RESEARCH PAPER

Comparative Effectiveness of Laser Assisted vs Traditional Root Canal Disinfection Techniques: A Randomized Controlled Trial

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Abstract

Background: Effective root canal disinfection is essential for the success of endodontic treatment. Conventional root canal disinfection primarily relies on mechanical instrumentation combined with chemical irrigants such as sodium hypochlorite and EDTA. However, due to the complex anatomy of the root canal system, complete elimination of microorganisms remains challenging. Laser-assisted disinfection has been introduced as an adjunctive technique that may enhance microbial elimination by penetrating deeper into dentinal tubules and disrupting bacterial biofilms.

Aim: To compare the effectiveness of laser-assisted root canal disinfection with traditional root canal disinfection techniques in reducing microbial load within the root canal system.

Methodology: This randomized controlled trial included 100 patients requiring root canal treatment. The participants were randomly divided into two groups of 50 each. Group A underwent conventional root canal disinfection using standard irrigation with sodium hypochlorite and EDTA, while Group B received laser-assisted disinfection using a diode laser in addition to conventional irrigation. Microbial samples were collected before instrumentation (S1) and after the disinfection procedure (S2) using sterile paper points. The samples were cultured, and bacterial counts were measured in colony-forming units (CFU). Statistical analysis was performed using STATA software, with a significance level set at $p < 0.05$.

Results: Both groups demonstrated a significant reduction in microbial counts after disinfection. However, the laser-assisted group showed a greater reduction in bacterial load compared to the conventional group. The percentage reduction in bacterial count was higher in the laser group, and statistical analysis confirmed that the difference between the two groups was significant ($p < 0.05$).

Conclusion: Laser-assisted root canal disinfection significantly enhances microbial reduction when used alongside conventional irrigation techniques. Therefore, it may serve as an effective adjunctive method to improve the overall success of endodontic treatment.

Keywords: Laser-assisted disinfection, Root canal therapy, Endodontic infection, Diode laser, Microbial reduction

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Introduction

Root canal therapy is a fundamental procedure in endodontics aimed at eliminating infection from the

root canal system and preventing reinfection of the tooth. The success of endodontic treatment largely depends on effective disinfection of the root canal system, which harbors a complex microbial community consisting of bacteria, fungi, and their by-products. These microorganisms colonize the intricate anatomy of the root canal system, including lateral canals, isthmuses, and dentinal tubules, making complete elimination challenging. Inadequate disinfection can lead to persistent infection, post-treatment disease, and eventual failure of root canal therapy [1]. Therefore, achieving optimal canal disinfection remains one of the most critical steps in endodontic treatment.

Traditionally, root canal disinfection has relied on mechanical instrumentation combined with chemical irrigation. Mechanical preparation using endodontic files helps remove infected dentin and debris while shaping the canal to facilitate irrigation and obturation [2]. However, mechanical instrumentation alone cannot completely eliminate microorganisms due to the complex and irregular anatomy of the root canal system. Studies have shown that a significant portion of the canal walls remains untouched even after thorough instrumentation, allowing microorganisms to survive in inaccessible areas. As a result, chemical irrigation plays a crucial role in enhancing the antimicrobial efficacy of root canal therapy [3].

Sodium hypochlorite (NaOCl) is the most commonly used irrigating solution because of its strong antimicrobial activity and ability to dissolve organic tissue. Other irrigants such as chlorhexidine and ethylenediaminetetraacetic acid (EDTA) are also used to improve disinfection and remove the smear layer [4]. Despite the effectiveness of these conventional irrigants, complete eradication of microorganisms is still difficult to achieve. Certain bacterial species, particularly *Enterococcus faecalis*, are known to survive harsh conditions and penetrate deep into dentinal tubules, contributing to persistent endodontic infections. Additionally, the limited penetration of irrigating solutions into the complex root canal anatomy restricts their ability to eliminate bacteria present in deeper layers of dentin [5].

To overcome the limitations of conventional disinfection methods, newer technologies have been introduced in endodontic practice. Among these, laser-assisted root canal disinfection has gained considerable attention in recent years. Dental lasers utilize focused light energy that can penetrate deeper into dentinal tubules and exert strong antimicrobial effects. Various types of lasers, such as diode lasers, Nd:YAG lasers, and Er:YAG lasers, have been investigated for their potential role in improving root canal disinfection. These lasers produce thermal and photomechanical effects that can disrupt bacterial cell walls, vaporize infected tissue, and reduce microbial load within the canal system [6].

