

The Effect of Lasers on the Healing of Periapical Lesion: A Systematic Review



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Abstract

Introduction: Endodontic treatment of teeth with periapical lesions presents more clinical difficulty. Various lasers in several methods are used in endodontics, and most of them are utilized as an adjunctive protocol in order to reduce the bacterial load of the root canal system. Improved disinfection plays a crucial role in enhanced and accelerated healing of periapical lesions. This review aims to summarize studies assessing the effect of lasers on periapical lesion healing.

Methods: PubMed/MEDLINE, Scopus, Embase, and Web of Science (ISI) online databases were searched, with no publication year or status restriction, for relevant articles on April 2023. Clinical studies evaluating the effect of laser application on the periapical lesion of patients using radiographic assessment were considered eligible for inclusion.

Results: Eight studies were included after carefully screening the obtained articles, first by their title and abstract and then by their full texts. Diode (4), Er, Cr: YSGG (3), and Nd: YAG (1) lasers were used with output powers that varied from 0.75 to 2 watts. Photodynamic therapy was employed in two studies, and in other studies, the root canal system was directly irradiated. Irradiation of the root canal system was adjunctive to standard preparation in all studies. The healing of the teeth treated with lasers was not inferior to those conventionally treated. In all of the included studies, laser application outperformed the standard cleaning and shaping protocol; however, this improved or faster healing was not statistically significant in most studies.

Conclusion: Lasers might expedite and improve the healing process of periapical lesions. Since lasers enhance the quality of cleaning of the root canal system, it is hard to point out the exact mechanism of it. Further investigations are needed to realize the effectiveness of this treatment modality and to discover the underlying biological concepts.

Keywords: Lasers; Root canal preparation; Periapical periodontitis; Periapical granuloma; Periapical diseases.



Introduction

A pathological cavity with an epithelial lining containing fluid or semi-fluid matter that develops from the epithelial remnants of the tooth formation process is called an odontogenic cyst. Odontogenic cysts are typically asymptomatic; as a result, they may grow to a significant size before any clinical signs or symptoms are detected. Accordingly, their presence is frequently discovered by accident during radiographic evaluation.¹ The most prevalent odontogenic cystic lesion with an inflammatory origin is a radicular cyst (also known as a periapical cyst), which is associated with the apex of a nonvital tooth.² If the epithelial remnants, referred to as the rests of Malassez, are not involved in the inflammatory response to the infection at the periapical area, the periapical cavity would not develop an epithelial lining and, therefore, is

described as a periapical granuloma.^{3,4} Root canal therapy (RCT) or surgical excision along with apicectomy is the gold standard for treating both radicular cysts and periapical granulomas.⁵

As RCT procedures have advanced over the past few decades, their success rate, which depends on periapical lesion healing, has steadily increased. Nowadays, the success rate of RCT surpasses 90% if full adherence to the recommended procedures of contemporary RCT techniques is maintained. However, the teeth associated with periapical lesions are harder for clinicians to treat, and their response to the standard treatment is less predictable.⁶ A clear understanding of the anatomy of root canals, appropriate mechanical and chemical preparation, and flawless filling of the root canal system are all essential elements that determine the effectiveness

of RCT.⁷ Implementing new methods and techniques, such as ultrasonic instruments and lasers, might enhance the success rate of RCT.⁸ This increased success rate is primarily associated with more effective eradication of bacteria, especially those that routine chemomechanical preparation cannot eliminate from the root canal system.⁹

The surgical removal of oral tumors was the first use of lasers in dentistry. Since then, several lasers have been invented and used in dentistry, including semiconductor diode (445-980 nm), carbon dioxide (CO₂, 10600 nm), helium-neon (He-Ne, 632.8 nm), neodymium: yttrium-aluminum-garnet (Nd: YAG, 1064 nm), argon (275-363.8 nm), and erbium (Er: YAG, 2940 nm and Er, Cr: YSGG, 2780 nm).¹⁰ Different lasers with different wavelengths are used in RCT in various methods and techniques, including antimicrobial photodynamic therapy (aPDT), laser-activated irrigation (LAI), photon-induced photoacoustic streaming (PIPS), and shock wave enhanced emission photoacoustic streaming technique (SWEEPS).¹¹ All of these methods have demonstrated encouraging results in reducing the bacterial load of the root canal system.¹² Bacterial load reduction is the main factor affecting the healing of periapical tissue.¹³

