ORAL HEALTH

# LASER APPLICATION FOR ROOT CANAL DISINFECTION DURING ENDODONTIC THERAPY

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## Abstract

Effective cleaning, irrigation, and sterilization of root canals are essential criteria for successful endodontic treatment of infected root canal systems. Conventional chemomechanical procedures for root canal debridement cannot reliably ensure complete disinfection of the entire endodontic space, particularly in anatomically complex areas such as the apical delta and accessory canals. Following mechanical instrumentation, approximately 35% of the dentinal walls remain covered with bacterial biofilm, and even after the application of antimicrobial agents, root canals are not completely disinfected. Considering that sterility of the root canal system is a key factor for successful treatment of apical periodontitis, continuous efforts have been made to identify more effective disinfection methods. Over the past decade, the use of lasers for root canal disinfection and cleaning has increased significantly, although their full potential is still under investigation.

The aim of this study was to explain the fundamental principles of laser–tissue interaction within root canals and to compare laser-assisted endodontic treatment with conventional irrigation using 3% sodium hypochlorite and ultrasonic activation in teeth diagnosed with chronic apical periodontitis. This in vivo study was conducted on 60 teeth diagnosed with chronic apical periodontitis, which were randomly divided into three groups. Mechanical preparation of the root canals was performed using a standardized protocol with nickel–titanium rotary instruments, followed by continuous irrigation with 2.5% sodium hypochlorite (NaOCl) in combination with 17% ethylenediaminetetraacetic acid (EDTA). After completion of chemomechanical preparation, the following disinfection protocols were applied: (1) 2.5% NaOCl in combination with EDTA, (2) 2.5% NaOCl with sonic activation using an endoactivator, (3) Application of a diode laser for sterilization of the root canal system. Treatment effectiveness was assessed through radiographic evaluation of the periapical status. Radiographic examinations were performed at three-time intervals: before treatment, at 3 months, and at 6 months follow-up. The results of this study demonstrated that all applied disinfection protocols led to a reduction in periapical lesions: over the observation period. However, the most pronounced decrease in Periapical Index (PAI) values was observed in the group treated with laser-assisted disinfection.

ОРАЛНО ЗДРАВЈЕ

# ПРИМЕНА НА ЛАСЕРИ ЗА ДЕЗИНФЕКЦИЈА НА КОРЕНСКИ КАНАЛИ ВО ТЕК НА ЕНДОДОНТСКА ТЕРАПИЈА

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## Извадок

Добрата обработка, иригацијата и стерилизација на коренските канали се важни предуслови за успешен ендодонтски третман кај инфицирани коренски канали. Традиционалните процедури за хемиско-механичко чистење на коренскиот канал не можат со сигурност да обезбедат комплетна успешна дезинфекција на целиот ендодонтски простор, особено во областите на апикалната делта, како и акцесорните канали. По механичката инструментација, околу 35% од ѕидот на дентинот останува покриен со бактериски биофилм, но и по примена на антимикробни агенси коренските канали не се целосно дезинфицирани. Имајќи предвид дека за успешен ендодонтски третман на апикалните пародонтити клучен фактор е стерилноста на каналниот систем, се прават постојани напори од страна на експертите да се најде најуспешен начин за тоа. Последнава декада употребата на ласери за дезинфекција и чистење на коренските канали е интензивирана, а нејзиниот потенцијал сè уште се истражува. Целта на овој труд беше да се објаснат основните принципи на интеракција на ласерите со ткивата во коренските канали, да се спореди ендодонтскиот третман со помош на ласер, наспроти конвенционалната употреба на 3% натриум хипохлорит и ултразвучната обработка на каналите кај заби со хроничен апикален периодонтитис. Испитувањето го реализиравме во in vitro услови на 60 заби со дијагностициран хроничен пародонтитис кои ги поделивме во три групи. Механичката подготовка на коренските канали ја спроведувавме со стандардизиран протокол на инструментализација со никел-титаниумски ротирачки инструменти, проследено со континуирана иригација со 2,5% натриум хипохлорит (NaOCl) во комбинација со 17% етилендиаминтетраоцетна киселина (ЕДТА). По завршување на механичко-медикаментозната обработка, ги применивме следните протоколи за дезинфекција: 1. 2,5% NaOCL во комбинација со ЕДТА, 2. 2,5% NaOCL во комбинација со ендоактиватор (UltraX, Eighteeth), 3. Употреба на соодветен мекоткивен ласер за стерилизација на ендодонтски третираните коренски канали. Ефективноста на третманот ја проценувавме преку радиографска анализа на периапикалниот статус, а радиографските снимки ги изработувавме во три временски интервали: пред почетокот на третманот, по 3 месеци, по 6 месеци. Резултатите од ова истражување покажаа дека сите применети протоколи за дезинфекција на коренско-каналниот систем доведуваат до намалување на периапикалните лезии во текот на периодот на следење. Сепак, најизразено намалување на PAI (Periapical Index) вредностите беше забележано кај групата третирана со ласерска дезинфекција.

