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# A COMPARATIVE EVALUATION OF LASER ASSISTED AND ULTRASONIC IRRIGATION IN ROOT CANAL DESINFECTION DURING ENDODONTIC TREATMENT – A REVIEW ARTICLE

# КОМПАРАТИВНА ПРОЦЕНКА НА ЛАСЕРСКИ АСИСТИРАНА И УЛТРАЗВУЧНА ИРИГАЦИЈА ВО ДЕЗИНФЕКЦИЈА НА КОРЕНСКИ КАНАЛИ ВО ТЕК НА ЕНДОДОНТСКИ ТРЕТМАН – РЕВИЈАЛЕН ТРУД

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## Abstract

**Aim:** This review article aims to provide a systematic analysis and comparison of laser-assisted and ultrasonically activated irrigation in endodontics, with the objective of determining their clinical effectiveness in root canal disinfection and mechanical debridement. **Materials and Methods:** A systematic search of scientific literature published in English over a ten-year period (2015–2025) was conducted using the following databases: PubMed, Scopus, Web of Science, and Google Scholar. The search strategy incorporated the following keywords and their combinations: diode laser, ultrasonic irrigation, root canal treatment, laser-assisted irrigation, ultrasonically activated irrigation, and endodontics. This review includes studies reporting findings from both clinical and laboratory research that investigated and compared the effects of laser-assisted and ultrasonically activated irrigation on root canal systems. **Results:** Following the analysis of the selected studies, several parameters were evaluated, including antimicrobial efficacy, smear layer removal, disinfection of lateral canals, postoperative pain, operational safety, and clinical applicability. The evidence gathered in this systematic review indicates that laser-assisted irrigation demonstrates superior efficacy compared to ultrasonically activated irrigation in the elimination of microorganisms, dentinal debris, andthe smear layer from the root canal system. Laser activation generally exhibits a higher antimicrobial potential, particularly when combined with chemical irrigants. **Conclusion:** Diode lasers stand out due to their ability to achieve deeper penetration into dentinal tubules and their pronounced antimicrobial effect. In contrast, ultrasonic activation offers advantages in mechanical cleaning, smear layer removal, and enhanced irrigant flow, particularly in lateral canals and complex anatomical regions of the root canal system. **Keywords:** laser-assisted irrigation, diode laser, ultrasonic irrigation, endodontic treatment.

## Апстракт

**Цел:** Целта на оваа ревијална студија е систематска анализа и споредба на примената на ласерска и ултразвучнаиригација во ендодонцијата, со цел да се утврди нивната клиничка ефикасност во однос на дезинфекцијата на коренските канали и нивно механичкото чистење. **Материјали и методи:** Се спроведе систематско пребарување на научна литература објавена на англиски јазик, со временски опсег од 10 години (од 2015 до 2025 година), во следниве бази на податоци: PubMed, Scopus, Web of Science и Google Scholar. Пребарувањето беше спроведенопреку користење на следниве клучни зборови и на нивните комбинации: diode laser, ultrasonic irrigation, root canal treatment, laser-assisted irrigation, ultrasonically activated irrigation, endodontics. Во овој преглед се содржани статии во кои се објавени резултати од клинички и лабораториски студии, во кои е испитуван и е спореден ефектот на ласерска и ултразвучна активирана иригација на коренските канали. **Резултати:** По обработката на вклучените студии, беа анализирани неколку параметри на испитуваните техники и тоа: антимикробен ефект, отстранување на smear layer, дезинфекција на латерални канали, постоперативна болка, безбедност при работа и нивната клиничка примена. Во рамките на овој систематски преглед, тековните докази укажуваат дека ласер-асистирана иригација има супериорна ефикасност во однос на ултразвучно-активирана иригација во елиминацијата на микроорганизми, дентински остатоци и размачкан слој од системот на коренскиот канал. Ласерската активација генерално покажува повисок антимикробен потенцијал, особено кога се комбинира со хемиски ириганси. **Заклучок:** Диодниот ласер се издвојува по својата способност за подлабока пенетрација во дентиналните тубули и изразен антимикробен ефект, додека ултразвучната активација покажува предност во механичкото чистење, отстранувањето на smear layer и подобрување на протокот на иригантот, особено во латералните канали и во комплексните анатомски делови од коренските канали. **Клучни зборови:** ласер-асистирана иригација, диоден ласер, ултразвучна иригација, ендодонтски третман.