However, some techniques are ineffective when used as the only treatment and should be preceded by the standard conventional preparation of the root canal system; for example, after single-instrument root canal preparation, SWEEPS outperformed ultrasonically activated irrigation (UAI) and conventional irrigation (CI) in the removal of pulp tissue in the apical region of round canals. However, without previous instrumentation, SWEEPS was ineffective in removing pulp tissue.¹⁴

In addition to the bactericidal effect of lasers, many researchers have reported other positive biological results improving clinical outcomes.^{15,16} For instance, depotphoresis and a diode laser for root canal disinfection dramatically reduced the post-endodontic discomfort, and some lesions completely healed in a short period of time.¹⁷ In the non-surgical treatment of large periapical cysts, combining aPDT with traditional endodontic treatment can enhance the rate of long-term success and the reduction of microbial load in the endodontic region.¹⁸

Regarding safety considerations, root canal disinfection can be carried out effectively without significant thermal stress on the periapical tissues at output powers as high as 2.0 W to 2.5 W.¹⁹ The choice of the proper laser and its parameters for endodontic treatment, such as wavelength, energy, application time, and the number of sessions, substantially depends on the characteristics of the patient and the tooth.²⁰

In addition to RCT, lasers can also be employed in endodontic surgeries. aPDT has shown encouraging medium-term results in conjunction with the preservation of all affected teeth when used as an adjuvant therapy technique in the surgical endodontic treatment

of periapical lesions.^{21,22} Compared to the conventional methods, surgical endodontic treatment combined with aPDT significantly increases microbial reduction, which could impact the treatment prognosis and periapical lesion healing.²³ Using low-level laser therapy (LLLT) in endodontics, either surgical or non-surgical, could result in improved soft and hard tissue healing after the surgery, as well as reduced postoperative pain and discomfort, especially in the early phase of the healing period.^{18,24}

These findings suggest that lasers enhance the quality of disinfection of the root canal system when implemented as an adjunctive therapy or solely, depending on their characteristics. Lasers, in addition, have demonstrated favorable results in accelerating and inducing oral tissue repair.^{18,25-29} Besides diminishing the bacterial load of the root canal system, the biomodulation effect of lasers can play a crucial role in enhancing periapical tissue healing.^{13,18}

This review study aims to accumulate a comprehensive knowledge of the effects of lasers in RCT on periapical lesion healing by reviewing former studies. Clinicians and researchers interested in lasers in endodontics will gain knowledge from this review study and could use this data to improve their clinical practice.

Material and Methods

Protocol

The present systematic review follows the guidelines of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Figure 1).³⁰

Information Sources and Literature Search

An electronic search of the PubMed/MEDLINE, Scopus, Embase, and Web of Science databases was conducted for articles published until May 2023. Three independent researchers performed the electronic search of the selected databases using keywords, related MeSH terms, and their synonyms. The search terms included, but were not limited to: “laser,” “beam,” “ray,” “radiation,” “periapical periodontitis,” “periapical lesion,” “apical cyst,” “apical granuloma,” “root canal therapy,” and “endodontics.”

Eligibility Criteria

Selected studies needed to include human subjects having teeth with periapical lesions for which RCT was indicated. Studies also needed to compare the healing of periapical lesions when laser irradiation was employed and when conventional RCT without laser irradiation was executed. Excluded from this review were studies that used animal models or in vitro experiments. In addition, employing radiographic evaluation to assess periapical lesion healing was deemed a requirement.

Using the PICO strategy, a specific clinical question was constructed: Could the use of lasers in RCT result in a greater decrease in the size of periapical lesions than

