Alındı/Received: 17.06.2026 Kabul Edildi/Accepted: 04.07.2026 Yayınlandı/Published: 19.08.2026

Uşak Üniversitesi Diş Hekimliği Fakültesi Dergisi

Journal of Dental Faculty of Usak University

e-ISSN: 2980-3195 Cilt / Volume: 4 Sayı / Issue: 2

Review Article

Lasers in Endodontics

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Abstract

Laser technology has increasingly gained attention in endodontics due to its potential to enhance disinfection, improve clinical outcomes, and support tissue healing. This review aims to provide a comprehensive overview of the applications of lasers in endodontics, including their mechanisms of action, clinical indications, advantages, and limitations.

Different laser systems, such as Nd:YAG, Er:YAG, Er,Cr:YSGG, diode, and CO_2 lasers, exhibit distinct interactions with dental tissues depending on their wavelength and absorption characteristics. These properties enable their use in a wide range of procedures, including vital pulp therapy, root canal disinfection, irrigation activation, retreatment, management of dentin hypersensitivity, bleaching, and endodontic surgery.

Laser-assisted techniques, particularly photoacoustic irrigation methods such as PIPS and SWEEPS, have been shown to improve irrigant penetration and biofilm disruption. Additionally, photodynamic therapy and low-level laser therapy contribute to antimicrobial effects and biostimulation. However, despite promising in vitro and short-term clinical findings, evidence regarding long-term clinical superiority remains limited.

While lasers offer advantages such as minimally invasive procedures, improved patient comfort, and enhanced antimicrobial efficacy, their widespread clinical adoption is restricted by high cost, technique sensitivity, and lack of standardized protocols.
In conclusion, lasers should be considered as adjunctive tools rather than replacements for conventional endodontic techniques. Further well-designed clinical studies are required to establish standardized protocols and to clarify their long-term clinical effectiveness.

Keywords: Endodontics, Laser-assisted irrigation, Root canal disinfection, Postoperative pain, Regenerative endodontic

Endodontide Lazerler

Öz

Lazer teknolojisi, dezenfeksiyonu artırma, klinik sonuçları iyileştirme ve doku iyileşmesini destekleme potansiyeli nedeniyle endodontide giderek artan ilgi görmektedir. Bu derlemenin amacı, lazerlerin etki mekanizmaları, klinik kullanım alanları, avantajları ve sınırlılıkları ile birlikte endodontideki uygulamalarını kapsamlı bir şekilde değerlendirmektir.

Nd:YAG, Er:YAG, Er,Cr:YSGG, diyot ve CO_2 lazerler gibi farklı sistemler, dalga boyu ve absorpsiyon özelliklerine bağlı olarak dental dokularla farklı etkileşimler göstermektedir. Bu özellikler, lazerlerin vital pulpa tedavileri, kök kanal dezenfeksiyonu, irrigasyon aktivasyonu, retreatment, dentin hassasiyeti tedavisi, beyazlatma ve endodontik cerrahi gibi geniş bir kullanım alanına sahip olmasını sağlamaktadır.

PIPS ve SWEEPS gibi fotoakustik irrigasyon teknikleri irrigant penetrasyonunu ve biyofilm uzaklaştırılmasını artırırken, fotodinamik terapi ve düşük seviyeli lazer tedavisi antimikrobiyal etki ve biyostimülasyon sağlamaktadır. Ancak umut verici in vitro ve kısa dönem klinik bulgulara rağmen, uzun dönem klinik üstünlük açısından kanıtlar sınırlıdır.

Lazerler minimal invazivlik, hasta konforu ve antimikrobiyal etkinlik gibi avantajlar sunsa da yüksek maliyet, teknik hassasiyet ve standart protokol eksikliği yaygın kullanımını sınırlandırmaktadır.

