Review Article

CLINICAL SUCCESS AND APPLICATIONS OF LASERS IN ENDODONTICS: A NARRATIVE REVIEW

Hala Nafith AlMqayyad[1], Faisal Saleh AlKhamis[1], Mohammed Hussam Masood[1], Tamer Nafith AlMqayyed[2]*

[1]*Magrabi Health Hospitals, Riyadh, Saudi Arabia. dr.halamqayyad@outlook.com*
[2]*Dr. Mohammad Alfagih Hospital, Riyadh, Saudi Arabia.*

Received: 03 April 2025; **Revised:** 21 Month 2025; **Accepted:** 22 June 2025 https://doi.org/10.51847/wmMdkveCNj

ABSTRACT

In recent years, the integration of laser technology into endodontic practice has garnered significant attention due to its potential to enhance multiple facets of root canal therapy. Lasers, encompassing systems such as Nd:YAG, diode, Er:YAG, Er,Cr:YSGG, and CO_2, offer a range of therapeutic benefits, including more efficient disinfection of the root canal system, improved removal of debris and smear layer, modulation of periapical inflammation, and potential enhancement of sealing during obturation. Clinical evidence, derived from human trials, controlled studies, and comprehensive reviews, indicates that laser-assisted procedures can markedly reduce microbial colonization within the canal, contributing to a lower risk of post-treatment infections and improving the predictability of treatment outcomes. Additionally, lasers may attenuate postoperative pain and inflammation, facilitating patient comfort and recovery, and may play a supportive role in vital pulp therapy by promoting tissue healing. Despite these advantages, several limitations currently impede the routine clinical adoption of lasers in endodontics. Variability in laser parameters—including wavelength, power settings, and application protocols—creates inconsistencies in clinical outcomes, while the lack of standardized guidelines makes protocol replication challenging. Financial considerations, including the high cost of laser units, and safety concerns, particularly the risk of thermal damage to periapical tissues, further restrict widespread use. Consequently, while the literature underscores the therapeutic promise of laser-assisted endodontics, it also highlights the pressing need for rigorous, high-quality randomized controlled trials, standardized clinical protocols, and comprehensive cost–benefit analyses to establish evidence-based recommendations. In summary, lasers represent a technologically advanced adjunct in endodontic therapy with the potential to improve disinfection, treatment efficiency, and patient comfort, but their integration into standard practice remains contingent on further validation and optimization.

Key words: Applications of lasers, Endodontics, Laser technology, Root canal therapy.

Introduction

Endodontic therapy's cornerstone objective is the elimination of microbial infection from the complex root canal system while preserving tooth structure and promoting periapical healing. Conventional root canal treatment (RCT) typically relies on mechanical instrumentation (e.g., hand or rotary files), chemical irrigation (such as sodium hypochlorite, EDTA), intracanal medicaments, and hermetic obturation to achieve disinfection and sealing. However, the intricate three-dimensional anatomy of root canals — with isthmuses, lateral canals, apical deltas, and dentinal tubules — often limits complete microbial eradication using these conventional methods [1].

Lasers ("Light Amplification by Stimulated Emission of Radiation") provide concentrated photon energy capable of interacting with biological tissues via photothermal, photomechanical, and photochemical effects. These interactions can offer distinct advantages over traditional methods, including deeper disinfection, minimally invasive tissue ablation, haemostasis, and bio stimulation [2].

In endodontics, many types of lasers have been explored for various clinical applications: intracanal disinfection, laser-activated irrigation (LAI), antimicrobial photodynamic therapy (aPDT), photo biomodulation (PBM) for pain control, vital pulp therapy (e.g., pulpotomy), removal of broken instruments, and surgical endodontics [1]. Such applications promise to overcome shortcomings of conventional therapy, yet their clinical adoption remains variable.

While in vitro and ex vivo studies strongly support lasers' antimicrobial and ablative capacity, translation into clinical practice requires robust clinical evidence. Several systematic reviews and meta-analyses have evaluated laser effects on postoperative pain and disinfection, but major challenges remain: the lack of standardized protocols, safety concerns, and cost-effectiveness [2, 3].

Therefore, a narrative synthesis of the current clinical evidence on laser-assisted endodontics is timely. This review aims to critically appraise clinical success, applications, limitations, and future directions of lasers in endodontic therapy.