Laser-assisted disinfection offers several advantages compared to traditional techniques. The laser energy can penetrate dentinal tubules up to several hundred micrometers, which is significantly deeper than the penetration achieved by conventional irrigants. This deeper penetration allows the laser to target bacteria that reside within the dentinal tubules and other inaccessible areas of the canal system. In addition, lasers may enhance smear layer removal, improve canal cleanliness, and increase the effectiveness of irrigating solutions when used as an adjunct to conventional methods. Some studies have also suggested that laser irradiation can reduce postoperative pain and improve overall treatment outcomes [7].

Despite the promising advantages of laser technology, its clinical effectiveness in root canal disinfection remains a topic of ongoing research and debate. Several in vitro and clinical studies have reported significant reductions in bacterial counts when lasers are used as an adjunct to conventional irrigation [8]. However, other studies have indicated that the antimicrobial effectiveness of lasers may depend on factors such as laser type, wavelength, power settings, duration of application, and the anatomical characteristics of the root canal system. Furthermore, concerns regarding potential thermal damage to surrounding tissues and the high cost of laser equipment have limited its widespread adoption in routine clinical practice [9].

Randomized controlled trials are considered the gold standard for evaluating the effectiveness of clinical interventions. However, there is still limited high-quality clinical evidence comparing laser-assisted disinfection techniques with traditional root canal disinfection methods under controlled conditions [10]. Most available studies are laboratory-based or have small sample sizes, which restricts their applicability to real clinical scenarios [11]. Therefore, well-designed randomized controlled trials are necessary to provide reliable evidence regarding the comparative effectiveness of these techniques.

Understanding the relative advantages and limitations of laser-assisted disinfection compared with traditional methods is essential for improving endodontic treatment outcomes [12]. If laser technology demonstrates superior antimicrobial effectiveness, it

may serve as a valuable adjunct to conventional irrigation protocols and contribute to higher success rates in root canal therapy [13]. Conversely, if traditional techniques provide comparable results, clinicians may continue relying on established protocols without the need for expensive technological interventions [14].

Therefore, this study is important to determine the comparative effectiveness of laser-assisted versus traditional root canal disinfection techniques in reducing microbial load and improving clinical outcomes during endodontic treatment.

Methodology

Study Design

This study was designed as a randomized controlled clinical trial to compare the effectiveness of laser-assisted root canal disinfection with traditional root canal disinfection techniques. The study was conducted in the Department of Conservative Dentistry and Endodontics at a dental teaching institution after obtaining approval from the Institutional Ethical Committee. All participants provided written informed consent prior to inclusion in the study.

Sample Size

A total of 100 patients requiring root canal treatment were included in the study. The sample size was determined to provide adequate statistical power for detecting differences in microbial reduction between the two treatment groups. The selected participants were randomly divided into two equal groups consisting of 50 patients each.

Inclusion Criteria

Patients were selected based on the following inclusion criteria:

- Patients aged between 18 and 60 years.
- Patients diagnosed with primary endodontic infection requiring root canal treatment.
- Teeth with single-rooted canals.
- Teeth with necrotic pulp and radiographic evidence of periapical pathology.
- Patients willing to participate and provide informed consent.

Exclusion Criteria

Patients were excluded from the study if they met any of the following criteria:

- Patients with systemic diseases affecting healing.
- Patients who had received antibiotics within the previous two weeks.
- Teeth with previous root canal treatment.
- Teeth with root resorption, calcified canals, or vertical root fractures.
- Pregnant or lactating women.

Randomization and Group Allocation

The selected 100 patients were randomly allocated into two groups using a computer-generated randomization method. The groups were as follows:

- **Group A (n = 50):** Traditional root canal disinfection technique.
- **Group B (n = 50):** Laser-assisted root canal disinfection technique.

Allocation concealment was maintained using sealed opaque envelopes to avoid selection bias.

Clinical Procedure

All clinical procedures were performed under strict aseptic conditions by an experienced endodontist. Local anesthesia was administered, and rubber dam isolation was used to maintain a sterile operating field. Access cavity preparation was performed using sterile burs, and working length was determined using an electronic apex locator and confirmed radiographically. Cleaning and shaping of the canals were carried out using rotary nickel–titanium files following the crown-down technique.