Sonuç olarak, lazerler konvansiyonel yöntemlerin yerine geçen değil, onları destekleyen yardımcı araçlar olarak değerlendirilmelidir. Standart protokollerin belirlenmesi ve uzun dönem etkinliğin ortaya konması için daha fazla klinik çalışmaya ihtiyaç vardır.

Anahtar Kelimeler: Endodonti , Lazer destekli irrigasyon, Kök kanal dezenfeksiyonu, Postoperatif ağrı, Rejeneratif endodonti

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Introduction

Lasers (Light Amplification by Stimulated Emission of Radiation) were first introduced into medicine and dentistry in 1960 following the development of the ruby laser by Maiman (1). Laser light possesses unique properties such as monochromaticity, coherence, directionality, and high energy density. Its interaction with biological tissues occurs through absorption, reflection, scattering, and transmission (2).

Today, laser technologies are widely utilized in various fields of dentistry, including surgery, periodontology, endodontics, prosthodontics, and esthetic applications (3, 4).

The advantages of lasers include minimally invasive application, bactericidal effects, deep penetration into dentinal tubules, effective bleeding control, improved patient comfort, and, in some cases, analgesic and anti-inflammatory effects. However, limitations such as the risk of thermal damage, high cost, and the need for specialized training must also be considered (3, 4).

Various laser systems with different wavelengths are used in endodontics, and their clinical indications depend on their tissue interaction characteristics. Erbium lasers are strongly absorbed by water and hydroxyapatite, making them suitable for hard tissue ablation and irrigant activation. Nd:YAG lasers are effective in antimicrobial applications due to their deep penetration into dentinal tubules, whereas diode lasers are favored for their compact design and versatility, including in soft-tissue procedures (5, 6). Diode lasers have also been investigated as an adjunct for postoperative pain control in endodontics, although the systematic-review evidence in this area remains heterogeneous (7, 8).

General Considerations

Types of dental lasers and wavelengths

The main laser systems used in dentistry include CO_2 (10,600 nm), Nd:YAG (1064 nm), Er:YAG (2940 nm), Er,Cr:YSGG (2780 nm), and diode lasers (810–980 nm). CO_2 lasers provide strong cutting and coagulation in soft tissues, while Nd:YAG lasers are effective in hemostasis and antimicrobial applications due to their deep tissue penetration. Er:YAG and Er,Cr:YSGG lasers are highly absorbed by water and hydroxyapatite, making them suitable for hard tissue procedures and root canal irrigation. Diode lasers are widely used in endodontics and periodontology due to their compact structure, relatively low cost, and photobiomodulation effects (1).

Table 1. Comparative overview of laser systems used in endodontics (data summarized from references 4, 5, 6, and 12).

Laser System	Wavelength	Primary Endodontic Applications	Advantages	Limitations
Er:YAG	2940 nm	Root canal irrigant activation (PIPS), smear layer removal, hard-tissue ablation, disinfection	Strong water absorption; low thermal risk relative to other systems; effective photoacoustic streaming	Limited penetration into lateral canals; requires precise fiber positioning; equipment cost
Er,Cr:YSGG	2780 nm	Irrigant activation, hard-tissue procedures, retreatment adjunct	High absorption in water/hydroxyapatite; effective photoacoustic irrigant activation and conservative hard-tissue ablation	Technique-sensitive; risk of extrusion if fiber inserted into canal; limited long-term clinical data
Nd:YAG	1064 nm	Antimicrobial disinfection, hemostasis, internal bleaching, endodontic surgery	Deep tissue penetration; effective hemostasis and antimicrobial effect	Higher thermal risk to periodontium/cementum ; less effective for hard-tissue ablation
Diode	810-980 nm	Postoperative pain control (LLLT), disinfection, photobiomodulation, soft-tissue surgery	Compact and cost-effective; versatile soft-tissue and biostimulatory applications	Minimal hard-tissue interaction; thermal effects on root surface at higher power settings
CO2	10600 nm	Endodontic surgery (soft-tissue incision/coagulation), hemostasis	Strong soft-tissue cutting and coagulation; good hemostasis	Not fiber-delivered in earlier systems; limited intracanal use; risk of thermal spread