## Introduction

Endodontic treatment of the root canal system aims to establish a microorganism-free environment while simultaneously shaping the canals to create optimal conditions for long-term therapeutic success. The primary etiological agents of root canal infections are microorganisms that invade the dental pulp and subsequently colonize the root canal system. These microorganisms produce metabolic by-products that rapidly penetrate periradicular tissues through apical and lateral foramina, triggering a cascade of inflammatory reactions accompanied bylysis of both soft and hard periradicular tissues[1].

Primary infections are predominantly associated with 40–50 Gram-negative obligate anaerobic species, particularly from the genera *Fusobacterium, Prevotella, Porphyromonas, Tannerella,* and *Treponema*. In contrast, secondary or persistent infections typically consist of less diverse microbial communities, mainly composed of Gram-positive facultative anaerobes, including species of *Streptococcus*, *Lactobacillus, Actinomyces,* and *Enterococcus*[2,3].

*Enterococcus faecalis* is one of the most frequently detected microorganisms in persistent secondary infections, while it is less commonly found in primary infections. This highlights its remarkable ability to survive under unfavorable conditions, especially in inadequately treated root canal systems[4,5,6].

Effective debridement and disinfection of the root canal system fundamentally depend on the use of appropriate irrigants and disinfectants. Sodium hypochlorite, chlorhexidine, EDTA, and MTAD are among the most commonly used agents in contemporary endodontic practice. Sodium hypochlorite remains the gold standard due to its broad-spectrum antimicrobial activity, whereas chlorhexidine is valued for its lower cytotoxicity and reduced risk of tissue damage. Continuous research in this field has led to the development of advanced approaches, including the use of nanoparticles, photodynamic therapy, and low-frequency ultrasound, all of which aim to enhance the efficacy of root canal disinfection[7].

Ultrasonic irrigation, as a viable adjunct in root canal therapy, can be applied in two distinct ways: in combination with simultaneous instrumentation or as a standalone technique without concurrent instrumentation, known as passive ultrasonic irrigation (PUI). In clinical practice, the former approach has largely been abandoned due to difficulties in controlling the removal of infected dentin and the increased risk of creating aberrant canal morphologies. Consequently, the literature supports the preferential use of passive ultrasonic irrigation, which ensures safer canal preparation while minimizing the risk of iatrogenic irregularities within the root canal system[8,9].

In modern endodontics, diode lasers occupy a prominent role in root canal disinfection. Operating within a wavelength range of 810 to 980 nm (infrared spectrum), they are capable of deep penetration into dentinal tubules, enabling effective elimination of bacteria residing in deeper tooth structures. Laser energy activation induces thermal effects that lead to the destruction of bacterial cells, including resistant species such as *Enterococcus faecalis*[10,11]. Additionally, diode lasers have been associated with a reduction in postoperative pain following endodontic treatment[12].

## Aim

The aim of this review study is to systematically analyze and compare current scientific evidence regarding the application of laser-assisted and ultrasonically activated irrigation in endodontics, in order to determine their clinical efficacy in terms of root canal disinfection, mechanical debridement, and overall treatment outcomes in patients.

## Material and methods

A systematic literature review was conducted to examine and compare the various characteristics of laser-assisted and ultrasonically activated irrigation, highlighting their role in root canal disinfection as part of endodontic treatment. A comprehensive search of scientific literature published in English was performed, with a time restriction of ten years, including publications from 2015 to 2025. The following databases were used: PubMed, Scopus, Web of Science, and Google Scholar.

The search strategy incorporated the following keywords and their combinations: diode laser, ultrasonic irrigation, root canal treatment, laser-activated irrigation, ultrasonically activated irrigation, and endodontic treatment.