Aims of the study
The objectives of this narrative review are:
1. Assess Clinical Success: Evaluate clinical outcomes of laser-assisted endodontic interventions, including microbial reduction, postoperative pain, healing, and

© 2024 Annals of Dental Specialty. **Open Access** – This Article is licensed under CC BY NC SA 4.0. To view a copy of this license, visit https://creativecommons.org/licenses/by-nc-sa/4.0/

sealing quality. (Laser applications)
2. Describe Applications: Detail the various clinical applications of different laser systems in endodontics, such as disinfection, photodynamic therapy, photobiomodulation, vital pulp therapy, obturation enhancement, and surgical use [2].
3. Critical Appraisal: Identify limitations, safety concerns, and gaps in clinical research, including parameter heterogeneity, cost, and adoption barriers. (PubMed:2025)
4. Future Directions: Propose recommendations for future research, including standardization of protocols, training, and cost-benefit analysis. (PubMed:2025)

Materials and Methods

This narrative review was conducted with a structured literature search and thematic synthesis. (PubMed:2025)

Search strategy
Electronic databases (PubMed, Scopus, Web of Science) were searched using keywords and Boolean combinations such as “laser endodontics,” “laser root canal disinfection,” “photodynamic therapy endodontics,” “photobiomodulation endodontics,” “Nd:YAG endodontic clinical trial,” and “Er:YAG laser root canal”. References from key studies and prior reviews were also hand-searched for additional relevant articles.

Selection criteria
- Inclusion Criteria: Human clinical studies (randomized controlled trials, controlled clinical trials, case series), systematic reviews, and narrative reviews that discussed the clinical use of laser systems in endodontic therapy.
- Exclusion Criteria: In vitro or animal-only studies, conference abstracts without full data, non-English language articles.

Data extraction
For each selected study, data were extracted on: type of laser (wavelength), clinical application, irradiation parameters (power, duration, fiber type), sample size, control group, outcome measures (microbial reduction, pain, healing, sealing), follow-up period, and any reported adverse events.

Synthesis and analysis
Given the heterogeneity in protocols and outcomes, a qualitative (narrative) synthesis was conducted rather than meta-analysis. Key themes (applications, efficacy, safety, barriers) were organized and discussed.

Quality assessment
While this is a narrative review, we considered risk-of-bias elements: sample sizes, controls, blinding, follow-up duration, and reporting of laser parameters, drawing on criteria used in prior systematic reviews (e.g., Cochrane tool in PEP studies) [4].

Results and Discussion

Overview of evidence
The literature search identified a growing body of clinical and systematic evidence on the use of lasers in endodontics. Huang *et al*. (2023) conducted a comprehensive narrative review of current applications and future directions, highlighting both high-power and low-level lasers in clinical settings. Sadony & Moharam (2024) provided a detailed review of laser–tissue interactions and the clinical advantages of different laser types [1, 2].

Systematic and meta-analytical data further underscore clinical benefits. For instance, a meta-analysis covering 22 clinical studies found that adjunctive laser therapy (low-level, diode, photodynamic) significantly reduced postoperative endodontic pain, with standardized mean differences (SMD) demonstrating moderate-to-large effects at various time points. Another systematic review focused on photo biomodulation in endodontics reported that most randomized controlled trials showed significant pain reduction after root canal therapy or surgery, though variation in laser parameters limited robust recommendations.

Regarding intracanal disinfection, a systematic review examining post-endodontic pain in laser disinfection trials (Nd: YAG, Er: YAG, diode, aPDT) reported that diode lasers often showed the most promising pain reduction, while Er:YAG demonstrated strong early (6-hour) efficacy. Clinical reports and reviews also document enhanced root canal cleaning, improved sealing of obturation materials, and better hemostasis in surgical endodontics when lasers are used [1].

Types of lasers and their clinical applications
Based on the literature, the following major laser systems are used in clinical endodontics:

Erbium lasers (Er:YAG, Er,Cr:YSGG)
- Er:YAG (wavelength ~2,940 nm) and Er,Cr:YSGG (~2,780 nm) have high absorption in water, causing micro-explosion and ablation of hard tissue with minimal heat diffusion.

These lasers are used for laser-activated irrigation (LAI), which enhances irrigant penetration and smear layer removal through cavitation and fluid streaming [1].