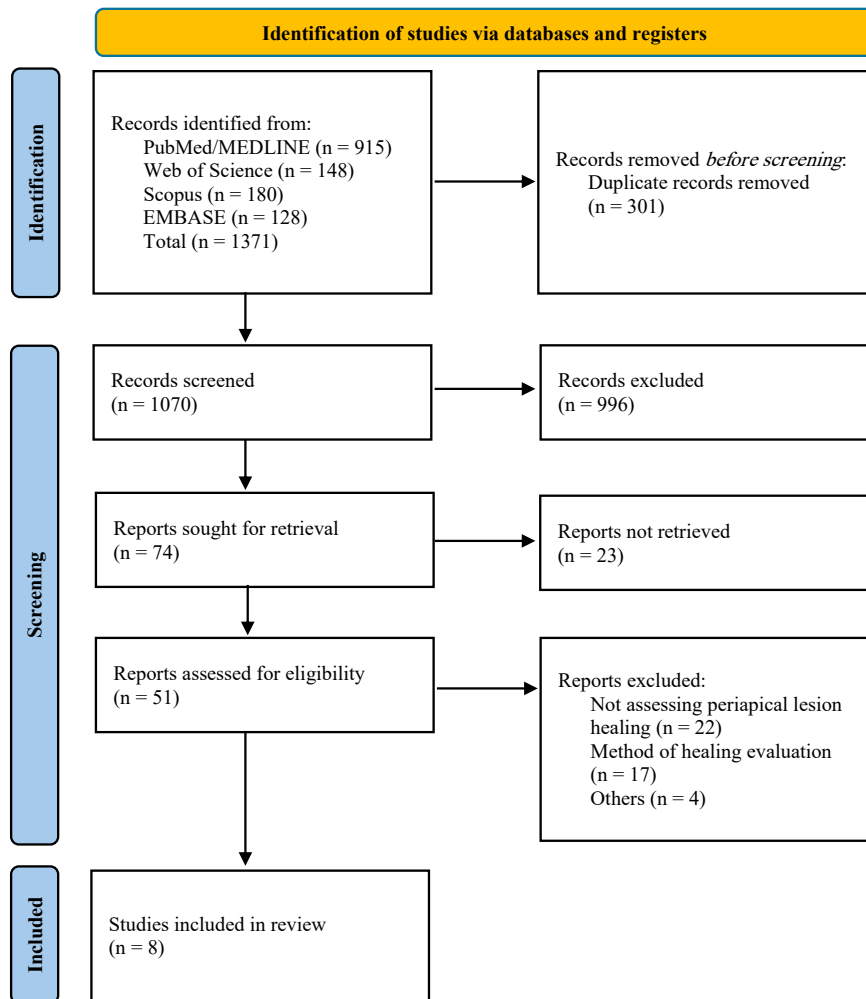


Figure 1. PRISMA Flowchart of the Systematic Review

conventional treatment methods? In this procedure, (P) represents patients with a periapical lesion, and (I) represents laser application in RCT as a sole or conjunctive treatment compared to (C) conventional endodontic treatment in terms of (O) periapical lesion healing.

Study Selection

Three researchers independently selected studies according to their titles and abstracts and categorized them for inclusion or exclusion. The articles selected for inclusion were read by three investigators, and a manual search of the reference lists was performed.

Data Collection Process and Data Items

Subsequently, the full texts of the selected articles were analyzed to answer the PICO question. Three researchers independently collected relevant information from the articles, including author's names, year of publication, type of study, patient population and sample size, type of laser used, laser parameters (including wavelength, emission mode, average power, fiber tip diameter, and exposure time), complementary techniques, and outcomes. The

heterogeneity of laser usage methods prevented the implementation of statistical analysis.

Risk of Bias

According to the Cochrane Collaboration's Tool for Assessing Risk of Bias in Randomized Trials,³¹ the authors assessed the bias of the included clinical trials. The domains evaluated were random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other biases.

Results

Study Characteristics

It was determined that there were a total of 1070 papers, but only eight of them matched the requirements to be eligible. These studies particularly focused on the changes in periapical lesions after RCT. All of the researches included in this review were clinical studies, and their primary objective was to determine whether or not the use of lasers in RCT may improve the healing of periapical lesions. The number of samples ranged from 15 to 90,

with a total of 420 teeth inspected over eight in vivo studies.^{17,32-38}

Lasers Used

Diode,^{17,33,35,36} erbium, chromium: yttrium, scandium, gallium, garnet (Er, Cr: YSGG),^{32,34,38} and neodymium-doped yttrium aluminum garnet (Nd: YAG)³⁷ were the most commonly utilized lasers. Table 1 summarizes the characteristics of the lasers used in the included articles.

The emission mode was pulsed in over half of the articles (5/9). Pulsed and continuous wave emission modes were both observed with diode lasers.

