THE EFFECT OF LASER IRRADIATION IN SMEAR LAYER REMOVAL – A REVIEW OF THE LITERATURE

Paulina Grinkevičiūtė[1], Gintarė Povilaitytė[2], Jolanta Siudikienė[2]

[1]Private practice, Lithuania;
[2]Lithuanian University of Health Sciences, Medical Academy, Faculty of Odontology, Department of Dental and Oral Pathology, Lithuania

Corresponding Author:
Gintarė Povilaitytė.
Adress: Versmės g. 7A – 2, Jonučiai II, LT – 53277,
Lithuania. Mobile: +37069615854.
E-mail: g.povilaityte@gmail.com

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Abstract

Objectives: Objectives of this study were to compare the impact of ultrasound and laser on the removal of the adhesive layer. Find out whether lasers activate the ability of irrigation solutions to remove the adhesive layer. Also compare different laser systems their efficiency.

Methods: a review of the literature in PubMed (MEDLINE) database and the Cochrane library. Keywords used and their combinations: smear layer, diode laser, Er:YAG, Nd:YAG, LAI, Er,Cr:YSGG. Search was done using PRISMA criteria.

Results: Of the 660 articles, 10 publications from 2014 through to March 2019 met the inclusion criteria. Laser systems together with irrigation solutions is more effective in removing the smear layer than using ultrasonic activation. There was one article that states the opposite.

Conclusions: The application of laser system can be a more effective way to remove the smear layer than ultrasound activation.

Keywords: *smear layer, diode laser, Er:YAG, Nd:YAG, LAI, Er,Cr:YSGG.*

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Introduction

The main purpose of endodontic treatment is to clean, shape and disinfect the root canals as thoroughly as possible and achieve adequate obturation [1]. Cleaning and shaping the root canal system with endodontic instruments produces a smear layer [2]. Smear layer is composed of inorganic debris, dentin particles, pulp tissue remnants, bacteria, their byproducts, blood cells [1,3] and can be packed into the dentinal tubules to a depth of up to 40 μm [4]. The thickness of the layer ranges from 1 to 5 µm, which is thick enough to block sealer penetration into the dentinal tubules [5]. It acts as a physical barrier, which may reduce dentin permeability and delay medications from accessing infected dentinal tubules [6].

Various methods such as solutions, ultrasonics and lasers in combination or alone, have been evaluated for the removal of the smear layer with varying results. To date, no single irrigant has shown to be capable of dissolving both the organic and inorganic parts of the dentin [7]. The use of two or more solutions is required as there is no single solution that has the ability to remove both organic and inorganic materials [8]. Sodium hypochlorite (NaOCl) is widely used in endodontic treatment because of its bactericidal properties and ability to dissolve organic tissues. Unfortunately, NaOCl is noneffective in removing the smear layer [9,10]. Decalcifying solutions used for removing the smear layer include phosphoric acid, citric acid, maleic acid, ethylenediaminetetraacetic acid (EDTA) [8]. Removing the smear layer from the apical thirds of root canals is very difficult, regardless of the solution used [11].

Passive ultrasonic irrigation (PUI) have been used to improve the chemical and mechanical effects of irrigation solutions, and recent studies have shown that ultrasonic activation of irrigants can provide an advantage over conventional needle and syringe irrigation for root canal debridement [7,8].Recently, laser-activated irrigation (LAI) has been introduced as an activation method by transfering the pulsed energyand it is proposed as an alternative to the conventional approach to cleaning and disinfecting the root canal system [12].