This review includes studies reporting results from both clinical and laboratory research, in which the effects of laser-assisted and ultrasonically activated irrigation on root canal systems were investigated and compared. In certain studies, in addition to comparing these two techniques, comparisons were also made with other conventional methods.

The study was conducted using predefined inclusion and exclusion criteria, as outlined below:

**Inclusion criteria**

- Randomized controlled trials
- *In vitro* and *in vivo* studies
- Studies comparing laser-assisted and ultrasonic irrigation, either with each other or with other disinfectants

- Studies analyzing postoperative pain, antimicrobial efficacy, and smear layer removal following the use of laser or ultrasonic irrigation

**Exclusion Criteria**

- Studies not published in full text
- Studies that did not investigate the effects of laser-assisted and ultrasonic irrigation
- Studies without direct comparison between the techniques
- Studies published before 2015
- Studies published in languages other than English

A total of multiple studies were initially identified, of which 18 studies were ultimately selected for final inclusion, as they were directly relevant to the aim of this review.

## Results

In this study, multiple relevant clinical and in vitro investigations were analyzed, comparing the efficacy of laser-assisted and ultrasonically activated irrigation in root canal disinfection as part of endodontic treatment. The data derived from the analyzed studies are presented in Table 1.

**Table 1.** Comparative analysis of the effects of laser-assisted and ultrasonically activated irrigation in root canal systems

| Authors | | Disinfection Method | Superior Effect (Outcome) | Journal |
|---|---|---|---|---|
| Sahar-Helft S et al. | 2015 | Laser-activated irrigation vs Passive ultrasonicirrigation (PUI) | Lasersuperior effect for smear layer removal | Journal of Endodontics |
| Sohrabi K et al. | 2016 | Diode laser vs NaOCl | Diode laser shows superior antimicrobial effect | Iranian Endodontic Journal |
| Amin Ket al. | 2016 | Diode laser vs ultrasonic irrigation | Diode laser more effective as monotherapy | J Conserv Dent |
| Dai S et al. | 2018 | Diode laser | High antimicrobial efficacy | BMC Oral Health |
| Rajakumaran A et al. | 2019 | Diode laser vs Ultrasonic irrigation | Laser shows better penetration into dentin | Journal of Clinical and Diagnostic Research |
| Verma A et al. | 2020 | Ultrasonic vs Laser vs Conventional | Both methods superior to conventional techniques | Journal of Clinical and Experimental Dentistry |

| Authors | | Disinfection Method | Superior Effect (Outcome) | Journal |
|---|---|---|---|---|
| Pereira TC et al. | 2021 | Ultrasonic irrigation | Ultrasonic technique superior for biofilm removal | International Endodontic Journal |
| Jambagi N et al. | 2021 | Diode laser vs Ultrasonic vs NaOCl | Diode laser shows greatest bacterial reduction (~60.9%) | Journal of Contemporary Dental Practice |
| Liu C et al. | 2022 | Ultrasonic vs Laser vs Sonic irrigation | Similar effects (ultrasonic and laser superior in apical region) | Journal of Applied Oral Science |
| Badami V et al. | 2023 | Laser vs Ultrasonic irrigation | Laser superior (antibacterial + smear layer); combination most effective | Cureus |
| Almohareb RA et al. | 2023 | Diode laser vs Ultrasonic irrigation | Both methods equally effective | Australian Endodontic Journal |
| Shirani Lapari S. et al. | 2024 | Two diode lasers vs three irrigation methods | Greatest reduction of *Enterococcus faecalis* with diode laser | J Lasers Med Sci |
| Abaza MM et al. | 2025 | Diode laser vs Ultrasonic irrigation | Ultrasonic superior for smear layer removal | Lasers in Medical Science |
| Karimzadeh S et al. | 2025 | Laser vs Ultrasonic irrigation | Similar efficacy (focus on safety) | Journal of Conservative Dentistry & Endodontics |
| Ahmad L et al. | 2025 | Ultrasonic vs Laser vs Sonic irrigation | Ultrasonic technique superior for canal cleanliness | Clinical/SEM Study Journal |
| Nagadi E et al. | 2025 | Diode laser vs Ultrasonic vs Sonic irrigation | Diode laser shows superior antimicrobial effect | Clinical, Cosmetic and Investigational Dentistry |
| Gulhane A et al. | 2025 | Laser vs Ultrasonic irrigation | Laser associated with reduced postoperative pain | Cureus |
| Al-Jaberi M et al. | 2025 | Different diode laser wavelengths | Effective against *Enterococcus faecalis* | Rev Recent Clin Trials |