Dalaei Moghadam et al used a diode laser with pulse emission and average power of 2 W.¹⁷ They used a 200 µm fiber tip and operated for three 20-second periods with a wavelength of 940 nm. Masilionyte et al used a

continuous wave diode laser with the same settings only with an average power of 1-1.3 W and a speed of 2mm per second four times.³³ Garcez et al also used a diode laser but with a wavelength of 660 nm and power of 0.04 W; also, they applied the laser for 240 seconds and used a photosensitizer.³⁶

Shaheed et al worked with the Er, Cr: YSGG laser on 40 patients. The first laser irradiation was performed for smear layer removal with the power of 1.25 W, and then disinfection for the root canal was done with the same laser device but with disinfection settings and 1 W of power. Their fiber tip was 320 µm in the coronal part and 200 µm in the apical and middle parts. They operated three times at a rate of 1-2 mm/s.³²

Martins et al also used a 2780 nm pulsed Er, Cr: YSGG laser with the same settings in two independent

Table 1. A Summary of the Treatment Properties of the Included Studies

Treatment Properties	Dalaei Moghadam et al, 2021 ¹⁷	Shaheed et al, 2020 ³²	Masilionyte et al, 2018 ³³	Karakov et al, 2017 ³⁵	Martins et al, 2014 ³⁸	Martins et al, 2013 ³⁴	Garcez et al, 2008 ³⁶	Koba et al, 1999 ³⁷
Single or multiple visits	Two sessions	One session	Two sessions for the control group and an average of two sessions (min 1, max 7) for the laser group	Two sessions	Two sessions	Two sessions	Two sessions	One session
Irrigating solutions	2.5% NaOCl and 17% EDTA	Copious irrigation with NaOCl and final irrigation with saline	2.5% NaOCl for the control group and 0.5% NaOCl, saline, and EDTA for the laser group	2.5% NaOCl	3% NaOCl plus CH paste for the control group and sterile saline solution for the laser group	3% NaOCl plus CH paste for the control group and sterile saline solution for the laser group	Alternate irrigation with 2.5% NaOCl, 3% hydrogen peroxide, and 5 mL of a 17% EDTA, followed by irrigation with 5 mL of PBS solution at the end of the procedure	Alternate irrigation with 5% NaOCl and 3% hydrogen peroxide
Intracanal medication	Calcium Curpal® in the dephosphoresis group and Ca(OH) ₂ in the laser group	None	Ca(OH) ₂ for the control group and none for the laser group	Calasept in the control group and none in the laser group	Ca(OH) ₂ in the control group and cresophène was used in the first visit in all groups	Ca(OH) ₂ in the control group and cresophène was used in the first visit in all groups	Ca(OH) ₂	None
Root canal filling material and technique	N/A	Carrier-based technique and cold lateral compaction with AH-plus sealer	Cold lateral compaction and warm vertical condensation and after that, backfilling with warm gutta-percha with AH-plus sealer	Lateral condensation	Lateral condensation with zinc oxide eugenol handmade paste	Lateral condensation with zinc oxide eugenol handmade paste	Lateral condensation with sealer 26	Lateral condensation with canals N sealer
Analysis of apical repair	Radiographic evaluation with CBCT before treatment and 6 months after RCT	Clinical and radiographic evaluation with periapical radiographs, according to periapical index (PAI), over the six-month follow-up period	Radiovisigraphies with periapical radiographs (before treatment, after obturation, and follow-up of either short-term, long term or both)	Radiographic examination with periapical radiographs one and 14 days, and 6 and 12 months postoperatively	Radiographic monitoring with periapical radiographs (parallel technique) 0 and 6 months postoperatively	Radiographic monitoring with periapical radiographs (parallel technique) 0 and 12 months postoperatively	Radiographic monitoring with periapical radiographs 0 and 6 months postoperatively	Radiographic monitoring with periapical radiographs 3 and 6 months postoperatively

studies.^{34,38} Patients received two-session RCT. They set the laser power to 0.75 W and 1.25 W in the first and second sessions, respectively. In turn, the fiber tip diameter was 270 μm and 320 μm in the first and second appointments. With a speed of 2 mm/s, they irradiated root canals four times with 15 seconds of resting time between each irradiation.

