significant difference between the diode and Er: YAG groups and the Side-vented needle group. The result showed Better irrigant penetration and smear layer reduction after diode or Er: YAG laser (PIPS) activation improved sealer penetration, sealing, and strength qualities of endodontic treated teeth [9].

Suk *et al.* (2017) investigated how well PIPS works in clearing root canals of any remaining filling material after the rotational phase of retreatment [10]. Forty-six single-rooted human teeth were removed and instrumented. Following PIPS, the fillings in all groups decreased significantly ($p < 0.05$). The MTA Fillapex was the easiest to remove during the rotating phase of the retreatment. Following the rotary phase, the EndoSequence BC and AH Plus groups showed no significant differences in the quantity of leftover filling material. All groups improved the elimination of filling residues after using the PIPS.

Micro-computed tomography was employed to evaluate the efficiency of lasers in an investigation by Keleş *et al.* (2015) by eliminating infill remains from oval-shaped canals after retreatment operations using rotary tools [11]. Forty-two mandibular canine teeth had their root canals cleaned and disinfected. The difference in residual filter matter was examined before and after laser application Using the matched sample t-test and the one-way analysis of variance within and between groups. When filling remnants were removed, the Er: YAG laser group had a considerably greater removal rate (13%) than the Er: YAG laser group (4%), the Nd: YAG group (3%), or the control group (0%). To sum up, none of the retreatment methods successfully eradicated the filler materials. After the retreatment operation using rotary equipment, lasers helped remove any remaining filling material more effectively.

The researchers Nasher *et al.*, (2016) compared the efficacy of various irrigant types in removing the endodontic smear layer using the Er: YAG PIPS method (2.94 m) [12]. In endodontic preparations up to size #40, 64 single-rooted teeth were randomly assigned to one of eight groups (a-h; n=8). The Coronal, middle, and apical thirds of groups b, c, f, and g all have the smear layer. Dentinal tubules in the coronal and middle thirds were open in groups a, d, e, and h. None of the apical third, however, had open dentinal tubules. There was no statistically significant difference ($p > 0.0018$) between the groups that received just irrigants and the groups that received both Er: YAG PIPS and irrigants. The Er: YAG PIPS method did not outperform only using irrigants in clearing the smear layer.

The purpose of the study by Eldeeb *et al.* (2021) was to compare the efficacy of various equipment tapers for removing the smear layer and introducing the sealer using the photon-initiated photoacoustic streaming (PIPS) technology in root canals [13]. One hundred twenty mandibular molars from humans were sorted into three groups of similar size based on the degree of taper in their apical preparations. We used a three-way ANOVA followed by Tukey's post hoc test to assess the sealer penetration data. When comparing root thirds, PIPS activation resulted in considerably greater smear layer reduction and sealer penetration ($P < 0.001$). No statistically significant difference ($P > 0.05$) between the two irrigation strategies for sealer penetration in the apical third after a root canal preparation of 25/4%.

Micro-CT was employed to evaluate the effectiveness of the photon-induced photoacoustic streaming (PIPS), ultrasonically activated irrigation (UAI), and shock wave

enhanced photoacoustic emission streaming (SWEEPS) in the removal of mandibular molars accumulated hard-tissue debris (AHTD) from the root canal system in a study by Yang *et al.* (2020) [14]. Three micro-CT scans were performed on 30 mandibular first and second molars with isthmuses connecting mesial root canals and a single distal canal. Pre- and post-instrumentation canal volumes and debris volumes after canal preparation were comparable across the three groups ($P > 0.05$). Irrigation with SWEEPS decreased debris in the mesial canals by 84.31 percent, substantially higher than the decreases associated with PIPS (58.79 percent) and UAI (50.2 percent). In the distal canals, the PIPS and UAI groups ($P > 0.05$) did not significantly differ in the %Rd of AHTD. In contrast, this change was noticeable in the UAI and SWEEPS groups ($P < 0.05$) and PIPS and SWEEPS groups. When comparing the SWEEPS to the PIPS and the UAI, the former had a higher %Rd of AHTD.

The analysis by Dönmez *et al.* (2019) used two nickel-titanium rotary systems, each with and without laser-activated irrigation, in the retreatment process [15]. The researchers used K files up to size 35 to instrument the root canals of 60 human mandibular premolars. The average amount of leftover filler material did not vary significantly between the experimental groups ($\chi^2 = 0.754$; $p = 0.86$). Therefore, there was no discernible difference between the HyFlex EDM and PTR systems regarding their ability to

eradicate the lingering filler material. Furthermore, in both rotary system evaluations, the PIPS approach did not significantly contribute to the expulsion of the filler material.