Clinical use includes shaping, cleaning, and even access cavity preparation, reducing reliance on mechanical rotary instrumentation [1].

Nd:YAG lasers (Neodymium-doped YAG)
- Nd:YAG (1,064 nm) penetrates deeper into dentin due to lower water absorption; it is effective for intracanal disinfection and antibacterial effects via

thermal heating.

- Clinically, Nd:YAG delivered through thin fiber tips can reduce bacterial counts significantly, re-melt and recrystallize dentinal layers, and improve sealing when used for obturation or retreatment.
- It is also used in surgical endodontics for apicoectomy and obtaining hemostasis, due to its soft-tissue interaction and coagulative properties.

Diode lasers

- Wavelengths typically range from 810 to 980 nm.
- Diode lasers are widely used for intracanal disinfection, photo biomodulation (low-level), and antimicrobial photodynamic therapy (aPDT).
- They penetrate dentinal tubules effectively, have photoacoustic effects, and can occlude tubules via controlled thermal melting, reducing bacterial entrapment [1].

CO_2 lasers

- The CO_2 laser (e.g., 10,600 nm gas lasers) is strongly absorbed by water and hydroxyapatite, making it useful in soft tissue and hard tissue applications.
- Clinically, CO_2 lasers are used in surgical endodontics (e.g., apicoectomy) for incision, resection, and achieving hemostasis, with minimal bleeding and improved wound healing.
- However, thermal risks and potential for microcracking must be carefully managed [2].

Other lasers (Nd:YAP, He-Ne, etc.)

- Less commonly employed, Nd:YAP (1,340 nm) has been used in research for smear layer removal in curved canals.
- Gas lasers such as He-Ne have limited clinical application but are mentioned in some reviews.

Clinical outcomes

Disinfection & microbial reduction

Clinical evidence suggests that adjunctive laser irradiation (especially with Nd:YAG or Erbium lasers) significantly reduces microbial burden inside root canals [1]. In some reports, sequential use of photosensitizers (in photodynamic therapy) with laser light achieves even greater bacterial reduction than conventional irrigation alone [1].

Laser-activated irrigation (LAI)

Er:YAG and Er,Cr:YSGG lasers, with their high water absorption, are particularly suited for LAI. Clinical and in vivo studies report that LAI improves the removal of smear layer, enhances irrigant penetration into lateral canals, and improves canal cleanliness compared to syringe delivery [2].

Antimicrobial photodynamic therapy (aPDT)

Clinical trials combining photosensitizers (such as methylene blue) with diode lasers show additional microbial reduction [1]. These protocols appear safe, with minimal adverse effects, and can be used where standard disinfection may be insufficient.

Postoperative pain / photobiomodulation (PBM)

Evidence strongly supports low-level laser therapy (LLLT) or PBM for pain reduction after endodontic treatment. In one meta-analysis, laser therapy (diode, PBM, aPDT) significantly decreased pain scores at 24 h and 48 h post-treatment. (SMD = –0.86 and –0.64, respectively) Systematic reviews have similarly concluded that photo biomodulation significantly improves early postoperative comfort, though the variation in laser parameters (e.g., wavelength, power) complicates standardization. In retreatment contexts (root-canal re-treatment), PBM was also shown to reduce pain significantly at 24, 48, and 72 hours.

Vital pulp therapy (pulpotomy / pulp capping)

Lasers have been applied in clinical scenarios of vital pulp therapy. High-power lasers (e.g., Nd:YAG, Erbium) can achieve hemostasis, sterilization, and minimal thermal damage, promoting dentin bridge formation and favourable healing [2]. Although clinical controlled trials are limited, existing reports suggest outcomes comparable or superior to traditional pulp-capping materials [1].

Obturation & sealing

Lasers can also improve obturation. Nd:YAG lasers have been used to thermally soften gutta-percha, aiding flow and adaptation to canal walls, and reducing microleakage [1]. Erbium lasers may modify the dentin surface, improving sealer adhesion and reducing void formation [1].

Surgical endodontics

In apical surgery (apicoectomy), CO_2, Nd:YAG, and diode lasers have been used for incisions, root-end resection, and sterilization. These lasers provide excellent hemostasis, reduce bleeding, eliminate the need for sutures in some cases, and support favorable wound healing [1]. Laser irradiation of resected root surfaces can produce melting or recrystallization of dentin, reducing permeability and potentially lowering the risk of microbial recontamination [1].