Karakov et al used a photosensitizer (Helbo Endo Blue) on 84 patients divided into two groups, with one being treated with photodynamic therapy. A pulsed laser with 0.75 W power and a wavelength between 670–690 nm was used on patients in group one, and irradiation lasted 120 seconds.³⁵

Koba et al used the Nd: YAG laser with pulse emission with 1 W of power, a 320 μm fiber tip, and a frequency of 15 pps (66 mJ/pulse, 150 ps pulse duration) for one second.³⁷

Treatment Procedure

Prior to laser irradiation, conventional chemomechanical preparation of the root canals was done in all of the included studies; however, the method described as the preliminary chemomechanical preparation varied between studies. PDT was carried out in one session^{32,37} or two sessions.^{17,34-36,38} In Masilionyte and colleagues' study, the number of PDT sessions varied from 1 to 7, depending on the severity of the situation, with an average of two sessions.³³

Various irrigating solutions were applied during the chemomechanical preparation. Dalaei Moghadam et al used 2.5% NaOCl and 17% EDTA for root canal irrigation.¹⁷ In Shaheed and colleagues' study, copious irrigation was carried out with 2 mL of NaOCl 5% following each ProTaper file with a recapitulation by #10 K-file. Final irrigation was done with 5 mL of saline solution after laser irradiation.³² Masilionyte et al used NaOCl 2.5% (syringe/needle) during instrumentation and prior to obturation for their conventional group. In contrast, irrigation was performed with distilled water (syringe/needle) during instrumentation in the laser group. In some instances (6 out of 24) with necrotic pulp tissue still present in root canals, 2 mL of diluted NaOCl (0.5%) was used initially for improved flushing and dissolving of organic debris, and distilled water was used solely afterward. To eliminate the smear layer, 1 ml per tooth irrigation with EDTA 17% was chosen.³³ Karakov et al irrigated the root canals using a 2.5% NaOCl solution and then thoroughly rinsed the canal with sterile water to eliminate any leftover irrigation solutions.³⁵ In the two studies conducted by Martins et al, the root canals of the control group were irrigated with 3% NaOCl with CH paste, whereas those of the laser group were irrigated with sterile saline solution.^{34,38} Garcez et al used alternate irrigation with 2.5% NaOCl and 3% hydrogen peroxide. To remove the smear layer, both groups did the final irrigation with 5 mL of 17% EDTA

followed by 5 mL of phosphate-buffered saline solution. These researchers irrigated the canal with 5 mL of sterile saline solution to eliminate the antimicrobial agent.³⁶ Koba et al used alternate irrigation with 5% NaOCl and 3% hydrogen peroxide.³⁷

For intracanal medication, Dalaei Moghadam et al prepared Cupral® paste according to the manufacturer's instructions (one unit of Cupral® was blended with nine units of calcium hydroxide) and delivered it via Lentulo spiral into the coronal third of the canal in the depotphoresis group. In the laser group, the root canals were filled with a mixture of calcium hydroxide and saline using a Lentulo spiral to administer the medication.¹⁷ Masilionyte and colleagues' study was carried out without any intracanal medication intersessions in the laser group or exchange of intracanal Ca(OH)₂ medication in the conventional-control group.³³ In the laser group, Karakov et al did not provide any intracanal medicine, whereas in the control group, they administered a Calasept mixture containing Ca(OH)₂.³⁵ Martins et al only applied Ca(OH)₂ paste in the control group, although all groups received Cresophène® (Septodont) during the first visit.^{34,38} In Garcez and colleagues' study, Ca(OH)₂ paste was placed into the canals.³⁶ Shaheed et al³² and Koba et al³⁷ did not use any intracanal medications.