There have been various examinations of the removal of the smear layer by using a number of different lasers such as the Argon laser [13,14], neodymium-doped yttrium aluminum garnet (Nd:YAG) laser [15,16], diode laser[17,14],erbium-doped yttrium aluminum garnet laser (Er:YAG) [18-20], the erbium, chromium: yttrium scandium gallium garnet Er,Cr:YSSGG laser [21]. LAI can remove the smear layer from the root canal walls, but may also cause extrusion of the irrigant through the apex [22].The effectiveness of lasers depends on the wavelength, the power, the duration of exposure, the absorption of light, the geometry of the root canal and the tip-to-target distance [23].The Nd:YAG laser was one of the first lasers applied for root canal disinfection. Most researchers have suggested using mid-infrared erbium lasers to activate the irrigation of root canal [12].An Er:YAG laser has the highest absorption in water and a high affinity for hydroxyapatite, and it is believed to provide effective removal of the debris and smear layer [4]. There are studies that proves the the bactericidal effect of a diode laser (810 nm) [24]. The effect is based on thermal properties and also bacteria cannot develop resistance to laser exposure [25].A new LAI system, photon-initiated photoacoustic streaming (PIPS), has been introduced. The PIPS tip is inserted just into the coronal access opening of the pulp chamber. PIPS was developed to reduce the risk of thermal damage to the dentin [12].Nevertheless, the biomechanical preparation cannot completely eliminate the microorganisms from the root canal system; each technique has unique limitations [26]. Therefore, root canal system disinfection plays an important role in the success of endodontic treatment [27].

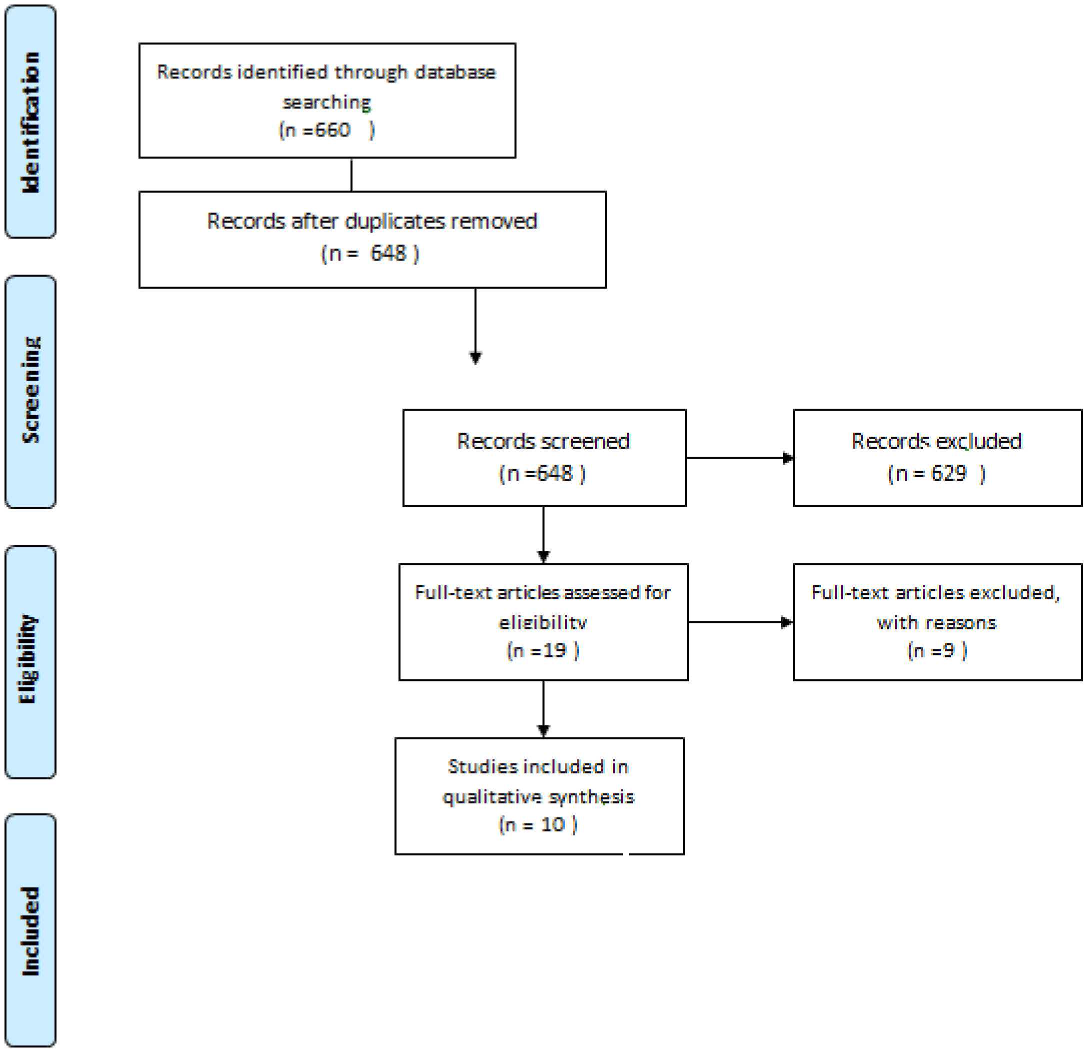
The aim of this study was to review the smear layer removal efficacy of lasers using different irrigation solutions.