## Introduction

Endodontic therapy represents a fundamental discipline in dentistry, primarily aimed at preserving the natural tooth through elimination of infection from the root canal system and prevention of reinfection. Apical periodontitis is an inflammatory response of the periapical tissues, most commonly caused by microbial infection of the pulp space, in which microorganisms and their by-products play a crucial role in the pathogenesis of the disease[1,2].

Microbiological investigations have demonstrated that root canal infections are polymicrobial in nature and predominantly composed of anaerobic bacteria organized in biofilms. Biofilms represent complex microbial communities that provide protection to bacteria and significantly increase their resistance to antimicrobial agents, thereby contributing to the persistence of infection and treatment failure[3,4].

The foundation of endodontic treatment relies on chemomechanical preparation of the root canal system, which includes mechanical instrumentation combined with the use of antimicrobial irrigants. Sodium hypochlorite (NaOCl) is considered the gold standard irrigant due to its potent antimicrobial and proteolytic properties[5]. However, despite its effectiveness, NaOCl does not ensure complete elimination of microorganisms, particularly in the deeper layers of dentin and within anatomically complex regions of the root canal system 6. This limitation is largely attributed to relatively high surface tension of NaOCl, which restricts its ability to penetrate into narrow isthmuses, lateral canals, and dentinal tubules, preventing adequate contact with bacteria residing in these areas. Furthermore, the capillary forces within the intricate microchannel network of dentin are insufficient to draw the solution deeply enough to exert a meaningful antimicrobial effect, leaving residual biofilm and necrotic tissue beyond the reach of conventional irrigation.

The complex anatomy of the root canal system—including lateral canals, isthmuses, and apical deltas—poses a significant challenge for complete disinfection. Studies have shown that a considerable portion of the canal walls remains untouched after mechanical preparation, allowing the survival of microorganisms[7]. Additionally, the formation of the smear layer reduces the penetration and effectiveness of irrigants[8].

Contemporary endodontic approaches include the activation of irrigants using ultrasonic and sonic systems in order to enhance their penetration and hydrodynamic behavior. These techniques have demonstrated improved efficacy, particularly in the apical third and in anatomically complex regions; however, they still do not achieve complete sterilization of the root canal system[5, 6, 9,37].

From the early 1990s, laser-activated irrigation has increasingly been introduced as an adjunctive method for disinfection in endodontics. Lasers emit coherent and monochromatic light energy that interacts with biological tissues through photothermal and photochemical mechanisms, resulting in microbial

destruction and protein denaturation[10].

One of the principal advantages of laser application is its ability to penetrate deeply into dentinal tubules, where conventional irrigants have limited effect. Studies have demonstrated that laser therapy can reduce more than 99% of bacterial load within the root canal system and is particularly effective against resistant species such as Enterococcus faecalis [11,12].