Laser–Tissue Interaction Mechanisms

Laser–tissue interactions occur through four primary mechanisms. The photothermal effect results from the conversion of laser energy into heat, leading to coagulation, ablation, and vaporization. The photomechanical effect, particularly observed in erbium lasers, generates cavitation and shock waves within the irrigant, enhancing mechanical cleaning. The photochemical effect occurs in photodynamic therapy (PDT), where activation of photosensitizers leads to the formation of reactive oxygen species, producing antimicrobial effects. Photobiomodulation, achieved through low-level laser therapy (LLLT), stimulates cellular metabolism, angiogenesis, and wound healing (2).

Among the four possible interactions between laser light and biological tissue, absorption is the interaction primarily responsible for converting photon energy into a therapeutic or ablative biological effect (9); reflection, scattering, and transmission do not themselves deposit energy in the target tissue, but they still shape how that energy is spatially distributed, how deeply it penetrates, and how much reaches adjacent structures. The magnitude of the resulting biological effect is governed by several interrelated, largely tissue-dependent factors rather than by wavelength alone. These include the specific absorption coefficient of the target tissue, which is dictated mainly by its water content, its mineral (hydroxyapatite) content, and the presence of pigmented chromophores such as hemoglobin and melanin; the vascularity and blood flow of the tissue, which influences heat dissipation and thermal tolerance; the energy density (fluence) and power density delivered by the laser; and the temporal delivery mode, since continuous-wave emission favors cumulative thermal build-up, whereas pulsed or gated delivery allows thermal relaxation between pulses and therefore reduces collateral damage (9).

Erbium lasers (Er:YAG, Er,Cr:YSGG), whose wavelengths coincide closely with the principal absorption peak of water, are strongly absorbed by hydrated hard and soft tissues, whereas Nd:YAG and diode lasers are preferentially absorbed by pigmented chromophores and therefore penetrate more deeply before being absorbed. As a result, the same nominal wavelength can behave quite differently depending on the operating mode and the optical properties of the tissue it meets, which is why generic power settings copied from one laser system to another often give inconsistent clinical results (9).

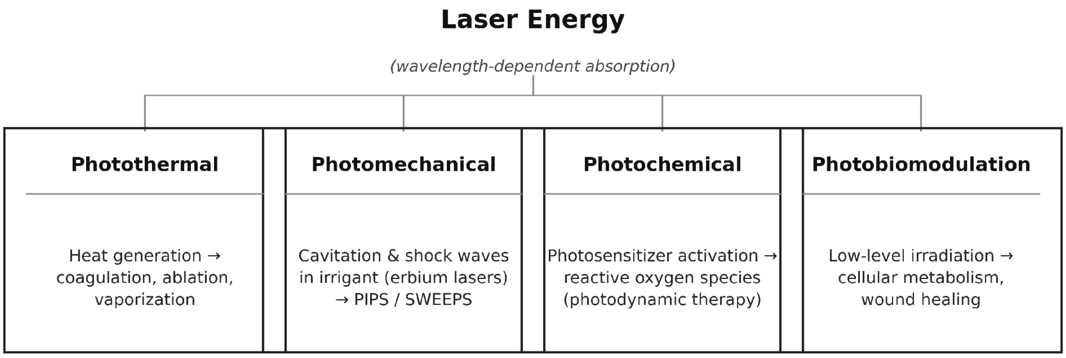

Figure 1. *Schematic overview of the four principal laser–tissue interaction mechanisms relevant to endodontic applications.*

General Applications in Endodontics

The first application of lasers in endodontics was reported by Weichman and Johnson in 1971 at the apical foramen (1).

Lasers have a wide range of applications in endodontics, serving both diagnostic and therapeutic purposes. In vital pulp therapy, they are valued for their tissue-preserving effects, while laser Doppler flowmetry provides an objective method for assessing pulp vitality (10, 11).