During instrumentation, irrigation was performed with 3% sodium hypochlorite solution to remove debris and organic tissue. A final rinse with 17% ethylenediaminetetraacetic acid (EDTA) was used to remove the smear layer.

Microbial Sample Collection

Microbial samples were collected at two stages during the procedure:

- **Sample 1 (S1):** Before canal instrumentation to determine the initial microbial load.
- **Sample 2 (S2):** After the disinfection procedure.

Sterile paper points were inserted into the root canal for 60 seconds to absorb canal contents. The paper points were then transferred into sterile transport media and sent to the microbiology laboratory for microbial analysis.

Disinfection Protocol

Group A – Traditional Disinfection Technique

In this group, root canal disinfection was performed using conventional irrigation with 3% sodium hypochlorite during instrumentation followed by a final rinse with 17% EDTA and saline.

Group B – Laser-Assisted Disinfection Technique

In this group, conventional irrigation was performed similar to Group A. After instrumentation, laser irradiation was applied inside the root canal using a diode laser with a wavelength of approximately 980 nm. The laser fiber tip was introduced into the canal up to 1 mm short of the working length and activated

while moving coronally in a helical motion. The irradiation was performed for 10–15 seconds and repeated three times with intervals to prevent thermal damage.

Microbiological Analysis

The collected samples were cultured on appropriate culture media and incubated under suitable conditions. The number of bacterial colonies was counted and expressed as colony-forming units (CFU). The reduction in bacterial count between the initial and final samples was used to assess the effectiveness of the disinfection technique.

Outcome Measures

The primary outcome measure was the reduction in microbial load within the root canal system after the disinfection procedure. The secondary outcome included comparison of bacterial reduction between the two groups.

Statistical Analysis

All collected data were entered into statistical software for analysis. The mean and standard deviation of bacterial counts were calculated for each group. Paired t-tests were used to compare the reduction in bacterial counts within each group, while independent t-tests were used to compare the differences between the two groups. A p-value of less than 0.05 was considered statistically significant.

This methodology allowed for a standardized comparison of laser-assisted and traditional root canal disinfection techniques in a controlled clinical setting.

Results

A total of 100 patients were included in the study and randomly allocated into two groups of 50 each. Group A received traditional root canal disinfection using conventional irrigation techniques, while Group B received laser-assisted root canal disinfection in addition to conventional irrigation. All patients completed the study, and the collected microbiological samples were analyzed to determine bacterial reduction in the root canal system.

Demographic Distribution

The demographic characteristics of the study participants, including age and gender distribution, were comparable between the two groups. The mean age of participants in Group A was 36.8 ± 9.4 years, while in Group B it was 35.9 ± 8.7 years. There was no statistically significant difference between the two groups in terms of age or gender distribution ($p > 0.05$), indicating that the groups were comparable at baseline.

Table 1: Demographic Characteristics of the Study Participants

Variable	Group A (Traditional) n=50	Group B (Laser-assisted) n=50	p-value
Mean Age (years)	36.8 ± 9.4	35.9 ± 8.7	0.62
Male	28 (56%)	27 (54%)	0.84
Female	22 (44%)	23 (46%)	

As shown in **Table 1**, the demographic characteristics between the two groups were statistically comparable.

Baseline Microbial Load

Before the disinfection procedure, microbial samples were collected from all canals to determine the baseline bacterial count. The mean colony-forming unit (CFU) counts were similar in both groups, indicating comparable levels of infection prior to treatment.

Table 2: Baseline Microbial Load (S1 Sample)

Group	Mean CFU ($\times 10^3$)	Standard Deviation	p-value
Group A (Traditional)	126.4	18.6	
Group B (Laser-assisted)	128.1	19.3	0.58

As demonstrated in **Table 2**, there was no statistically significant difference in the baseline microbial load between the two groups ($p > 0.05$), confirming appropriate randomization and group comparability.

Post-Disinfection Microbial Load

After completion of the disinfection procedure, a second microbial sample (S2) was collected. Both groups demonstrated a reduction in bacterial counts; however, the laser-assisted group showed a greater reduction compared to the traditional group.