Recent clinical and systematic studies have confirmed that laser therapy, especially when combined with sodium hypochlorite, leads to a significant reduction in bacterial load and enhances root canal disinfection. This combined approach demonstrates superior outcomes compared to conventional methods alone [13]. Furthermore, randomized clinical trials suggest that diode laser application may contribute to improved periapical healing during follow-up periods[14].

Despite these advantages, systematic reviews indicate that laser therapy cannot replace conventional chemomechanical preparation but should be considered an adjunctive method that enhances the effectiveness of root canal disinfection[15]. Additional well-designed clinical studies with standardized protocols and long-term follow-up are required to establish its definitive clinical efficacy[16].

The aims of this study were:

- to explain the fundamental principles of laser–tissue interaction within the root canal system;
- to compare laser-assisted endodontic treatment with conventional irrigation using 3% sodium hypochlorite and ultrasonic activation in teeth diagnosed with chronic apical periodontitis;
- to radiographically evaluate, over a follow-up period of 3 and 6 months, the reduction of periapical lesions after the application of three different irrigation and disinfection techniques in root canal therapy.

## Materials and methods

To achieve the objectives of this study, the investigation was conducted under in vivo conditions on a total of 60 teeth diagnosed with chronic apical periodontitis. The study was carried out at the Clinic for Restorative Dentistry and Endodontics,

Faculty of Dentistry – Skopje, Ss. Cyril and Methodius University in Skopje during a period of 18 months.

Inclusion Criteria

- Permanent teeth with clinical and radiographic diagnosis of chronic apical periodontitis
- Teeth with necrotic pulp
- Presence of a periapical radiolucent lesion on radiographic examination
- Single-rooted or multi-rooted teeth with negotiable root canals.

Exclusion Criteria

- Patients who had received antibiotic therapy within the previous 3 months

- Teeth with previous endodontic treatment
- Teeth with vertical root fractures
- Patients with systemic diseases that could affect the healing process
- Third molars were not included.

Following initial selection, the teeth were randomly assigned into three experimental groups (n = 20), according to the applied irrigation and disinfection protocol.

Clinical Endodontic Protocol

The tooth was isolated with a rubber dam, and a straight-line access cavity was prepared to expose all canal orifices. The canals were located to confirm patency prior to rotary instrumentation.

Orifice shaping was performed with ProTaper SX to eliminate coronal interferences and improve straight-line access to the apical third.

Working length was determined using an apex locator (iPexII), with a size #10 or #15 file placed and confirmed via periapical radiograph. The working length was set at the point of apical constriction, approximately 0.5–1 mm short of the radiographic apex.

A reproducible glide path was confirmed to full working length using a #15–#20 hand file, reducing the risk of file separation and canal transportation in the curved molar canals.

A sequential crown-down technique was employed. Each file was used with a light in-and-out pecking motion (2–3 mm amplitude), with no more than 2–3 seconds of continuous engagement per file:

**Table 1.** List of files, tip size and function

| File | Tip size (D0) | Function |
|---|---|---|
| S1 (Shaping 1) | 0.17 mm | Coronal/middle third shaping |
| S2 (Shaping 2) | 0.20 mm | Extended shaping toward apical third |
| F1 (Finishing 1) | 0.20 mm | First apical finishing file |
| F2 (Finishing 2) | 0.25 mm | Second apical finishing file |
| F3 (Finishing 3) (as needed) | 0.30 mm | Used for wider canals |

Recapitulation with a #10–#15 hand file was performed between each rotary file to maintain patency and remove debris. Irrigation was carried out after every instrument change. The final apical size was selected based on the initial canal diameter and tactile resistance at working length. Narrower, curved canals were finished at F1–F2, while wider or straighter canals were taken to F3 or beyond.

This was accompanied by continuous irrigation with 2.5% sodium hypochlorite (NaOCl) in combination with 17% ethylenediaminetetraacetic acid (EDTA).