Lasers have been reported to be effective in the treatment of dentin hypersensitivity and in reducing post-bleaching sensitivity. In root canal disinfection, laser-assisted irrigation techniques such as PIPS (Photon-Induced Photoacoustic Streaming) and SWEEPS (Shock Wave Enhanced Emission Photoacoustic Streaming) enhance irrigant activation and improve efficacy. Additionally, photodynamic therapy contributes to the elimination of biofilms within the root canal system (12).

Furthermore, lasers are used in retreatment procedures, management of periapical lesions, and biostimulation. They also provide advantages in endodontic surgery by improving hemostasis and accelerating postoperative healing, and they serve as an adjunctive tool in the diagnosis of cracked and fractured teeth (6).

Advantages and Limitations

Lasers offer significant advantages, including antimicrobial efficacy, minimally invasive procedures, and biostimulatory effects that enhance patient comfort. However, their clinical use is limited by factors such as high cost, a learning curve, risk of thermal damage, and lack of standardized protocols (5).

Pulp Therapy and Regenerative Endodontics

Vital Pulp Therapy

Vital pulp therapy (VPT) encompasses conservative approaches aimed at preserving the biological function of the pulp. These include indirect pulp capping, direct pulp capping, and partial or full pulpotomy. In VPT, lasers are not used as standalone treatments but as adjuncts in combination with biocompatible materials to support pulp vitality and regenerative processes (13).

Er:YAG and Er,Cr:YSGG lasers reduce mechanical trauma in cavities, decrease the need for anesthesia, and remove the smear layer, thereby improving the interface between pulp tissue and capping materials (11). Diode and Nd:YAG lasers provide deeper penetration and effective hemostasis, facilitating pulp bleeding control (14).

Regenerative Endodontics

Regenerative endodontics aims to restore necrotic or damaged pulp tissue biologically. Lasers play a role through both antimicrobial effects and biostimulation (15, 16).

In regenerative procedures, erbium lasers enhance root canal wall conditions by reducing microbial load and smear layer, facilitating stem cell attachment. LLLT promotes stem cell proliferation and differentiation, accelerating regeneration (17).

High-power lasers (Nd:YAG, Er:YAG, Er,Cr:YSGG) reduce bacterial load, whereas LLLT and PDT support stem cell activity and angiogenesis (18, 19). In vitro studies have demonstrated that diode laser irradiation may provide antimicrobial effects comparable to triple antibiotic paste against Enterococcus faecalis (20).

However, some studies suggest that laser-induced denatured layers may negatively affect healing. Therefore, appropriate wavelength, power settings, and protocols are critical for clinical success (21).

This evidence should be read with some caution. Most of it comes from in vitro or short-term animal work, and few studies compare laser-assisted protocols directly against conventional calcium hydroxide- or bioceramic-based approaches under matched conditions; where such comparisons do exist, laser type, wavelength, and irradiation parameters differ widely from one study to the next. Reported benefits such as reduced bacterial load and enhanced dentin bridge formation do not always translate into better long-term pulp survival once non-laser controls are included, and power settings that are too high can leave a denatured or carbonized surface layer that works against healing rather than for it (21). At present, lasers look like a useful addition to an already sound restorative protocol rather than a factor that changes outcomes on its own.

Assessment of Pulp Vitality

The assessment of pulp vitality represents one of the most critical steps in endodontic diagnosis. Compared to conventional methods, newer techniques offer advantages such as being non-invasive, objective, and capable of detecting vitality at earlier stages, particularly in trauma cases and pediatric patients (22).

Although conventional methods such as electric pulp testing (EPT) and cold tests are widely used, they may yield false-negative results, especially in traumatized teeth (23). This limitation has increased the demand for more reliable and objective diagnostic methods (24).

In this context, laser-based technologies have gained prominence. Laser Doppler Flowmetry (LDF) is a non-invasive and objective technique that evaluates pulp vitality by measuring pulpal blood flow (10).