The research by Laky *et al.* (2013) aimed to evaluate the effectiveness of calcium hydroxide removal from the root canal by photon-induced photoacoustic streaming (PIPS) to needle irrigation and irrigation with sonic activation [16]. Sixty artificial teeth were cleaned, filled with calcium hydroxide, and sorted into four categories for this study. Teeth were randomly randomized to receive either needle irrigation, sonic device irrigation, PIPS with a lower energy setting (10 mJ, 15 Hz), or PIPS with a higher energy level (25 mJ/40 Hz). Apical extrusion caused color changes in the agarose gel, which were digitally analyzed in Photoshop. In terms of calcium hydroxide removal, there were no evident differences between the two laser groups. Ultrasonic-aided removal resulted in much higher calcium hydroxide removal than needle irrigation. Both laser groups showed significant differences for sonic-assisted removal and needle irrigation in calcium hydroxide removal. Regarding apical extrusion, the group exposed to the highest laser power (25 mJ/40 Hz) had the most dramatic change in periapical gel color. PIPS, at a setting of 10 mJ/15 Hz, removed calcium hydroxide without increasing the apical extrusion of the irrigation solution.

Table 3. Summary of findings from the included studies

| Author's name | specimens | Objective | Techniques | Outcome |
|-------------------------------------|-----------|--|--|---|
| Lloyd <i>et al.</i> , (2016) [7] | 30 | This study compared the efficacy of three different irrigation techniques: Er: YAG laser-activated irrigation (PIPS), passive ultrasonic irrigation (PUI) with EndoUltra, and standard needle irrigation (SNI) to remove calcium hydroxide [Ca(OH)2] from the mesial roots of Weine Type II mandibular molars. | PIPS, PUI, SNI | Ca(OH)2 clearance in the apical third was significantly greater in PIPS as compared to PUI and SNI ($p < 0.001$). |
| ElShafei <i>et al.</i> , (2022) [8] | 60 | The purpose of this work was to evaluate the efficacy of photoinduced photoacoustic streaming utilizing a 2940 nm Er: YAG laser and a 980 nm diode laser for smear layer removal | 2940 nm Er: YAG laser and a 980 nm diode laser | Using the diode or Er: YAG laser (PIPS) for irrigant activation resulted in improved irrigant penetration and smear layer reduction |
| Suk <i>et al.</i> , (2017) [10] | 36 | The assessment of the efficiency of photon-initiated photoacoustic streaming (PIPS) in the removal of filling residues from root canals during the rotational phase of retreatment was the goal of the study. | PIPS | After the rotary phase of the retreatment, the remaining filling material between EndoSequence BC and the AH Plus groups did not differ from the initial amount. The PIPS improved the removal of filling remnants in all groups. |

| | | | | |
|------------------------------------|-----|--|---|--|
| Keleş <i>et al.</i> , (2015) [11] | 42 | The purpose of this research was to determine the effectiveness of lasers in eliminating filling remains from oval-shaped canals after retreatment operations with rotary tools | micro-computed tomographic imaging, Er: YAG laser and Nd: YAG | A comparison of the groups revealed that Er: YAG laser application after the use of rotary instruments removed considerably more filling remains (13%) than Er: YAG laser-based photon generated photoacoustic streaming (4%) and Nd: YAG (3%) (P.05). |
| Nasher <i>et al.</i> , (2016) [12] | 64 | This research compared the Er: YAG PIPS procedure's removal degree of endodontic smear layer with other irrigants. | Er: YAG PIPS | There was no significant difference between the groups treated solely with irrigants and those treated with Er: YAG PIPS and the same irrigants |
| Eldeeb <i>et al.</i> , (2021) [13] | 120 | To assess the influence of the photon-initiated photoacoustic streaming (PIPS) approach on irrigation performance in root canals with varying instrumentation tapers in terms of smear layer removal | three-way analysis of variance (ANOVA) | PIPS activation resulted in considerably higher smear layer reduction and sealant penetration (P0.001). |
| Yang <i>et al.</i> , (2020) [14] | 30 | To compare the efficacy of ultrasonically activated irrigation (UAI), photon-induced photoacoustic streaming (PIPS), and SWEEPS activation for the removal of accumulated hard-tissue debris (AHTD) | micro-CT scans, UAI, PIPS, SWEEPS. | The three groups did not have a specific difference in canal volume before or after instrumentation. The debris volume after canal preparation did not significantly vary (P > 0.05). |
| Dönmez <i>et al.</i> , (2019) [15] | 60 | Efficacy of Two Different Nickel-Titanium Rotary Systems in Retreatment Procedures With and Without Laser-Activated Irrigation | HyFlex EDM and PTR systems, PIPS | The PIPS approach had no significant supplemental influence on filling material removal in all rotary system tests. |
| Laky <i>et al.</i> , (2013) [16] | 60 | The elimination of calcium hydroxide from the root canal using photon-induced photoacoustic streaming (PIPS) was compared to needle irrigation and irrigation utilizing sonic activation. | needle irrigation and irrigation utilizing sonic activation | PIPS at ten mJ/15 Hz accomplished almost full calcium hydroxide removal without increasing irrigation fluid apical extrusion. |

The PIPS tip does not leave the access cavity as it does with SNI and PUI to create cavitation bubbles that move as shear stresses along the canal walls. In the mesial roots of mandibular molars with Weine Type II canal morphology and isthmuses, we found no traces of Ca (OH)₂ anywhere in the root canal system. Ca (OH)₂ was absent throughout the root canal, even the tip, where irrigation is often more difficult. These findings may be attributable to the higher average fluid velocity between the structure's middle and upper thirds. Weine Type II canal systems were also present in the test samples, which provide fluid exchange in a circular pattern between the mesiobuccal and mesiolingual canals. Ca (OH)₂ removal from the apical third may have been improved by the canal's inherent structure, which allows for more fluid flow and higher shear stresses [17].