Sodium hypochlorite (NaOCl), 2.5–5.25%, (10–20 mL per canal) was used as the primary irrigant, delivered with a side-vented needle positioned 2–3 mm short of working length, using slow, passive delivery to avoid apical extrusion.

A 17% EDTA solution was applied for 1 minute in the final stage to remove the smear layer, followed by a final NaOCl flush. A final rinse with saline or sterile water was performed to neutralize residual chemicals before obturation.

After accomplishment of chemomechanical preparation, the following disinfection protocols were applied:

Group 1 – Conventional Irrigation

Irrigation with 2.5% sodium hypochlorite (NaOCl) combined with 17% EDTA was performed to remove the smear layer and enhance chemical disinfection of the root canal system.

Group 2 – Activated Irrigation

Irrigation with 2.5% NaOCl activated using an EndoActivator (UltraX, Eighteeth) was applied to improve irrigant penetration and fluid dynamics within complex anatomical areas, including lateral and accessory canals.

Group 3 – Laser Disinfection

Root canal disinfection was performed using a soft-tissue diode laser, (Woodpecker – Smart Laser Blue) applied according to the manufacturer's protocol, aiming to achieve photothermal reduction of microorganisms and disruption of the bacterial biofilm within the root canal system.

Intracanal Medication and Obturation

Following disinfection, the canals were dried with sterile paper points and filled with an inter-appointment calcium hydroxide [$Ca(OH)_2$]-based intracanal medicament, which was left *in situ* for 15 days. The access cavity was temporarily sealed with glass ionomer cement.

In the absence of clinical symptoms, a second visit was scheduled. During this appointment, the $Ca(OH)_2$ paste was removed using 5 mL of 2.5% NaOCl and a Hedström file. The canals were then dried with sterile paper points and obturated using gutta-percha and AH26 sealer (Dentsply, Konstanz, Germany) employing the single-cone technique.

A glass ionomer base was placed over the obturation, followed by a composite restoration using a total-etch adhesive technique.

Radiographic Evaluation

Treatment effectiveness was assessed by radiographic evaluation of the periapical status. Radiographs were obtained at three-time intervals:

- before treatment (baseline),
- after 3 months,
- after 6 months.

Changes in the periapical region were evaluated based on the reduction of periapical radiolucency using the Periapical Index (PAI) (37).

**Table 2.** Periapical Index (PAI) Scoring System

| PAI Score | Radiographic Findings |
|---|---|
| 1 | Normal periapical structures |
| 2 | Small changes in bone structure |
| 3 | Changes in bone structure with some mineral loss |
| 4 | Well-defined radiolucent area |
| 5 | Severe periodontitis with exacerbating features |

## Results

Statistical analysis

In this clinical study, a total of 60 teeth with periapical lesions were analyzed, divided into three groups according to the applied root canal disinfection protocol. Each group consisted of 20 teeth.

Radiographic evaluation was performed using the Periapical Index (PAI) before treatment, at 3 months, and at 6 months. All groups showed a gradual reduction in PAI values during the follow-up period, indi-

**Table 3.** List of files, tip size and function

| Group | Baseline Mean (± SD) | Mean at 3 Months (± SD) | Mean at 6 Months (± SD) | p-value (ANOVA) |
|---|---|---|---|---|
| Conventional irrigation | 4.15 ± 0.72 | 3.40 ± 0.65 | 2.55 ± 0.60 | <0.001* |
| Sonic-activated irrigation (UltraX) | 4.20 ± 0.70 | 3.10 ± 0.58 | 2.05 ± 0.52 | <0.001* |
| Laser-assisted disinfection | 4.25 ± 0.68 | 2.85 ± 0.55 | 1.60 ± 0.48 | <0.001* |