For root canal filling, in the study by Shaheed et al, patients were divided into two groups; the first group was obturated using a carrier-based technique, while the second group was obturated by using a cold lateral compaction technique with AH-plus sealer.³² Masilionyte et al used cold lateral compaction, warm vertical condensation, and backfilling with warm gutta-percha using an AH-plus sealer.³³ Laterally condensed gutta-percha technique was used in the rest of the studies but with various endodontic sealers: canals N sealer,³⁷ sealer 26,³⁶ and zinc oxide eugenol handmade paste.^{34,38} Karakov et al used lateral condensation, but they did not report what type of sealer was used.³⁵ Dalaei Moghadam et al did not report their obturation technique and the type of sealer they used.¹⁷

To evaluate apical repair, Dalaei Moghadam et al used cone beam computed tomography (CBCT) before and 6 months after RCT.¹⁷ Shaheed et al evaluated the healing of apical periodontitis in their cases both clinically and radiographically for six months. The clinical aspect of the assessment relied on the signs and symptoms, but the radiographic part was based on periapical index (PAI) scoring.³² Radiovisiographies were used by Masilionyte et al (before treatment, after obturation, and follow-up of either short-term, long term or both). The first radiographic follow-up examination for the laser group (mean: 12 weeks) was performed considerably sooner than for the conventional group (mean: 16 weeks).³³ Karakov et al used radiographical examinations one and 14 days and 6 and 12 months postoperatively.³⁵

Garcez et al and Martins et al analyzed at 0 and 6 months postoperatively^{34,36}; also, Martins et al analyzed at zero and 12 months postoperatively.³⁸ Martins et al evaluated the same group of patients in two separate studies^{34,38} with radiographic monitoring 0 and 6 months postoperatively in one study and 0 and 12 months in another.³⁸ Koba et al used radiographic monitoring 3 and 6 months postoperatively.³⁷ There is a summary of all treatment properties in [Table 1](#).

Outcomes

In Dalaei Moghadam and colleagues' study, laser therapy improved periapical healing, although it was not statistically significant ($P > 0.05$).¹⁷ After 6 months, 97.5% of lesions in Shaheed and colleagues' study had successful outcomes (80% of the lesions had complete healing and 17.5% was improved but not completely healed).³² Masilionyte et al showed that laser-assisted cleaning of root canals is a reliable method comparable to conventional ones. Additionally, it leads to faster healing of periapical lesions. However, the periapical index of healing was not influenced by laser application in the long term ($P = 0.22$).³³ According to Karakov et al, laser irradiation could enhance the recovery process of the apical bone.³⁵

Garcez et al reported the lesions of all teeth shrank, as observed in the radiographic follow-up. The reduction of the lesion area did differ significantly between individual teeth, perhaps due to the same factors that affect contamination and healing differently for every patient. The area reduction ranged from 65% to 100%, with an average of 78%.³⁶

The laser-assisted protocol of root canal cleaning is as effective as conventional methods, according to Martins et al ($P = 0.38$).³⁴ They also reported in another study that teeth treated with laser therapy exhibited results comparable to those of the control group, displaying statistically significant reductions in PAI scores ($P < 0.05$). However, the reduction of PAI scores did not vary between the control and laser groups ($P = 0.11$).³⁸ In Koba and colleagues' study, no significant difference was reported between the laser and conventional groups.³⁷

In [Table 2](#), a summary of all included investigations is provided according to the laser settings they used, the complementary methods they employed, and the results they obtained.

Risk of Bias Within Studies

The elements evaluated for the risk of bias are summarized in [Table 3](#). The articles by Martins et al presented a low risk of bias for all essential domains.^{34,38} On the other hand, the other included trials exhibited at least one high-risk item.^{17,35-37}

Discussion

Laser applications in endodontics have steadily increased

in variety and use rate over the past 20 years. Most commonly, lasers are employed in canal preparation in order to reduce the bacterial load of the root canal system. There have been many studies investigating this issue, either in vivo or in vitro.¹¹ The RCT of nonvital teeth with periapical lesions poses more significant clinical complications and, therefore, has a lower success rate when managed non-surgically.³⁹ Thus, equipping new technologies and methods in the treatment of this condition might be a promising way to improve the quality of the treatment. Since the primary etiologic factor of endodontic diseases, specifically periapical periodontitis, is an infection, most new techniques focus on improving the quality with which the disinfection is performed. In addition to reducing the bacterial load, researchers have claimed that lasers could assist in the healing of various oral tissues through their biomodulation effects.^{18,25-27} Hence, we searched for articles focusing on periapical lesion healing following the application of lasers in the RCT.