LDF systems typically employ a low-power helium-neon or semiconductor diode laser as the light source; light backscattered from moving red blood cells undergoes a Doppler frequency shift proportional to their velocity, while light reflected from static tissue remains unshifted, and the resulting signal is processed to yield a flux value that reflects both the concentration and the velocity of moving blood cells within the pulp microcirculation (25). Recording depth and signal strength are strongly influenced by the thickness of the overlying enamel and dentin: experimental work has shown that the blood-flow signal recorded through intact enamel is markedly weaker than that recorded from exposed dentin, with signal strength increasing substantially as residual tissue thickness decreases, a factor that can confound comparisons between teeth of different anatomical dimensions or between intact and restored teeth (26). LDF recordings are also sensitive to local and systemic pharmacological agents: intrapulpal blood flow decreases significantly following administration of local anesthetics containing a vasoconstrictor, with the greatest reduction typically observed within the first ten minutes after injection, while systemically administered vasoactive or sedative agents can independently alter baseline flow values (27). These technique-related and pharmacological sources of variability, together with contamination from periodontal blood flow, mean that LDF readings are best interpreted alongside conventional vitality tests rather than used on their own (25).

Light- and Laser-Based Caries Detection

In addition to their therapeutic applications, several laser-based technologies have been developed for the non-invasive detection and quantification of dental caries, complementing conventional visual-tactile and radiographic examination. Quantitative light-induced fluorescence (QLF) uses blue or laser-induced fluorescence to detect mineral loss in enamel, with demineralized areas showing reduced fluorescence relative to sound tissue, allowing both qualitative detection and quantitative longitudinal monitoring of early lesions. Laser fluorescence devices such as DIAGNOdent generate a pulsed 655 nm diode laser beam directed onto the tooth surface; bacterial metabolites within carious dentin and enamel fluoresce at a longer wavelength than sound tissue, and the device converts this signal into a numeric score corresponding to lesion severity (28).

Comparative studies indicate that laser fluorescence-based systems generally demonstrate higher sensitivity and specificity than caries detector dyes for intraoperative assessment during selective caries removal, although reported accuracy varies considerably across studies and lesion types, and factors such as extrinsic staining, surface hydration, and calculus can produce false-positive readings (28). Digital imaging fiber-optic transillumination (DIFOTI) represents a further laser/light-based diagnostic modality that uses transmitted light to visualize approximal and occlusal lesions; it has shown diagnostic accuracy comparable to, and in some studies exceeding, conventional film and digital radiography, particularly for early enamel lesions (29). None of these tools replaces clinical judgment or radiographic examination, but they can pick up early lesions that would otherwise be missed and support a more conservative approach to cavity preparation.

Bleaching

Bleaching procedures have become one of the most commonly performed treatments in dentistry due to increasing esthetic demands. They are particularly preferred for the esthetic rehabilitation of endodontically treated and discolored teeth.

However, conventional bleaching agents, such as high-concentration hydrogen peroxide (30–35% H_2O_2) and carbamide peroxide, may lead to the accumulation of oxygen radicals in the pulp chamber, resulting in temporary dentin hypersensitivity and postoperative discomfort (30).

Laser-assisted bleaching has attracted attention due to its ability to achieve faster color change and reduce postoperative sensitivity compared to conventional methods. In this approach, laser energy acts as an activating agent that enhances the efficacy of chemical bleaching agents. Nd:YAG, diode, and KTP lasers are the most commonly used systems for this purpose (31).

Nd:YAG laser (1064 nm) has been found particularly effective in internal bleaching due to its deep penetration. Shokouhinejad et al. (2022) reported that Nd:YAG-assisted bleaching resulted in faster color change compared to conventional methods, although sensitivity scores remained similar (31).

Diode lasers (810–980 nm) are widely used due to their compact design and relatively low cost. In vitro studies have shown that diode laser activation enables similar color changes in shorter time periods (32).