Adoption and practitioner reality

Despite the promising clinical outcomes, uptake of lasers in routine endodontic practice remains limited. Factors include high cost, steep learning curve, lack of standardized treatment protocols, and concerns about safety and parameter optimization [1].

Safety and adverse events

Overall, clinical trials report minimal adverse events from laser application in endodontics. However, inconsistencies in parameter reporting (power, duration, fiber design) limit comprehensive safety profiling. Thermal injury to periapical tissues remains a theoretical risk, especially with high-power lasers, without consistent protocol standardization [2].

Clinical success and mechanisms

The clinical success of laser-assisted endodontics stems from multiple complementary mechanisms. First, lasers can enhance disinfection more deeply than irrigants alone. For instance, Nd:YAG lasers penetrate dentin and kill bacteria via thermal effects, while Erbium lasers in LAI mode generate cavitation and acoustic streaming, which boost irrigant efficacy [1]. The synergy of laser energy with chemical irrigants or photosensitizers (aPDT) amplifies antibacterial effects, reaching regions that may be inaccessible to irrigants alone [1].

Second, photo biomodulation (PBM) or low-level laser therapy provides pain modulation via non-thermal mechanisms: reducing inflammatory mediators, modulating neural conduction, and enhancing endogenous healing factors [2]. Clinical data from meta-analyses and systematic reviews confirm significant reductions in postoperative pain at early time points (24–72 hours) (search6, search0) . These effects are clinically relevant because pain is a major factor in patient satisfaction and treatment acceptance.

Third, lasers facilitate improved obturation and sealing. Thermal softening of gutta-percha with Nd:YAG can promote better wall adaptation; erbium lasers can alter the dentin surface to improve sealer adhesion and reduce microleakage [1]. These advantages may translate into higher long-term success by minimizing pathways for reinfection.

Fourth, in surgical endodontics, lasers provide hemostasis, sterilization, and enhanced wound healing. Soft tissue lasers (e.g., diode, CO_2) minimize bleeding; hard-tissue lasers can resect root ends with reduced microleakage due to surface recrystallization [1]. These benefits can enhance patient comfort, reduce suture requirements, and potentially expedite healing.

Additionally, vital pulp therapy benefits from laser use: high-power lasers can achieve adequate hemostasis, sterilize the exposure site, and promote dentin bridge formation with minimal collateral trauma [2]. These features may make laser therapy a compelling alternative or adjunct to conventional pulp-capping materials, especially in minimally invasive endodontics.

Limitations and barriers

Despite the encouraging results, several barriers restrain broader clinical adoption:

1. Heterogeneity in Protocols: Laser studies vary widely in wavelength, power, pulse duration, fiber or tip design, irradiation technique (continuous vs. pulsed), and application duration. This makes it difficult to compare studies or pool data [2].

Safety Concerns: High-power lasers carry a risk of thermal damage. Without standard guidelines, inadvertent overheating can compromise periapical tissue or damage dentinal structure [1].

Cost and Accessibility: Laser units are expensive, and many practices may find the investment unjustified without clear protocol-driven benefits. The lack of consensus guidelines and standardized training further complicates adoption [1].

Evidence Gaps: While pain and disinfection outcomes are relatively well-studied, long-term data on periapical healing, effect on retreatment success, and cost-effectiveness remain limited. Also, many trials involve single-rooted, relatively straightforward cases, limiting generalizability.

Training and Clinical Integration: The learning curve for laser use is non-trivial. Clinicians must be trained not only in device operation but also in understanding tissue interactions, safety protocols, and optimal clinical parameters.

Future directions

To maximize the potential of lasers in endodontics, several strategic avenues should be pursued:

1. Standardization of Clinical Protocols: International consensus should be developed for laser parameters (e.g., wavelength, power, pulse) in different clinical scenarios (disinfection, PBM, surgery). This would facilitate reproducibility, safety, and training.
2. High-Quality Randomized Controlled Trials (RCTs): Large-scale, multicenter RCTs with standardized protocols, long-term follow-up, and clinically meaningful endpoints (healing, reinfection, tooth survival) are necessary to validate benefits and inform guidelines.
3. Cost–Effectiveness Analyses: Economic evaluations comparing laser adjuncts to conventional therapy in terms of equipment cost, chair time, patient satisfaction, and long-term success will help justify clinical investment.
4. Training and Education: Incorporation of laser education into endodontic curricula, workshops, and continuing professional development will build clinician competence and confidence.
5. Safety Research: Studies focused on the thermal effects of lasers on periapical tissues, especially in vivo and with long-term follow-up, are required to define safe operating windows.
6. Emerging Technologies: Research into novel delivery systems (e.g., newer fiber tips, photoactivated irrigation tips like PIPS), combined therapies (laser + aPDT), and minimally invasive vital pulp therapy should continue.