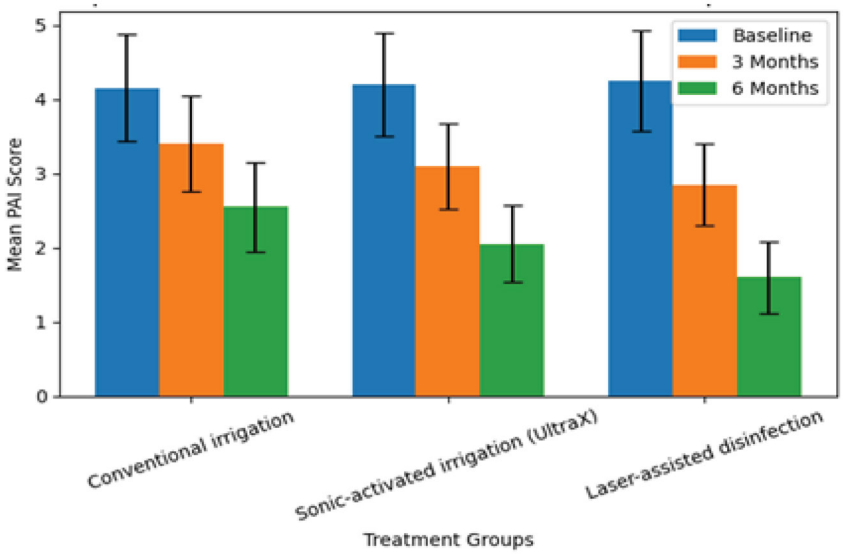



**Figure 1:** Comparison of PAI score reduction in treatment groups during the evaluation period

cating progressive periapical healing.

As shown in Table 1 and Figure 1, all three groups demonstrated a continuous decrease in mean PAI values throughout the evaluation period. The most pronounced reduction in PAI values was observed in the laser-assisted disinfection group. The average PAI in this group decreased from 4.25 ± 0.68 at baseline to 2.85 ± 0.55 at 3 months and 1.60 ± 0.48 at 6 months.

In the sonic-activated irrigation group, the average PAI decreased from 4.20 ± 0.70 to 3.10 ± 0.58 at 3 months and 2.05 ± 0.52 at 6 months.

The conventional irrigation group also showed a reduction in PAI values, although to a lesser extent, from 4.15 ± 0.72 at baseline to 3.40 ± 0.65 at 3 months and 2.55 ± 0.60 at 6 months.

At baseline, no statistically significant differences were observed between the groups ($p > 0.05$), indicating homogeneity. At 3 months, a trend of decreasing PAI values was observed in all groups, with the most pronounced reduction seen in the laser group.

At 6 months, the laser group showed the lowest mean PAI value (1.60 ± 0.48), followed by the sonic-activated irrigation group (2.05 ± 0.52), while the highest value was observed in the

**Table 4.** Clinical outcomes at 6 months

| Group | Total Teeth | Complete Healing | Partial Healing | Unsuccessful Healing |
|---|---|---|---|---|
| Conventional irrigation | 20 | 9 (45%) | 7 (35%) | 4 (20%) |
| Sonic-activated irrigation (UltraX) | 20 | 12 (60%) | 6 (30%) | 2 (10%) |
| Laser-assisted disinfection | 20 | 15 (75%) | 4 (20%) | 1 (5%) |