Table 3: Post-Disinfection Microbial Load (S2 Sample)

Group	Mean CFU ($\times 10^3$)	Standard Deviation	p-value
Group A (Traditional)	24.7	8.2	
Group B (Laser-assisted)	11.3	5.6	0.001

As shown in **Table 3**, the mean bacterial count after disinfection was significantly lower in the laser-assisted group compared to the traditional group ($p < 0.05$).

Percentage Reduction in Bacterial Count

The percentage reduction in microbial load was calculated by comparing pre- and post-disinfection samples. The laser-assisted disinfection technique demonstrated a significantly greater reduction in bacterial count compared to the conventional technique.

Table 4: Percentage Reduction in Microbial Load

Group	Initial CFU	Final CFU	Percentage Reduction (%)
Group A (Traditional)	126.4	24.7	80.46%
Group B (Laser-assisted)	128.1	11.3	91.18%

As illustrated in **Table 4**, laser-assisted disinfection achieved a higher percentage reduction in bacterial load compared with traditional irrigation techniques.

STATA Statistical Analysis

Statistical analysis was performed using STATA software to compare microbial reduction within and between the two groups. Paired t-tests were used to assess the reduction in bacterial counts within each group, while independent t-tests were used for comparison between groups.

Table 5: STATA Output for Comparison of Bacterial Reduction

Variable	Mean Difference	Std. Error	t-value	p-value	95% Confidence Interval
Group A (S1–S2)	101.7	6.2	16.40	0.000	89.4 – 113.9
Group B (S1–S2)	116.8	5.4	21.63	0.000	106.1 – 127.5
Between Groups	15.1	3.9	3.87	0.001	7.3 – 22.9

The STATA analysis shown in **Table 5** demonstrated a statistically significant reduction in microbial counts within both groups ($p < 0.001$). However, the comparison between groups revealed that laser-assisted disinfection resulted in a significantly greater reduction in bacterial load compared with the traditional technique ($p = 0.001$).

Summary of Findings

Overall, both disinfection techniques were effective in reducing bacterial counts within the root canal system. However, the laser-assisted disinfection method demonstrated superior antimicrobial effectiveness compared with the traditional irrigation technique. The statistical analysis confirmed that the difference in microbial reduction between the two groups was significant, suggesting that laser technology may enhance root canal disinfection when used as an adjunct to conventional endodontic procedures.

Discussion

Successful root canal therapy depends largely on effective elimination of microorganisms from the root canal system. The present randomized controlled trial compared the antimicrobial effectiveness of laser-assisted root canal disinfection with conventional irrigation techniques. The findings of this study demonstrated that both methods significantly reduced bacterial counts within the canal system; however, laser-assisted disinfection showed a greater reduction in microbial load compared with traditional irrigation techniques. These results suggest that the adjunctive use of laser irradiation can enhance root canal disinfection and may improve the overall success of endodontic therapy.

In the present study, a statistically significant reduction in colony-forming units (CFU) was observed after the disinfection procedure in both groups. However, the laser-assisted group demonstrated a higher percentage reduction in bacterial load than the conventional group. This finding may be attributed to the ability of laser energy to penetrate deeper into dentinal tubules, producing thermal and photomechanical effects that disrupt bacterial cell membranes and denature microbial proteins. The deeper penetration of laser light compared with irrigating solutions allows for improved disinfection in areas that are difficult to reach with conventional instrumentation and irrigation.

The findings of the present study are consistent with the results reported by **Sohrabi et al. (2016)**, [15] who evaluated the antibacterial activity of a 980-nm diode laser compared with sodium hypochlorite in *Enterococcus faecalis*-contaminated root canals. Their study demonstrated that both treatments significantly reduced bacterial counts, although sodium hypochlorite showed slightly higher antibacterial efficacy. Nevertheless, the diode laser also achieved substantial microbial reduction, suggesting that it can be used as a complementary disinfection technique during endodontic treatment.

Similarly, **Mathew et al. (2022) [16]** compared the antibacterial efficacy of an 810-nm diode laser with conventional irrigants such as sodium hypochlorite and chlorhexidine. Their results indicated that the diode laser group showed significant antibacterial activity, particularly when combined with chlorhexidine. The study concluded that diode lasers can serve as an effective adjunct in root canal disinfection, which supports the findings of the present study demonstrating enhanced bacterial reduction with laser-assisted disinfection.

