IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 25, Issue 8 Ser. 2 (August. 2026), PP 01-05
www.iosrjournals.org

Laser-Assisted Root Canal Therapy: Comparative Efficacy Of Diode, Er:YAG, And Nd:YAG Systems In Endodontics

Andreza Calazans Rodrigues
(Specialist In Endodontics, Inco 25 – University Redentor;, Niterói, Rj, Brazil;
Clinical Assistant Professor At Nova Southeastern University, Clearwater, Fl, Usa)

Maria Luisa Silva De Melo
(Specialist In Endodontics, Faculdade De Odontologia Do Recife;, Recife, Pe, Brazil)

Angelo Zottele Piasentin
(Specialist In Endodontics,Centro Universitário Uningá, Santa Maria, Rs, Brazil;

Sinario Alves De Arruda
(Graduated In Dentistry, Centro Universitário Tocantinense Presidente Antônio Carlos, Araguaina, To, Brazil)

Regina Sanglard De Souza
(Specialist In Endodontics, Cetao, São Paulo, Sp, Brazil)

Bruno Freire Moura
(Graduated In Dentistry, Federal University Of Pernambuco (Ufpe), Recife, Pe, Brazil)

Elissa Frauches Dalla
(Specialist In Endodontics, Abo/Es, Es, Brazil)

Sabrina Lima Dantas Nóbrega
(Specialist In Endodontics, Federal University Of Minas Gerais, Belo Horizonte, Mg, Brazil)

Abstract:
Background: *Lasers have become an increasingly investigated adjunct to conventional chemomechanical root canal preparation, with proposed benefits including enhanced microbial reduction, reduced postoperative pain, and preservation of dentin structure. However, several wavelengths and delivery systems — diode, Er:YAG, and Nd:YAG — are used interchangeably in the literature despite differing photophysical mechanisms and clinical indications.*
Materials and Methods: *A narrative literature review of systematic reviews, meta-analyses, and randomized clinical trials (2015–2026) was conducted to identify which laser system is best supported by current evidence for specific endodontic objectives, drawing on PubMed-indexed sources across root canal disinfection, postoperative pain management, apical periodontitis, and primary-tooth pulpotomy.*
Results: *Er:YAG-based laser-activated irrigation, particularly through photon-induced photoacoustic streaming (PIPS) and shock wave-enhanced emission photoacoustic streaming (SWEEPS), shows the strongest evidence for smear layer removal and biofilm disruption with minimal thermal risk to dentin. Diode lasers demonstrate superior penetration into dentinal tubules and consistent benefit for postoperative pain control and primary-tooth pulpotomy. Nd:YAG lasers show meaningful antimicrobial effect against polymicrobial infections in vitro but remain limited by uncertainty regarding dentin structural safety and a lack of standardized irradiation parameters.*
Conclusion: *No single laser system is unconditionally superior; selection should be guided by the specific clinical objective, root anatomy, and patient risk profile.*
Key Word: *Laser Dentistry; Endodontics; Er:YAG Laser; Diode Laser; Nd:YAG Laser; Root Canal Disinfection; Postoperative Pain.*

Date of Submission: 04-08-2026 Date of Acceptance: 14-08-2026

I. Introduction

Effective elimination of microorganisms from the root canal system remains the central determinant of endodontic treatment success, particularly in cases of apical periodontitis. Conventional chemomechanical instrumentation and sodium hypochlorite (NaOCl) irrigation cannot reliably reach lateral canals, isthmuses, and the apical delta, leaving residual bacterial reservoirs that can compromise healing[1]. Over the past two decades, laser technology has been proposed as an adjunct to conventional irrigation, acting through thermal, photomechanical, or photochemical mechanisms depending on wavelength and target chromophore. Diode, erbium-doped yttrium-aluminum-garnet (Er:YAG), and neodymium-doped yttrium-aluminum-garnet (Nd:YAG) lasers are the systems most frequently investigated in endodontics, each interacting differently with water, hemoglobin, and dentin[2,3]. Despite a growing body of systematic reviews, no consensus has been reached regarding which laser system offers the most favorable balance of antimicrobial efficacy, structural safety, and clinical practicality[4]. This review synthesizes the most recent comparative evidence to clarify which laser option is best supported for specific endodontic objectives.