KTP laser (532 nm), producing green light, is preferred in esthetic dentistry. Clinical studies have reported lower thermal effects and reduced dentin hypersensitivity (33).

Dentin Hypersensitivity and Post-Bleaching Sensitivity

Dentin hypersensitivity (DH) is characterized by a short, sharp pain arising from exposed dentin in response to thermal, chemical, or mechanical stimuli. Its prevalence ranges between 4% and 74% and is more common in young adults.

Etiological factors include gingival recession, aggressive tooth brushing, erosion, and exposure of dentin following periodontal treatments. Lasers are considered an effective treatment option for both classical dentin hypersensitivity and post-bleaching sensitivity (34).

Mechanisms of Laser Action in Dentin Hypersensitivity

The effects of lasers on dentin hypersensitivity are primarily explained by two mechanisms:

Tubule occlusion: Nd:YAG and Er:YAG lasers induce melting and recrystallization of the dentin surface, leading to the occlusion of dentinal tubules. Scanning electron microscopy (SEM) studies have demonstrated significant tubule occlusion following Nd:YAG laser application (35).

Photobiomodulation: Diode lasers (810–980 nm) modulate nerve conduction through low-level irradiation, producing an analgesic effect and suppressing pain mediators (36).

Beyond their occlusive and photobiomodulatory effects, low-level lasers also appear to exert a direct analgesic action on dental tissues. Proposed mechanisms include a transient reduction in peripheral nerve excitability, with some evidence pointing to altered membrane potential and modulation of voltage-gated sodium and potassium channel activity in sensory nerve fibers, alongside effects on local inflammatory mediators (37). Because this analgesic effect does not appear to depend on tissue heating, it can plausibly occur at sub-ablative power densities that do not raise pulpal or periodontal temperature, although the precise contribution of each mechanism in dental tissue specifically remains to be established.

Clinical studies have demonstrated significant reductions in Visual Analog Scale (VAS) scores following laser application. For instance, randomized controlled trials using 980 nm diode lasers have reported marked decreases in VAS scores (36).

Root Canal Shaping and Disinfection

The success of endodontic treatment depends on effective disinfection and three-dimensional obturation of the root canal system. However, conventional irrigation techniques may not adequately reach the complex anatomy of the root canal system.

Therefore, various activation methods have been developed to enhance irrigation efficacy (38).

Laser-assisted irrigation improves irrigation effectiveness, particularly through the photoacoustic effects of erbium lasers (Er:YAG, Er,Cr:YSGG). Laser energy generates vapor bubbles within the irrigant, leading to cavitation and acoustic streaming, which facilitate the penetration of irrigants into inaccessible areas (39).

PIPS (Photon-Induced Photoacoustic Streaming) is based on the application of Er:YAG laser at low energy (20 mJ) and short pulse duration (50 µs). The fiber tip is positioned at the canal orifice rather than inserted into the canal, allowing effective irrigant distribution with more conservative shaping (40).

SWEEPS (Shock Wave Enhanced Emission Photoacoustic Streaming) is an advanced version of PIPS, utilizing a dual-pulse technique to generate stronger shock waves by optimizing pulse intervals (41).

Photodynamic therapy (PDT) involves the use of low-power lasers in combination with photosensitizers such as toluidine blue, methylene blue, and indocyanine green. Activation produces reactive oxygen species, which exhibit cytotoxic effects, particularly against Enterococcus faecalis biofilms (42).