Following the analysis of the included studies, the primary focus was directed toward comparing the effects of laser-assisted techniques versus ultrasonic irrigation on root canal disinfection and mechanical cleaning, which are critical determinants of the overall outcome of endodontic treatment. Several key parameters were evaluated, including antimicrobial efficacy, smear layer removal, disinfection of lateral canals, postoperative pain, operational safety, and clinical applicability.

## Antimicrobial Effect

According to the analyzed studies, diode lasers demonstrate a superior antimicrobial effect compared to ultrasonic activation and conventional irrigation methods in root canal treatment. This superiority is primarily attributed to the deeper penetration capability of diode lasers into dentinal tubules and their photothermal effect, which effectively destroys microorganisms, particularly *Enterococcus faecalis*, a species associated with secondary, persistent infections and failed endodontic treatments. Studies by Sohrabi et al.[14], Dai et al.[16], Jambagi et al.[20], and Nagadi et al.[28] report significant reductions in *Enterococcus faecalis*, which can be linked to the deep penetration of laser energy into the dentinal tubules. Furthermore, Shirani Lapari et al.[24] and Al-Jaberi et al.[30] confirm that variations in diode laser wavelengths influence the efficacy against biofilm formation.

On the other hand, while ultrasonic irrigation provides positive results in microbial reduction, its action is largely superficial, leading primarily to mechanical disruption of the biofilm rather than deep disinfection within dentinal tubules. This was demonstrated in the study by Liu et al.[21].

Nevertheless, the systematic review by Badami et al.[22] indicates that the majority of studies support the superior antimicrobial efficacy of laser-activated irrigation over ultrasonic-activated irrigation. Overall, the current evidence in this systematic review suggests that laser-activated irrigation is more effective than ultrasonic-activated irrigation in eliminating microorganisms, dentinal debris, and smear layer from the root canal system. Laser activation generally exhibits higher antimicrobial potential, particularly when combined with chemical irrigants.

## Smear Layer Removal

Variable results have been reported regarding smear layer removal for the two techniques, largely due to their differing mechanisms of action. Diode lasers function through photothermal energy, whereas ultrasonic activation promotes improved irrigant circulation within the canal. The study by Sahar-Helft et al.[13] demonstrated superior smear layer removal with laser activation, while Abaza et al.[25] reported better results using ultrasonic irrigation, particularly in the apical third. Amin et al.[15] highlighted that combining EDTA with ultrasonic activation significantly enhances smear layer removal.

## Cleaning of Lateral Canals

One of the major challenges during endodontic treatment is effective disinfection and mechanical cleaning of lateral canals and anatomically inaccessible areas. In root canals with complex anatomy and lateral canals, studies indicate that ultrasonic activation achieves more effective disinfection due to the dynamic movement of irrigants. Pereira et al.[19] demonstrated that ultrasonic activation better removes biofilm from lateral canals because of its hydrodynamic effects.

Conversely, lasers contribute to microbial elimination within the root canals, but their effect is primarily antimicrobial rather than mechanical. Rajakumaran et al.[17] showed that lasers achieve deeper penetration into dentinal tubules, making them superior for deep disinfection. Liu et al.[21] concluded that combining both techniques can yield optimal results in anatomically complex root canal systems.

## Postoperative Pain

Most of the analyzed studies report that patients treated with diode lasers experience lower postoperative pain following endodontic treatment, attributed to reduced microbial load and a consequently diminished inflammatory response. Gulhane et al.[29], in a systematic review, indicated that laser-assisted irrigation is associated with less postoperative pain compared to ultrasonic and conventional methods, likely due to improved microbial elimination and reduced irritation of periapical tissues.