II. Material And Methods

A narrative literature review was conducted focusing on peer-reviewed, English-language systematic reviews, meta-analyses, and randomized clinical trials on laser use in endodontics, published between 2015 and 2026, supplemented by earlier foundational studies where relevant to context. Search terms combined “laser,” “endodontics,” “root canal,” “Er:YAG,” “Nd:YAG,” “diode laser,” “laser-activated irrigation,” “photobiomodulation,” and “pulpotomy.” Because this is a narrative rather than systematic review, no formal dual-reviewer screening, PRISMA flow diagram, or Cochrane risk-of-bias appraisal was applied to the primary literature; instead, priority was given to the most recent systematic reviews and meta-analyses available for each clinical objective, cross-compared to distinguish long-established evidence from genuinely recent findings.

III. Result

Mechanisms Of Laser–Tissue Interaction In Endodontics

Laser effectiveness in the root canal depends on the wavelength's absorption coefficient in the target chromophore. Er:YAG lasers (2,940 nm) are strongly absorbed by water, producing a photomechanical photoacoustic streaming effect when irrigant is present in the canal; this generates cavitation bubbles that disrupt biofilm and remove the smear layer with comparatively low heat generation and dentin penetration[2]. Diode lasers (810–980 nm) are absorbed less by water and more by pigmented tissue, but their longer wavelength allows deeper optical penetration into dentinal tubules, reaching bacteria that irrigants cannot access; however, diode beams diverge considerably within the canal, limiting precision[3]. Nd:YAG lasers (1,064 nm) act primarily through a photothermal mechanism, denaturing bacterial proteins, disrupting cell membranes, and degrading mixed-species biofilms, but the same thermal effect raises concern about microcracking and structural alteration of root dentin when parameters are not tightly controlled[4].

Root Canal Disinfection And Smear Layer Removal

A systematic review of 15 studies (2015–2025) found that Er:YAG laser activation consistently improved root canal disinfection compared with conventional or ultrasonic irrigation across all included studies, with PIPS and SWEEPS protocols achieving superior apical bacterial reduction and permitting the use of lower NaOCl concentrations without loss of efficacy[2]. Comparative in vitro data similarly found that Er:YAG- and diode-activated irrigation both outperformed conventional syringe irrigation for smear layer removal, with outcomes further modulated by irrigant concentration and laser duty cycle[9]. For polymicrobial and resistant infections specifically, Nd:YAG demonstrated significant reductions in total microbial load through photothermal mechanisms in vitro, although complete sterilization was not consistently achieved and clinical standardization is still lacking[4].

Postoperative Pain Management

A systematic review and meta-analysis of randomized clinical trials found that intraoral laser therapies modestly but measurably improved short-term postoperative pain control after primary and secondary root canal treatment[5]. A separate meta-analysis reached a comparable conclusion, attributing pain reduction to a combination of intracanal antibacterial action and extracanal photobiomodulation[6]. An updated systematic review of low-level laser therapy (LLLT) similarly found significantly less postoperative pain after LLLT across most included trials, though certainty of evidence remained low to very low[12]. A systematic review comparing laser-activated irrigation (LAI) with ultrasonic irrigation (UI) across nine randomized controlled trials and 547 patients found that LAI produced faster pain reduction in the first 24–48 hours, while UI achieved comparable efficacy beyond that window; both outperformed conventional syringe irrigation, with no severe adverse events reported[7].

Apical Periodontitis And Radiographic Healing

A systematic review and meta-analysis restricted to diode laser-assisted irrigation in apical periodontitis concluded that diode therapy produced clinical outcomes broadly comparable to conventional irrigation, with potential benefit for bacterial load reduction and early postoperative pain, but noted that heterogeneity in study protocols and an overall moderate-to-high risk of bias currently limit its recommendation as a routinely superior alternative[1].

Primary Teeth (Pulpotomy)

A review of 36 studies on laser pulpotomy in primary teeth, categorized by laser type, found diode lasers to be the most frequently used and among the most clinically successful (>85% success across various dressing materials), with Nd:YAG also showing favorable long-term outcomes; Er:YAG produced inconsistent results, and evidence for CO2 and low-level laser therapy remained comparatively limited[8]. A randomized clinical trial comparing MTA pulpotomy alone with diode laser-assisted MTA pulpotomy in primary molars found higher clinical and radiographic success in the laser-assisted group at 3-, 6-, and 9-month follow-up (94–95% vs. 84–90%)[15], and a broader comprehensive review of laser photobiomodulation in pediatric endodontics reported favorable clinical evidence across direct pulp capping, pulpotomy, and postendodontic pain management using this technique[11].