Objectives of this study were to compare the impact of ultrasound and laser on the removal of the adhesive layer, find out whether lasers activate the ability of irrigation solutions to remove the adhesive layer and also to compare efficiency of different laser systems.

Methods

The review of the scientific literature followed the methodological guidelines of the PRISMA Statement (The PRISMA Statement). The electronic databases search accomplished in PubMed (MEDLINE) database and the Cochrane library. Data collection protocol was prepared before two investigators started collect the data and analysis of literature. The search for publications was based on keywords and word combinations. Keywords used and their combinations: *smear layer*, *diode laser, Er:YAG, Nd:YAG, LAI, Er,Cr:YSGG*. In case of disagreement, two authors resolved it during the discussion. The search results are presented in Figure 1. In the electronic search MEDLINE (by PubMed) and in the Cochrane Collaboration databases were found 660 articles published between 2014 and March 2019. Subsequently, after reading all the abstracts and discarding duplicates, 620 articles were excluded because their abstracts failed to conform to the aims of the study. Thus, 19 full-text articles were evaluated; 9 articles were excluded. Inclusion criteria: *in vitro* studies, full text, articles in English, scanning electron microscope evaluation. Exclusion criteria: no full text, different purposes of the study, retreatment procedures.

Figure 1. Prisma flow diagram.



Results

In the data bases, 10publications were selected that included research on various lasers used in dentistry to remove the smear layer[28-37]. SEM was used in all studies to evaluate not only qualitatively but also quantitatively by different scoring systems. The most common lasers in the studies were: diode laser [28,29,37], Er,Cr:YSGG [33,35], Er;YAG [31,34,35-37], Nd:YAG [30,32,37]. They were compared with other irrigation protocols or other irrigation systems (Table2). Two studies were conducted with several lasers [35,37] and compared with each other ordifferent irrigation protocols.

In several studies [28,31,32,34,37], the efficiency of lasers and ultrasound was compared by removing the smear layer. The results showed that using laser systems together with irrigation solutions is more effective in removing the sme

ar layer than using ultrasonic activation. Diode laser alone removes smear layer better than ultrasound, but usage of 17% EDTA with laser or ultrasound results in no statistically significant difference between groups [28].In this study, Er:YAG and PIPS laser activation were slightly more effective than passive ultrasonic irrigation (PUI) on smear layer removal[37].Another study states that LAI in the pulp chamber with the combination of 2.5% NaOCl and 17% EDTA better removed the smear layer than PUI with the same NaOCl and EDTA combinations using an ultrasonically activated file inserted 1mm short of the working length [31].Scanning electron microscopy showed that the smear layer is removed most efficiently using laser activated irrigation with 17% EDTA and this result was more effective than PUI [34]. However, one article states the opposite [32].The ultrasound group performed significantly better than Nd:YAG laser group [32].

Most studies compared the effectiveness of traditional solutions, chelating agents by removing the smear layer with the help of the laser. Diode laser treatment with solutions (EDTA and Qmix)decreased the amount of smear layer without significance[29]. The QMix + Er:YAG group removed the smear layer more effectively than the nonactivated QMix group in the apical third ($P<0.05$) and QMix removed more smear layer in the coronal thirds when activated with the PIPS technique [36].The application of diode laser significantly increased the efficiency of 17% EDTA solution at the apical thirds[29]. However,the laser activations significantly enhanced the effect of the NaOCl, EDTA, and NaOCl+EDTA irrigations in removing smear layer. On the other hand, there were publications where the irrigation solutions were activated by laser systems, and their efficiency did not increase. Laser-activated irrigation with 5% NaOCl was effective to remove smear layer and the difference was statistically significant ($P<0.001$), but still 17% EDTA and 5.25% NaOCl irrigation without LAI showed significantly better outcomes ($P < 0.001$) [30].The study did not find a statistically significant difference between the deactivated solution17% EDTAand the activated diode laser in the smear removal [28].