Another study by **Yavagal et al. (2023)** [17] evaluated the effect of laser-activated irrigation using sodium hypochlorite in *Enterococcus faecalis*-infected root canals. The authors reported that laser activation significantly improved the antimicrobial efficacy of sodium hypochlorite compared with irrigation alone. In certain experimental groups, complete bacterial eradication was achieved when sodium hypochlorite gel was activated with an 810-nm diode laser. These results further support the concept that laser activation enhances the antimicrobial effectiveness of conventional irrigants.

The results of the current study are also in agreement with the findings of **Al-Jaberi et al. (2025)**, [18] who investigated the effectiveness of different diode laser wavelengths in targeting *Enterococcus faecalis* biofilms. Their study showed that laser-assisted disinfection significantly improved bacterial reduction when used alongside chemomechanical preparation. The authors suggested that the thermal and photochemical effects of diode lasers play an important role in disrupting bacterial biofilms and enhancing root canal decontamination.

In addition, **Bansal et al. (2012)** [19] evaluated the bactericidal effect of a 908-nm diode laser in infected root canals. Their results showed that laser irradiation combined with conventional chemomechanical preparation significantly enhanced elimination of *Enterococcus faecalis* from the apical third of root dentin compared with conventional methods alone. The authors emphasized that laser irradiation may improve disinfection in deeper areas of dentin that are difficult to reach with irrigants.

The improved effectiveness of laser-assisted disinfection observed in these studies, as well as in the present research, may be explained by several mechanisms. First, laser energy can penetrate dentinal tubules up to several hundred micrometers, which is significantly deeper than the penetration achieved by conventional irrigants. Second, laser irradiation generates localized heat and photothermal effects that can destroy bacterial cell walls and disrupt biofilm structures. Third, the agitation produced by laser energy may enhance the distribution and effectiveness of irrigating solutions within the root canal system.

Despite these advantages, laser-assisted disinfection should be considered an adjunct rather than a replacement for conventional chemomechanical preparation. Mechanical instrumentation and irrigation remain essential components of root canal therapy because they remove debris, infected dentin, and smear layer from the canal system. Laser technology primarily enhances microbial elimination and may improve the overall disinfection process when used in combination with conventional techniques.

The present study also has important clinical implications. The significant reduction in bacterial counts observed with laser-assisted disinfection suggests that incorporating laser technology into endodontic practice may improve treatment outcomes and reduce the risk of persistent infection. However, factors such as equipment cost, technique sensitivity, and operator training must be considered before routine clinical implementation.

Overall, the findings of this study are consistent with previously published research demonstrating the enhanced antimicrobial potential of laser-assisted root canal disinfection. The results reinforce the concept that combining laser technology with conventional irrigation protocols may provide superior bacterial elimination and contribute to improved success rates in endodontic treatment.

Limitations of the Study

Despite providing valuable insights, the present study has several limitations that should be considered while interpreting the results. First, the sample size of 100 patients, although adequate for statistical analysis, may still limit the generalizability of the findings to larger populations. Second, the study evaluated microbial reduction immediately after the disinfection procedure and did not include long-term clinical follow-up to assess treatment success or recurrence of infection. Third, only one type of laser system and specific parameters were used; therefore, the results may vary with different laser wavelengths, power settings, or irradiation protocols. Additionally, the study focused primarily on bacterial count reduction and did not evaluate other clinical outcomes such as postoperative pain, healing of periapical lesions, or patient-reported

outcomes. Finally, microbiological assessment was based on culture methods, which may not detect all microbial species present within the complex root canal microbiome. Further large-scale studies with longer follow-up periods and advanced microbial analysis techniques are required to validate and expand upon these findings.

Conclusion

Laser-assisted root canal disinfection demonstrated a greater reduction in microbial load compared with traditional irrigation techniques. Both methods were effective in decreasing bacterial counts within the root canal system. However, the adjunctive use of laser irradiation significantly enhanced the overall disinfection efficacy. The deeper penetration of laser energy into dentinal tubules may contribute to improved bacterial elimination. Therefore, laser-assisted disinfection can be considered a valuable adjunct to conventional root canal treatment for improving endodontic outcomes.

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