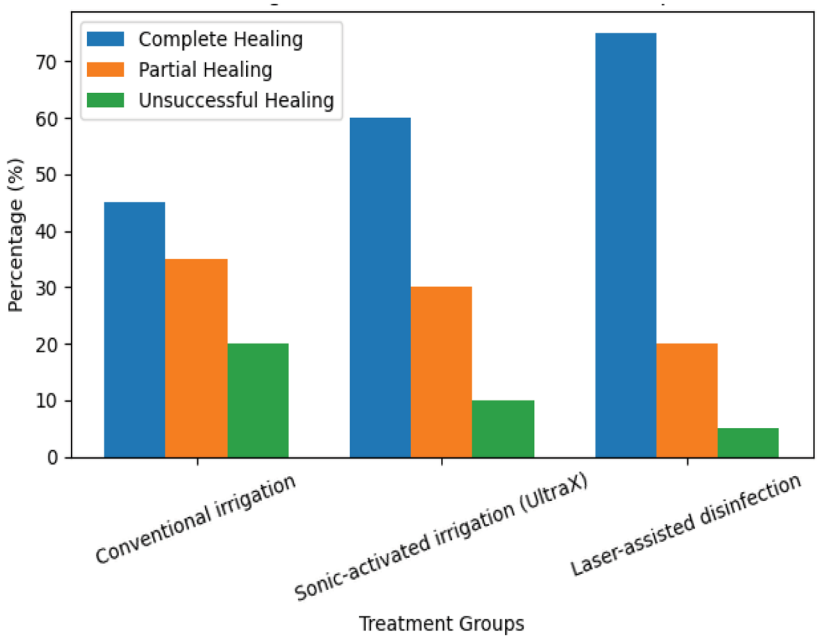



**Figure 2:** Healing outcomes across treatment groups

conventional irrigation group (2.55 ± 0.60). ANOVA analysis revealed statistically significant differences between groups ($p < 0.001$).

Clinical evaluation at 6 months (Table 2, Figure 2) indicated that:

- The highest rate of complete healing was observed in the laser group (75%).
- Sonic-activated irrigation achieved 60% complete healing.
- Conventional irrigation showed the lowest rate (45%).

Regarding unsuccessful cases, the highest rate was observed in the conventional group (20%), while the lowest was in the laser group (5%). Chi-square test revealed a statisti-

**Table 5.** List of files, tip size and function

| PAI Score | Conventional Irrigation (n=20) | Sonic-activated Irrigation (UltraX) (n=20) | Laser-assisted Disinfection (n=20) |
|---|---|---|---|
| PAI 1 | 5 (25%) | 7 (35%) | 10 (50%) |
| PAI 2 | 4 (20%) | 5 (25%) | 5 (25%) |
| PAI 3 | 5 (25%) | 4 (20%) | 3 (15%) |
| PAI 4 | 4 (20%) | 3 (15%) | 1 (5%) |
| PAI 5 | 2 (10%) | 1 (5%) | 1 (5%) |