Other study compared the efficiency of different laser systems and revealed that PIPS showed the best removal of smear layer when compared with PUI, ANP, Nd:YAG, and Er:YAG, but the difference was not statistically significant ($P>0.05$). PIPS technique were statistically significant different from those of obtained with control, conventional syringe irrigation and diode laser groups ($P<0.05$). Irrigation activated techniques except diode laser have a positive effect on removing of smear layer[37].According to the smear layer scores, no significant difference was detected between the Er:YAG laser and the Er,Cr:YSGG laser when combined with NaOCl, EDTA, or NaOCl+EDTA [31].

Table 2. Characteristics of studies assessing the relationship between irrigation methods and smear layer removal.

Authors, year	**Irrigation methods and solutions used**	**Laser type and technical properties**
Amin K et al., 2016 [28]	A: 3% NaOCl + 3% NaOCl B: 17% EDTA + 3% NaOCl C: Diode laser application D: 17% EDTA for 40 s + diode laser application. E: distilled water with PUI followed by 3% NaOCl. F: 17% EDTA with PUI followed by 3% NaOCl.	Diode laser: 970 ± 15 nm, power max 7 W (20 s)
Kocak S et al., 2015 [29]	A: No irrigation B: 17% EDTA C: QMiX solution D: 17% EDTA + diode laser E: QMiX + diode laser.	Diode laser: 810 nm, power max 2W using the pulsed mode (10 Ton ms/Toff 10 ms) (20s)
ShahriarS et al., 2017 [30]	A: EDTA 17% and 5.25% NaOCl B: 1% NaOCl activated with Nd:YAG laser C: 2.5% NaOCl activated with Nd:YAG laser D: 5% NaOCl activated with Nd:YAG laser	Nd:YAG : 1.064 nm power 1 W, pulse energy 50 mJ/pulse, pulse frequency 20 Hz and pulse duration 100 µs (20s)
Ayranci LB et al., 2016 [31]	A: PUI + 2.5% NaOCl B: PUI + 17% EDTA + 2.5% NaOCl C: LAI + 2.5% NaOCl D: LAI + 17% EDTA + 2.5% NaOCl	Er:YAG : 2940 nm, 20W source power with a 50-Hz frequency
Lima CGA et al., 2015 [32]	A: no agitation (control), B: ProTaper Universal file C: Ultrasound D: CanalBrush E: Nd:YAG laser.	Nd:YAG : 1064 nm , 150 mJ/pulse and 10 Hz, average power = 1.5 W (4 times for 5 seconds each with 10-second intervals in between)
Miralles-Montero P et al. 2018 [33]	A: 17%EDTA B: Er,Cr:YSGG laser agitation C: 17% EDTA + laser agitation	Er,Cr:YSGG: 2.780 nm,1.25 W, 50 Hz, (5 cycles of 5 s each, with a break of 20 seconds between each cycle)