For ultrasonic activation, postoperative pain levels are moderate and vary depending on the technique and type of irrigants used. Verma et al.[18] demonstrated that both laser and ultrasonic activation contribute to improved clinical healing compared to conventional irrigation methods.

## Safety and clinical application

Operational safety is a critical factor when selecting irrigation techniques. Although diode lasers are highly effective, their use requires proper training, careful parameter selection, and adherence to correct protocols to avoid damage to periapical tissues or injury to surrounding oral structures. Ultrasonic activation, on the other hand, is generally considered safer and more broadly applicable, with a lower risk of thermal damage. Karimzadeh et al.[26] emphasize the importance of controlling laser parameters to pre-

vent thermal injury to periapical tissues. Ahmad et al.[27] also note that ultrasonic activation may lead to irrigant extrusion into periapical tissues if proper usage guidelines are not followed.

While most studies are in vitro, clinical evidence reported by Verma et al.[18] and Ahmad et al.[27] confirms that both techniques significantly enhance the effectiveness of endodontic treatment. Systematic reviews by Badami et al.[22] and Gulhane et al.[29] indicate that there is no single universally superior method. Instead, a combined approach-integrating laser, ultrasonic activation, and chemical irrigation-provides the most favorable outcomes in the overall success of endodontic therapy.

## Discussion

The analysis of the available literature indicates some inconsistency in the reported results, which can largely be attributed to variations in study design. Differences in the choice and concentration of irrigants, duration of activation, and laser energy parameters significantly influence the final outcomes[13,15,21]. This is particularly evident in studies employing different diode laser wavelengths, where variations are observed in antimicrobial efficacy and depth of penetration into dentinal tubules[24,30].

It is also important to note that most of the analyzed studies were conducted under in vitro laboratory conditions[13,14,15,16,17,19,20,21,23,24,25,26,28,30]. While such an approach allows for better control of experimental parameters, it cannot fully capture the complexity of clinical situations. The absence of biological factors, such as immune response and individual anatomical variability, may lead to overestimation or underestimation of the efficacy of certain techniques[19,21].

Although lasers often demonstrate superior results under laboratory conditions[14,16,20,28,] clinical studies do not always show a significant difference in overall treatment outcomes[18,23,27]. This suggests that increased antimicrobial activity does not necessarily translate into better clinical results, highlighting the importance of a comprehensive treatment approach.

Furthermore, several authors emphasize that combining different irrigation techniques can provide better results than using each method alone[21,22,29]. Such combinations leverage the advantages of each technique: the mechanical action of ultrasound and the deeper penetration capability of lasers, which is particularly valuable in complex root canal morphologies and in the presence of lateral canals[17,19].

Recent research also shows a notable trend toward minimally invasive endodontic approaches, aiming to achieve effective disinfection while preserving healthy tissue and minimizing irritation to surrounding structures[23,26,27]. In this context, laser and ultrasonic activation play an important role as adjunctive techniques that can enhance treatment success without aggressive mechanical instrumentation. Together, these modern endodontic strategies contribute to more efficient and predictable clinical outcome.

## Conclusion

Based on the analysis of the available literature, it can be concluded that both diode lasers and ultrasonic irrigation represent significant advancements over conventional irrigation methods in endodontics. Both approaches demonstrate improved efficacy in disinfecting the root canal system, particularly in eliminating microorganisms and removing organic and inorganic debris.

The diode laser stands out for its ability to penetrate deeper into dentinal tubules and for its pronounced antimicrobial effect, whereas ultrasonic activation offers advantages in mechanical cleaning, smear layer removal, and enhanced irrigant flow, especially in lateral canals and anatomically complex areas of the root canal system. However, no single technique alone can achieve complete disinfection of the root canal system.

In this regard, a combined approach-incorporating chemical irrigants alongside different activation methods-emerges as the most rational solution for achieving optimal disinfection. Additionally, careful attention must be paid to safety considerations, particularly regarding the control of laser energy and preventing irrigant extrusion into periapical tissues.

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