Laser-assisted disinfection also has real limitations that need to be weighed against its antimicrobial benefits. Depending on the laser system and activation protocol, energy may be delivered through a fiber inserted into the canal or from a tip positioned at the pulp chamber or canal orifice; direct irradiation remains limited by canal anatomy, so that lateral canals, isthmuses, and other irregularities outside the direct line of the beam are not reliably disinfected by the laser itself (12). Excessive temperature increases during laser activation may damage periodontal tissues and the root surface, particularly in thin-walled roots and when adequate cooling or appropriate pulse intervals are not used (43); concerns raised in this context include cementum damage, external root resorption, and dentin surface charring, although the supporting evidence for each of these specific outcomes is limited and stems mainly from ex vivo or primary-tooth models rather than confirmed clinical sequelae. Although poorly selected energy settings or intracanal fiber positioning can increase the risk of apical extrusion, protocols in which the fiber tip is kept in the pulp chamber or canal orifice, as in PIPS/SWEEPS activation, have generally produced lower extrusion values than conventional positive-pressure irrigation, as discussed below. Combined with the high cost of the equipment, the learning curve involved, and the absence of standardized protocols, these limitations mean laser-assisted irrigation works best as a supplement to thorough chemomechanical preparation, not as a way to shorten or replace it (12).

Irrigant Extrusion

In endodontic treatment, the safety of irrigation is as critical as its efficacy. Apical extrusion of irrigants, particularly sodium hypochlorite (NaOCl), may lead to severe complications (44).

In conventional irrigation methods, high flow rates and positioning of the needle close to the apical region increase the risk of extrusion (45).

Laser-assisted irrigation techniques (PIPS, X-Pulse, Preciso) have been shown to significantly reduce extrusion. In particular, PIPS minimizes extrusion due to the non-insertion of the fiber tip into the canal, resulting in controlled irrigation with low extrusion values (0.14 ± 0.03 g) (46).

These findings suggest that laser-assisted irrigation offers advantages not only in disinfection efficacy but also in safety.

Retreatment

Endodontic retreatment involves the removal of existing filling materials from previously treated root canals, followed by re-disinfection and obturation of the canal system. Complete removal of gutta-percha and sealer residues remains a significant clinical challenge (47).

Due to these limitations, lasers have been investigated as adjunctive tools in retreatment procedures. In vitro studies using Nd:YAP lasers in combination with rotary systems have demonstrated a significant reduction in residual gutta-percha, although with increased procedure time (48).

Similarly, Er:YAG laser applications have been shown to enhance the removal of smear layer and sealer remnants. Systematic reviews indicate that lasers alone are insufficient for complete removal of filling materials; however, when combined with rotary instrumentation, they improve overall efficacy (49).

These findings suggest that lasers not only contribute to mechanical cleaning but may also play a role in biostimulation and healing processes.

Periapical Lesions

The primary objective in the treatment of periapical lesions is the elimination of infection originating from the root canal system, followed by the promotion of periapical healing.

Lasers have attracted increasing interest in this field due to their antimicrobial and biomodulatory properties (50).

Garcez et al. (2008) reported that photodynamic therapy resulted in a 65–100% reduction in lesion size, with an average healing rate of 78% (51). However, the long-term effects of laser applications appear to be more limited. Masilionyte et al. (2018) found that while laser use was associated with faster radiographic healing, it did not produce a significant difference in long-term Periapical Index (PAI) scores (52).

Endodontic Surgery

Endodontic surgery is indicated in cases where conventional root canal treatment or retreatment fails. Procedures such as apical resection, retrograde filling, and cyst removal are included within this scope (53).

Laser technologies are utilized both intraoperatively and in the postoperative period. Photobiomodulation (PBM), achieved through low-level laser therapy, reduces postoperative pain and inflammation. Clinical studies using diode lasers (940 nm) have demonstrated faster resolution of pain and paresthesia (54, 55).

Additionally, lasers provide effective hemostasis, improving visibility of the surgical field and reducing operative time. CO_2 and Nd:YAG lasers are commonly preferred for this purpose (56).

Diagnosis of Cracks and Fractures

Accurate diagnosis of cracks and fractures is critical for proper endodontic treatment planning. Conventional diagnostic methods include transillumination, staining techniques, and percussion tests; however, these methods may be insufficient, particularly in localizing symptomatic cracks (57).