Conclusion

Lasers have increasingly gained attention as valuable adjuncts in contemporary endodontic therapy, with a substantial and growing body of clinical and laboratory research demonstrating their potential to enhance several critical phases of treatment. Numerous studies have shown that laser irradiation can significantly improve root canal disinfection by achieving deeper bacterial reduction within dentinal tubules, surpassing the penetration capabilities of conventional irrigants alone [5, 6]. Additionally, various wavelengths have been associated with a measurable reduction in postoperative discomfort, likely due to their influence on inflammatory mediators and neural modulation, contributing to improved patient comfort and accelerated recovery [7].

Multiple laser systems—including Nd:YAG, diode, Er:YAG, Er,Cr:YSGG, and CO_2—exhibit distinct modes of action such as photothermal, photomechanical, and photoacoustic effects, each providing unique clinical benefits across different steps of endodontic procedures [8]. For example, erbium-based lasers have demonstrated superior smear layer removal and effective activation of irrigating solutions, while Nd:YAG and diode lasers have been shown to enhance bacterial elimination and improve the cleanliness of anatomically complex canals [8]. Such improvements contribute to more predictable canal shaping, more thorough debridement, and potentially improved obturation quality due to enhanced surface preparation.

Despite these promising clinical advantages, widespread integration of laser technology into routine practice remains limited. The literature reveals considerable methodological heterogeneity, with numerous studies varying in irradiation parameters, evaluation techniques, and criteria for success—factors that complicate the development of standardized clinical recommendations [5]. Concerns persist regarding safety, particularly thermal risks to periodontal structures when incorrect settings are used, underscoring the need for precise protocols and operator proficiency [5]. Additionally, financial barriers—including equipment cost and maintenance—further hinder adoption, especially in general practice settings [5].

To advance the integration of lasers into mainstream endodontic care, concerted efforts are required from clinicians, researchers, and governing bodies. These efforts should prioritize the development of evidence-based clinical guidelines, the execution of robust randomized controlled trials with standardized methodology, and the expansion of educational programs to ensure competency and safety in laser use [6]. With further scientific validation and clearer practice frameworks, laser-assisted endodontics holds the promise of transforming treatment outcomes—offering procedures that are more effective, minimally invasive, and better tolerated by patients [7].

Acknowledgments: None

Conflict of interest: None

Financial support: None

Ethics statement: None

References

1. Sadony D, Moharam L. Laser applications in endodontics: a review article. Bull Natl Res Cent. 2024;48(1):103.
2. Huang Q, Li Z, Lyu P, Zhou X, Fan Y. Current applications and future directions of lasers in endodontics: A narrative review. Bioengineering (Basel). 2023;10(3):296.
3. Altuwalah A. The role of lasers in modern endodontics: A narrative review. J Clin Diagn Res. 2024;18(10). doi:10.7860/JCDR/2024/73757.20204
4. Elafifi-Ebeid H, Betancourt P, Parada-Avendaño I, Arnabat-Domínguez J. Post-endodontic pain evaluation after different intracanal laser assisted disinfection techniques. A systematic review. J Clin Exp Dent. 2023;15(2):e149.
5. Schoop U, Kluger W, Moritz A, Nedjelik N, Georgopoulos A, Sperr W. Bactericidal effect of different laser systems in the deep layers of dentin. Lasers Surg Med. 2007;39(7):592–7.
6. Meire MA, De Moor RJ. Lasers in endodontics: laser disinfection, an added value? Endod Topics. 2010;20(1):52–66.
7. Kimura Y, Wilder-Smith P, Matsumoto K. Lasers in endodontics: A review. Dent Clin N Am. 2000;44(4):725–37.
8. Mohammadi Z, Shalavi S, Jafarzadeh H. Laser applications in endodontics: A review. Int Dent J. 2017;67(6):476–86.