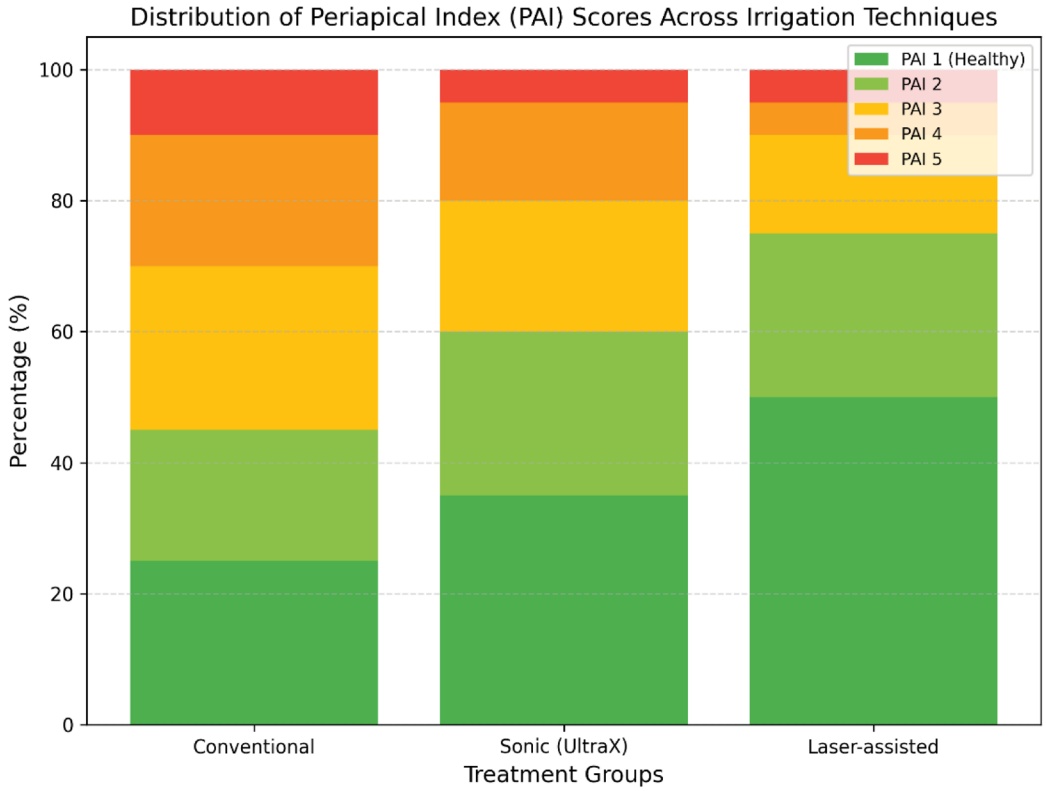



**Figure 3:** Distribution of PAI scores at 6 months

**Table 5.** Intergroup comparison of PAI values at 6 months

| Group | Mean ± SD | Difference vs. Conventional | p-value (post-hoc Tukey) |
|---|---|---|---|
| Conventional irrigation | 2.55 ± 0.60 | – | – |
| Sonic-activated irrigation (UltraX) | 2.05 ± 0.52 | ↓ 0.50 | 0.01* |
| Laser-assisted disinfection | 1.60 ± 0.48 | ↓ 0.95 | <0.001* |

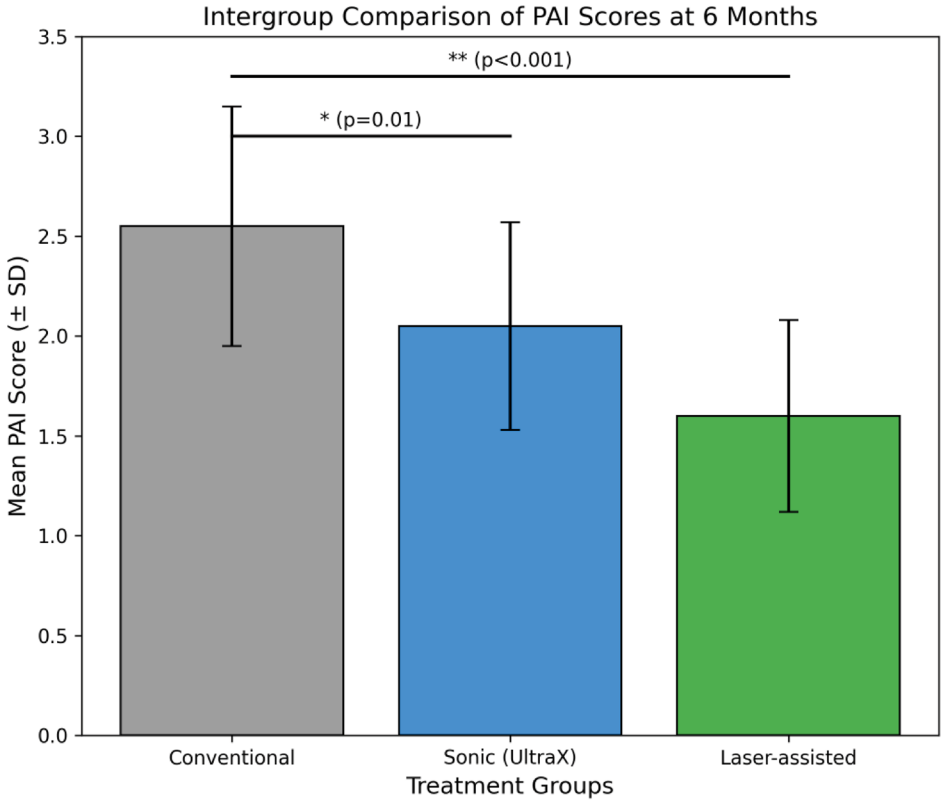



**Figure 4:** Intergroup comparison of PAI values at 6 months

cally significant difference between the groups ($\chi^2$ = 6.85; p = 0.03), indicating that the choice of disinfection method significantly affects treatment outcomes.