Laser technologies have been proposed as adjunctive diagnostic tools. Diode lasers (810 nm), when applied along the crack line, can produce a characteristic sharp pain response, aiding in localization (58).

In a study with a four-year follow-up, 9 out of 12 patients treated after crack detection using diode lasers were completely asymptomatic, while the remaining 3 patients exhibited reduced symptoms (59).

These findings suggest that laser-assisted diagnostic methods may not only improve diagnostic accuracy but also positively influence long-term clinical outcomes.

Postoperative Pain

Postoperative pain is one of the most common complications following endodontic treatment. It may arise from mechanical, chemical, or microbial factors, making its management essential for clinical success (60).

Lasers are considered a supportive modality for pain control, particularly in the early postoperative period (61).

The effects of lasers on postoperative pain have been evaluated mainly in the context of low-level laser therapy (LLLT) and laser-assisted irrigation. Systematic reviews indicate that laser applications can significantly reduce pain intensity within the first 24–48 hours. However, long-term differences between laser and control groups are generally not significant (62).

Clinical studies using Nd:YAG lasers have demonstrated significantly lower pain scores at 48 hours in vital pulp cases compared to controls. Similarly, randomized controlled trials with 980 nm diode lasers have reported reduced pain scores and decreased analgesic consumption within the first 24–48 hours (63).

In another randomized clinical trial comparing LLLT and laser-assisted irrigation, the lowest pain scores at 24 hours were observed in the LLLT group, while both methods showed similar efficacy at 48 hours. By 72 hours, pain levels were comparable across all groups (64).

The evidence on laser-assisted pain control is still a mixed picture. Reported benefits are most consistent in the first 24-48 hours after treatment and fade afterward, trial designs vary widely in laser type, wavelength, dosimetry, and outcome timing, and two recent systematic reviews specifically addressing laser-assisted postoperative endodontic pain both note a high risk of bias and considerable heterogeneity between the included trials (7, 8). Pooled effect estimates from this literature should therefore be read as suggestive rather than as firm proof that lasers outperform conventional analgesic protocols.

Conclusion

In conclusion, lasers represent a valuable adjunctive technology in endodontics, offering both biological and technical advantages. Their contributions to enhanced disinfection, reduction of postoperative pain, and promotion of healing have established their role in clinical practice.

Despite these benefits, limitations such as high cost, the need for operator training, and the lack of standardized protocols should be considered. Future research focusing on protocol optimization and long-term clinical outcomes is essential to further define the role of lasers in endodontic practice.

Future research should prioritize adequately powered, standardized randomized controlled trials that directly compare specific laser parameters (wavelength, energy density, pulse duration, and delivery mode) against well-defined conventional controls, with long-term clinical and radiographic follow-up rather than short-term surrogate outcomes. Priority areas include the comparative efficacy of laser-assisted disinfection versus conventional irrigation in anatomically complex canal systems, the role of lasers as adjuncts in regenerative endodontic procedures and vital pulp therapy using contemporary bioceramic materials, and the development of consensus-based, wavelength-specific irradiation protocols that minimize the risk of thermal injury. Cost-effectiveness analyses and studies addressing the learning curve associated with laser-assisted techniques would further support their rational integration into everyday endodontic practice.

Ethics Committee Permission Statement

Ethics committee approval was not required for this study because no human or animal subjects were involved in this review article. The study was conducted in accordance with the Ethical Principles of Scientific Research and Publication.

Conflict of Interest Statement

The authors declare that they have no conflict of interest.

Funding

This research received no external funding.

Authors Contribution Statement

Gizem Yüksel: Conception, Design, Literature Review, Analysis and/or Interpretation, Writing, Critical Review.

Oğuz Tavşan: Conception, Design, Supervision, Literature Review, Critical Review.

Data Availability Statement

No new datasets were generated or analyzed in this study. All information presented in this review is based on previously published literature cited in the manuscript.

Acknowledgement

Not applicable.

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