We found out that diode, Er, Cr: YSGG, and Nd: YAG lasers have been employed in treating teeth with periapical lesions with output powers ranging from 0.75 to 2 W. According to our findings, lasers improved the healing process of periapical lesions. Healing of a periapical lesion depends on a variety of factors, including but not limited to the quality of cleaning and shaping and the apical extent of obturation and preparation. Previous studies have shown that lasers effectively reduce the bacterial load of the root canal system.^{11,40,41} Also, the penetration depth of lasers into dentinal tubules is more than that of conventional irrigation techniques.⁴⁰ Bacteria could penetrate into dentinal tubules as deep as 1.1 mm,⁴² but 0.13 mm deep is the maximum penetration depth of chemicals used in RCT, according to Berutti et al⁴³ Probably the increased success rate of non-surgical RCT with the use of lasers is mainly because of the efficacy of lasers in eradicating bacteria from the root canal.

In addition to the bacteria residing in the root canal system, in an in vitro study simulating periapical lesions, Bytyqi et al have demonstrated that laser irradiation can destroy the bacteria that live within a periapical lesion more effectively than conventional methods ($P < 0.001$).⁴⁴ However, as the size of periapical lesions increases, the efficacy of lasers in killing bacteria decreases ($P < 0.001$).⁴⁴ The longer the duration of laser irradiation, the more effective the killing of bacteria in periapical lesions ($P < 0.001$).⁴⁴ Therefore, prolonged irradiation is recommended in treating larger periapical lesions. Most constructors and researchers recommend twenty-second irradiation episodes interrupted by resting periods because sustained laser irradiation can cause tissue irritation. Using lasers with inappropriate parameters, including irradiation time, could cause severe complications such as necrosis of periradicular tissue, degeneration of the

Table 2. A Summary of All Included Studies According to the Parameters of the Laser They Used, Their Complementary Techniques, and Their Outcomes

Author(s), Year	Number of Patients	Type of Laser	Parameters					Complementary Techniques	Outcomes
			Wave- Length	Emission Mode	Average Power	Fiber Tip Diameter	Exposure Time		
Dalaei Moghadam et al, 2021 ¹⁷	90; Root: 98	Diode	940 nm	Pulsed	2 W	200 µm	3 × 20 s	Preliminary conventional chemomechanical preparation	Laser aided in periapical healing, but it was not statistically significant ($P > 0.05$).
Shaheed et al, 2020 ³²	40	Er, Cr: YSGG	2780 nm	N/A	1.25 W 1 W	Coronal: 320 µm Apical and middle: 200µm	2 × (3 × 1-2 mm/s)	Preliminary conventional chemomechanical preparation. The laser was used twice, one time for smear layer removal, and the other time for disinfection	After 6 months, 97.5% of lesions had successful outcomes (80% healed, 17.5% healing)
Masilionyte et al, 2018 ³³	46	Diode	940 nm	CW	1-1.3 W	200 µm	4 × 2 mm/s	Preliminary conventional chemomechanical preparation	Laser-assisted cleaning of root canals was a reliable method comparable to conventional ones. Additionally, it led to faster healing of periapical lesions. However, laser application did not improve periapical index of healing significantly ($P = 0.22$)
Karakov et al, 2017 ³⁵	84; Canals: 88	Diode	670-690 nm	Pulsed	0.75 W	N/A	120 s	Preliminary conventional chemomechanical preparation + prior stirring of the photosensitizer with a hand file	Laser irradiation enhanced the recovery process of apical bone
Martins et al, 2014 ³⁸	43	Er, Cr: YSGG	2780 nm	Pulsed	0.75 W 1.25 W	RFT: 270 µm RFT: 320 µm	4 × 2 mm/s	Preliminary conventional chemomechanical preparation	Laser-assisted protocol of root canal cleaning is as effective as conventional methods. Laser irradiation did not affect healing of periapical lesion healing ($P = 0.11$)
Martins et al, 2013 ³⁴	36	Er, Cr: YSGG	2780 nm	pulse	0.75 W 1.25 W	270 µm 320 µm	4 × 2 mm/s (15 s rest)	In addition to standard mechanical preparation, teeth were prepared with saline solution and irradiated with Er, Cr: YSGG laser in the first and second appointment, respectively, four times each, moving at 2 mm/s from apical to coronal	Teeth treated with laser therapy produced results comparable to those of the control group, displaying statistically significant reductions in PAI scores ($P < 0.05$), but the difference between PAI of groups was not significant ($P = 0.38$)
Garcez et al, 2008 ³⁶	15	Diode	660 nm	N/A	0.04 W	200 µm	240 s	All teeth were prepared with preliminary chemomechanical therapy + final irrigation with EDTA 17% and PBS solution Study: photosensitizer solution was injected and remained for 2 minutes + laser activation + irrigation with sterile saline	After 6 months follow-up control group (5 teeth) showed a 46% reduction in lesion size, while in the study group (10 teeth) this reduction recorded as 68%.
Koba et al, 1999 ³⁷	38; Teeth: 44	Nd: YAG	N/A	Pulsed	1 W	320 µm	1 s 15 pps	Control: Each tooth crown and surrounding area were disinfected with iodine 5% and alcohol 70% + Preliminary conventional chemomechanical preparation with 5% NaOCl and H_2O_2 Study: Each tooth crown and surrounding area were disinfected with iodine 5% and alcohol 70% + Preliminary conventional chemomechanical preparation with 5% NaOCl and H_2O_2 + Laser activation when the tip of the laser reaches the apical seat	After 3 months of follow-up: In the laser group, 10 lesions were healed, and 12 lesions remained unchanged, but in the control group, 5 lesions were healed, and 17 lesions remained unchanged. After 6 months of follow-up: In the laser group, 12 lesions were healed, and 10 lesions remained unchanged, but in the control group, 6 teeth lesions were healed, and 16 lesions remained unchanged. These results did not show significant differences between the two groups.