Post-hoc analysis (Tukey test) demonstrated that:

- Sonic-activated irrigation resulted in significantly better outcomes compared to conventional irrigation (p = 0.01).
- Laser-assisted disinfection was superior to both other groups (p < 0.001).
- These results indicate a higher effectiveness of disinfection protocols using laser-assisted therapy.

## Discussion

The results of this study demonstrated that all three applied root canal disinfection protocols—conventional irrigation, sonic activation, and laser-assisted disinfection—led to a measurable reduction in periapical lesions in the follow-up period. How-

ever, the most pronounced reduction in Periapical Index (PAI) values was observed in the laser-assisted disinfection group, suggesting a superior antimicrobial efficacy of laser application in endodontic therapy[17,18].

The enhanced outcomes in the laser group can be attributed to the specific mechanisms of laser-tissue interaction. Diode and other endodontic lasers generate photothermal energy that induces direct bacterial cell destruction and enables deeper penetration into dentinal tubules, where residual microorganisms often persist despite conventional chemomechanical preparation[19,20]. This deeper penetration is particularly relevant for complex root canal anatomies, including apical deltas and accessory canals, which are frequently inaccessible to standard irrigants and ultrasonic activation[21,22].

Furthermore, laser activation improves irrigant dynamics within the root canal system by inducing microstreaming and cavitation-like effects, thereby enhancing the circulation of disinfecting solutions into lateral and accessory canals. This contributes to more effective elimination of the bacterial biofilm, which is critical for the resolution of periapical inflammation and subsequent bone healing[23,24].

The sonic-activated irrigation group also demonstrated superior outcomes compared to conventional irrigation. This improvement can likely be explained by enhanced fluid dynamics, allowing better irrigant penetration and removal of smear layer and microbial biofilm, particularly in the apical third of the root canal[25,26]. The observed differences between sonic activation and conventional irrigation align with previous studies that reported increased bacterial reduction and improved PAI outcomes when mechanical energy is applied to the irrigant[27,28].

Despite these positive results, it is important to emphasize that laser-assisted disinfection should not be considered a replacement for conventional chemomechanical root canal preparation. Instead, it should be viewed as an adjunctive technique that enhances the overall effectiveness of endodontic therapy[29,30]. The combination of thorough mechanical instrumentation, chemical irrigation, and laser or sonic activation appears to offer the most predictable clinical outcomes in teeth affected by chronic apical periodontitis.

Several limitations of the present study should be considered. The follow-up period of six months is relatively short, and periapical healing may continue beyond this interval. Long-term clinical studies with follow-up periods of 12–24 months are warranted to fully assess the durability of the observed treatment outcomes[31,32]. Additionally, the sample size of 60 teeth, while sufficient to detect significant differences in PAI reduction, may not fully capture variations related to root canal morphology, patient age, or systemic health, which can all influence healing outcomes[33].

Future research should focus on comparing different laser wavelengths, power settings, and activation protocols to optimize clinical efficacy while minimizing the risk of thermal damage to periapical tissues. Moreover, combining laser

disinfection with novel irrigation solutions or nanoparticles may further enhance microbial elimination, particularly in resistant biofilm-associated infections[34,35]. The integration of three-dimensional imaging, such as cone-beam computed tomography (CBCT), could provide more precise evaluation of periapical healing and improve the objectivity of outcome assessment in future clinical trials[36,37].

In conclusion, the findings of this study support the clinical utility of laser-assisted root canal disinfection as an effective adjunct to conventional chemomechanical preparation. Both laser and sonic activation techniques offer measurable benefits in reducing periapical pathology and promoting healing. Nevertheless, comprehensive mechanical preparation and chemical irrigation remain essential, and long-term studies are necessary to confirm the sustained advantages of laser use in endodontic therapy.

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