General Adjunctive Evidence Across Endodontic Therapy

A systematic review of clinical trials evaluating lasers across direct irradiation, laser-activated irrigation, antimicrobial photodynamic therapy, and photobiomodulation found that almost all included studies (14 of 17) showed a statistically significant improved outcome with laser-assisted endodontic therapy, with the remainder showing no adverse effects[10]. An earlier narrative review focused on high-power diode laser and photodynamic therapy likewise concluded that soft-tissue lasers offer a valuable adjunct role in endodontic treatment[13], and a more recent narrative review reached a similar overall conclusion while cautioning that inconsistent methodology across studies continues to make direct comparisons between laser systems challenging[14].

IV. Discussion

Comparing The Evidence: Is There A "Best" Laser?

Taken together, the literature reviewed does not support declaring one laser system categorically superior to the others. Rather, the strongest evidence is objective-specific. Er:YAG-based laser-activated irrigation has the most consistent support for canal disinfection and smear layer removal with minimal thermal risk to dentin[2], making it the preferable option when structural preservation is a priority, such as in thin-walled or immature roots. Diode lasers offer the deepest antimicrobial penetration into dentinal tubules and the most consistent evidence for postoperative pain reduction and primary-tooth pulpotomy[3,8,15]. Nd:YAG lasers show promising in vitro antimicrobial activity against polymicrobial infections but require further standardization and clinical validation before broader adoption[4]. This pattern echoes the broader adjunctive-therapy literature, in which most controlled studies favor laser-assisted protocols overall, without isolating a single wavelength as definitively superior across every outcome measured[10].

Limitations of the Study

This review has several limitations inherent to its narrative design. First, no formal systematic search protocol, dual-reviewer screening, or risk-of-bias appraisal was applied, so the selection of primary studies cannot exclude selection bias. Second, laser parameters (wavelength, power, pulse mode, duty cycle, fiber tip design) are rarely standardized between studies, which the Er:YAG and Nd:YAG systematic reviews both identify as the principal obstacle to direct comparison[2,4]. Third, meta-analyses of postoperative pain frequently pool heterogeneous laser modalities into a single category, which may obscure wavelength-specific effects[5]. Fourth, much of the antimicrobial evidence for Nd:YAG remains confined to in vitro or ex vivo models, with limited translation to controlled clinical trials[4]. Finally, only English-language, peer-reviewed sources were considered, which may have excluded relevant regional literature.

Proposals for Future Work

1. Conduct adequately powered, multi-center randomized controlled trials directly comparing diode, Er:YAG, and Nd:YAG systems head-to-head for the same clinical objective, rather than relying on indirect comparisons across separate reviews.
2. Establish standardized reporting of laser parameters (wavelength, power, pulse mode, duty cycle, exposure time) to allow pooling of results across studies and centers.
3. Extend follow-up of laser-assisted pulpotomy and disinfection protocols beyond the short- to medium-term windows currently available in most series.

4. Determine the long-term structural safety margin of Nd:YAG and diode irradiation on root dentin under clinically realistic parameters.
5. Incorporate cost-effectiveness and accessibility analyses — particularly relevant for laser adoption within public health systems such as Brazil's SUS — alongside biological outcome measures in future comparative trials.

V. Conclusion

Current evidence does not support a single, universally superior laser system in endodontics. Er:YAG-based laser-activated irrigation (particularly PIPS/SWEEPS protocols) has the strongest support for canal disinfection and smear layer removal with minimal thermal risk to dentin. Diode lasers offer the deepest antimicrobial penetration into dentinal tubules and the most consistent evidence for postoperative pain reduction and primary-tooth pulpotomy. Nd:YAG lasers show promising in vitro antimicrobial activity against polymicrobial infections but require further standardization and clinical validation before broader adoption. Clinicians selecting a laser system should therefore match the wavelength to the specific therapeutic objective, root anatomy, and available clinical evidence rather than assuming interchangeability between systems. Future well-designed, standardized randomized clinical trials with head-to-head wavelength comparisons are needed to resolve the remaining uncertainty identified across recent systematic reviews.

Table no 1: Clinical synthesis — best-supported laser option by objective.