Table 3. Risk of Bias Within Studies

Items	Koba et al, 1999 ³⁷	Garcez et al, 2008 ³⁶	Martins et al, 2013 ³⁴	Martins et al, 2014 ³⁸	Karakov et al, 2017 ³⁵	Dalaei Moghadam et al, 2021 ¹⁷
Random sequence generation	?	?	+	+	?	+
Allocation concealment	?	?	+	+	?	+
Blinding of participants and personnel	?	-	+	+	?	+
Blinding of outcome assessment	?	?	+	+	?	+
Incomplete outcome data	-	?	+	+	?	-
Selective reporting	-	-	+	+	-	-
Other bias	?	-	+	+	-	-

+ Low risk of bias, - high risk of bias, ? unclear risk of bias.

root, and root ankylosis.⁴⁵ Additionally, in Jyotsna and colleagues' study, it was reported that intra-canal laser irradiation effectively eliminates the bacteria present beyond the apex, and it is more effective when the size of the periapical preparation is smaller ($P=0.004$).⁴⁶

Most of the studies included in this review used plain periapical radiographs for the initial diagnosis of periapical lesions and evaluation of healing over the follow-up period. Only Dalaei Moghadam et al used CBCT, which shows buccolingual dimensions of the periapical lesion in addition to mesiodistal and apicocoronal dimensions that are displayed in plain radiographs and, therefore, is preferred.¹⁷

Some researchers believe that the mechanism of action of lasers in killing bacteria is photochemical, meaning that killing bacteria is one of the characteristics of laser light. However, it has been demonstrated that the heat produced by laser light is the leading cause of disinfection because when the heat produced by laser irradiation was controlled, lasers failed to kill bacteria.⁴⁷

It should be noted that in all studies included in this review, the conventional mechanical preparation of root canals was executed. Usual irrigating solutions, most commonly NaOCl, were used in all studies too. Only in Martins and colleagues' studies,^{34,38} no chemical antibacterial irrigation was used, and root canals were only washed with saline. Concerning the safety issues of potent chemical irrigators, such as NaOCl and hydrogen peroxide, it seems reasonable that safer treatment modalities with equal or higher success rates are suggested.

More clinical studies are needed to make firm conclusions about the efficiency of lasers in treating teeth with apical periodontitis; however, the current systematic review suggests that lasers could be a more prosperous and safer option for managing this condition.

The goal of this systematic review was to summarize the current literature on the subject of periapical lesion healing following the implementation of lasers in RCT so that clinicians and researchers can use the findings of this study to treat patients or conduct research projects.

Conclusion

According to the current evidence, lasers might be a

potential adjunctive tool in treating periapical lesions. It can accelerate and improve bone healing in the periapical region. However, there is limited evidence regarding this issue, and further investigation is recommended.

Authors' Contribution

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Competing Interests

All authors declare that they have no competing interests.

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