Sahar-Helft S et al., 2015 [34]	A: ProTaper F3 Ni-Ti files B: Positive-pressure irrigation with a syringe; C: PUI inserted 1mm short of the working length; D: PUI inserted in the upper coronal third of the root E: Er:YAG laser-activated irrigation, inserted 1mm short of the working length F: Er:YAG laser-activated irrigation, inserted in the upper coronal third of the root.	Er:YAG : 2940 nm, 0.5 W, 50 mJ, 10HZ , (60 s)
Wang X et al., 2017 [35]	A: 5.25% NaOCl B: 17% EDTA C: NaOCl + EDTA D: Er:YAG + NaOCl E: Er,Cr:YSGG + NaOCL F: Er:YAG + EDTA G: Er,Cr:YSGG + EDTA H: Er:YAG + NaOCl + EDTA I: Er,Cr:YSGG + NaOCl + EDTA	Er:YAG : 2940 nm, 20 mJ, 15 Hz, 0.3 W, and the super-short pulse mode with50 µs. Er,Cr:YSGG: 2780 nm, 25 mJ, 50 Hz, 1.25 W, 24% air, a pulse duration of 60 µs.
Arslan D et al., 2016 [36]	A: QMix B:QMix + EA C:QMix + PIPS D:QMix + Er:YAG.	Er:YAG: 2940nm, 1 W, 20 Hz, and 50 mJ Er:YAG: 2940 nm, PIPS was performed at 0.3 W, 15 Hz, and 20 mJ
Akyuz Ekim SNA et al., 2015 [37]	A: distilled water B: 2.5% NaOCl + 17% EDTA (CSI) C: 2.5% NaOCl + 17% EDTA (PUI) D: 2,5% NaOCl + 17% EDTA + EndoVac E: 2,5% NaOCl + 17% EDTA + diode laser F: 2,5% NaOCl +17% EDTA + Nd:YAG laser G: 2,5% NaOCl + 17% EDTA + Er:YAG laser H: 2,5% NaOCl + 17% EDTA + Er:YAG laser using with photon-induced photoacoustic streaming (PIPSTM).	Diode laser : 810nm , 1.2 W Nd:YAG : 100 mJ repetition rate of 15 Hz, 1.5 W Er:YAG: 2940 nm, 50 mJ repetition rate of 10Hz, 0.5 W Er:YAG laser-PIPS: 2940nm, 50 ms pulse, 20 mJ at 15 Hz, 0.3 W

PUI - passive ultrasonic activation, LAI - laser-assisted irrigation, EA- the EndoActivator system, PIPS- photon-initiated photoacoustic streaming, CSI- conventional syringe irrigation

Discussion

To achieve a successful endodontic treatment, chemomechanical treatment of the root canal system, especially in the apical third, is very important. An effective irrigation can help to overcome the morphological difficulties in oval-shaped, C-shaped root canals [38]. Laser-activated irrigation has been introduced for the purpose of smear layer removal [39,40]. During laser activation, the formation of vapor bubbles, the collapse of the bubbles, acoustic streaming, and cavitation processes occur [41].Surface tension is disrupted with the blow-back of steam bubbles from the apical region, allowing the irrigation solution to move towards the apical third [42,43].

Lasers with wavelengths from 940 to 2940nm have been suggested to activate irrigants in the root canal [44]. It can be because of the wide openings of dentinal tubules in coronal and middle thirds[45].The differences between these studies may be related to the methodology used. SEM evaluations have some limitations as this method allows assessment of only limited area of the canal wall. Nonetheless, lasers are expensive and also require the ability to know how to use them properly. Incorrectly used lasers may not bring any benefit to chemomechanical root canal preparation.

The main challenge with laser removal of the smear layer is to access the small canal spaces with the relatively large tips that are now available on the market [9]. On the other hand, the PIPS tip does not need to reach the canal apex, and it is placed into the coronal part of the root canal only [46]. It is shown that Er:YAG laser is more efficient in removing the smear layer due to the consecutive laser pulse [47]. The reason that PIPS is less effective in removing the smear layer is related to the reduction of thermal effects of low-energy laser [48,49]. Most important limitation of the Nd:YAG laser is that lateral irradiation is impossible. The Nd:YAG laser technique is known to remove smear layer at the points where the laser is in contact with the dentine surface [50].Morphological findings showed that irradiation without water produces an enamel and dentin carbonization, associated to an irregular structure [21,51].

However, no method has been able to fully remove the smear layer from the root canal walls in the apical region. Further in vivo investigations of irrigation systems for an appropriate evaluation of the removal of the smear layer are needed. It is essential to achieve a consensus regarding the laser parameters, as wavelengths and/or dosis, for treatment to be safe and efficient.

Conclusion

Within the limitations of this study, we estimated that the application of laser system can be a more effective way to remove the smear layer than ultrasound activation. In addition laser systems can have a positive effect on the ability of irrigation solutions to remove the smear layer. There is a lack of studies in order to compare the efficiency of laser systems with each other. More studies are needed to develop lasers systems ability to clean and prepare the root canals.

Conflicts of Interest

The authors declare no conflict of interest.

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