Endodontic irrigation is the primary use of lasers, and their use has been optimized for a considerable amount of time using a variety of laser types. Root canal therapy, apical surgery, viable pulp preservation therapy, and other endodontic procedures benefit from using lasers in the future [17]. Lasers with a wide variety of properties, such

as the Diode 980 nm, Er: YAG, Nd: YAG, and CO₂, are effective in removing the smear layer, killing bacteria, and sealing wounds. The study reports have been minimal, and there is a need for additional clinical research to give a scientific foundation for using specialized lasers in endodontics [18, 19].

Only two studies [20, 21] have assessed the removal of epoxy resin-based sealant using PIPS in root canal retreatment. After rotational retreatment, Keleş *et al.* examined the efficacy of PIPS, laser-activated irrigation with an Er: YAG, and laser removal with an Nd: YAG to remove AH Plus material and gutta-percha. All groups demonstrated significantly increased debris clearance, although the most effective strategy included placing the fiber tip deep inside the canal (three millimeters from the WL). When comparing PIPS to passive ultrasonic irrigation and sonic irrigation for AH Plus elimination during ProTaper retreatment, Jiang *et al.* found that PIPS was more effective [22].

The researchers in the present study found that lasers significantly cut down on the quantity of filler material that

needed to be removed during retreatment using R-Endo rotary devices. When comparing the Er: YAG laser to the Er: YAG laser-based PIPS and the Nd: YAG laser, the proportion of filler materials removed by the Er: YAG laser was much greater. As a result, the hypothesis being tested was found to be false. Er: YAG lasers, in contrast to Nd: YAG lasers, have a photomechanical interaction based on photothermal and photoablation processes, which is mediated by water [23]. Though carbonization of filler material due to the photothermal effect is possible [24].

Er: YAG PIPS has successfully removed the endodontic smear layer in many trials [25, 26]. To remove the smear layer from the canal walls, especially the apical third, these experiments indicated that activating 5% NaOCl and 17% EDTA with the Er: YAG PIPS approach enhanced the irrigants' effect. This investigation showed that the PIPS method did not improve smear layer removal efficiency.

The PIPS method was more effective than PI in removing the smear layer from all test samples. After using PIPS, sealer penetration was noticeably greater than with PI. There is a correlation between PIPS and an increased EDTA effect, which would account for the increased sealer penetration. The action of EDTA on the dentin surface was enhanced by vigorous agitation, leading to greater permeability [27]. This might be because of the high-powered lasers' ability to remove the smear layer more effectively or because of the inorganic/organic ratio shift in the root dentin [28].

When researchers compared SWEEPS with PIPS, it was shown that SWEEPS was superior in its ability to flush AHTD out of canals. Shock waves created by popped bubbles in small areas like root canals may be amplified using the SWEEPS technology, which uses synchronized laser pulses. When cleaning out debris from artificial root canal imperfections, PIPS performed better than UAI. Sectioning technique data for debris removal from the main canal and isthmus region showed no significant difference between PIPS and UAI [29].

Supplemental cleaning using the PIPS approach did not influence the volume of residual filling material compared to standard needle irrigation in the current investigation. Martins *et al.* used sonic and ultrasonic irrigation as auxiliary techniques and found similar outcomes, corroborating our findings [30]. While we found that retreatment techniques with rotary devices were effective in removing filling material, Kelesx *et al.* found that using the PIPS approach as a complementary technique was more effective [31]. The filling material was removed using a supplemental technique using XP-endo Finisher R in the AH Plus group. Still, according to another research, no such result was shown in the TotaFill BC Sealer group.

Calcium hydroxide was nearly completely removed using PIPS with both power levels. Li *et al.* also found that PIPS

and needle irrigation were successful in 99 and 81% of cases, respectively, when calcium hydroxide was removed [32]. Our findings support this since we found almost complete elimination of calcium hydroxide in the PIPS groups, 90% elimination in the sonic group, and 70% elimination in the needle irrigation group. Needle irrigation has been shown in many studies [33-35] to be less effective in removing calcium hydroxide than other methods, such as passive ultrasonic irrigation, the EndoActivator, and the Rinsendo.

Conclusion

Four out of nine included studies did not show any significant difference in removing sealers with or without lasers. However, the other five studies did show significantly improved removal of sealer remains from the root canals. Therefore, lasers can effectively remove most of the remaining sealing materials from the root canals.

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