Clinical Objective	Best-Supported Laser	Key Mechanism	Main Limitation
Root canal disinfection with dentin preservation	Er:YAG (PIPS/SWEEPS)	Strong water absorption; photoacoustic streaming disrupts biofilm and smear layer with low thermal risk	Protocols and parameters vary widely across studies
Deep antimicrobial penetration into dentinal tubules	Diode laser	High water absorption in hard tissue allows deeper tubular penetration	Beam divergence limits optical precision
Postoperative pain reduction	Diode / Er:YAG (LAI)	Intracanal antibacterial action plus extracanal photobiomodulation	Heterogeneous laser modalities pooled in meta-analyses
Polymicrobial / resistant infections (adjunct)	Nd:YAG	Photothermal effect: protein denaturation, membrane disruption, biofilm degradation	Uncertain safety margin for dentin structural integrity; parameters not standardized
Pulpotomy in primary teeth	Diode / Nd:YAG	High clinical/radiographic success across follow-up studies	Er:YAG shows inconsistent results; CO2 evidence still limited

References

[1]. Casaretto-Gamonal, M. G., Moreno-Prieto, V., Murillo-Almache, A. M., Calzada-Gonzales, N., Rivera-Lozada, O., & Barboza, J. J. (2026). Efficacy Of Diode Laser Compared To Conventional Irrigation In Endodontic Treatment Of Apical Periodontitis: A Systematic Review And Meta-Analysis. Frontiers In Oral Health. Https://Doi.Org/10.3389/Froh.2026.1814056
[2]. Fiegler-Rudol, J., Grzech-Leśniak, Z., Tkaczyk, M., Grzech-Leśniak, K., Zawilska, A., & Wiench, R. (2025). Enhancing Root Canal Disinfection With Er:Yag Laser: A Systematic Review. Dentistry Journal. Https://Doi.Org/10.3390/Dj13030101
[3]. Zaneva-Hristova, D., Borisova, T., Svetlozarova, S., Kirova, M., & Valkov, B. (2025). The Role Of Laser Technology In Modern Endodontics: A Literature Review. Folia Medica (Plovdiv). Https://Doi.Org/10.3897/Folmed.67.E153378
[4]. Fiegler-Rudol, J., Skaba, D., & Wiench, R. (2025). Antimicrobial Efficacy Of Nd:Yag Laser In Polymicrobial Root Canal Infections: A Systematic Review Of In Vitro Studies. International Journal Of Molecular Sciences. Https://Doi.Org/10.3390/Ijms26125631
[5]. Elmsmari, F., Shujaie, H., Alzaabi, R., González, J. A., Aljafarawi, T., Olivieri, J. G., Jurado, C. A., & Afrashtehfar, K. I. (2024). Lasers Efficacy In Pain Management After Primary And Secondary Endodontic Treatment: A Systematic Review And Meta-Analysis Of Randomized Clinical Trials. Scientific Reports. Https://Doi.Org/10.1038/S41598-024-74998-X
[6]. Luo, L., Et Al. (2024). Efficacy Of Laser Adjuvant Therapy In The Management Of Post-Operative Endodontic Pain: A Systematic Review And Meta-Analysis. International Endodontic Journal. Https://Doi.Org/10.1111/Iej.14140
[7]. Gulhane, A., Sapkale, K. D., Sayed, A., Ramugade, M., Kamble, S., & Magar, A. (2025). Comparative Evaluation Of The Effectiveness Of Laser-Assisted Irrigation And Ultrasonic Irrigation On Postoperative Pain In Single-Visit Endodontics: A Systematic Review. Cureus. Https://Doi.Org/10.7759/Cureus.84947
[8]. Felemban, O. M. (2025). Laser Pulpotomies' Clinical And Radiographic Success In Primary Teeth By Type Of Laser. Children. Https://Doi.Org/10.3390/Children12111508
[9]. Huang, Q., Li, Z., Lyu, P., Zhou, X., & Fan, Y. (2023). Current Applications And Future Directions Of Lasers In Endodontics: A Narrative Review. Bioengineering. Https://Doi.Org/10.3390/Bioengineering10030296
[10]. Anagnostaki, E., Mylona, V., Parker, S., Lynch, E., & Grootveld, M. (2020). Systematic Review On The Role Of Lasers In Endodontic Therapy: Valuable Adjunct Treatment? Dentistry Journal. Https://Doi.Org/10.3390/Dj8030063
[11]. Khan, M. K., Sharma, D. S., & Jindal, M. K. (2024). Laser Photobiomodulation As Noninvasive Therapeutic Modality In Pediatric Endodontics: A Comprehensive Review. Journal Of The Scientific Society. Https://Doi.Org/10.4103/Jss.Jss_48_23
[12]. Guerreiro, M. Y. R., Monteiro, L. P. B., De Castro, R. F., Magno, M. B., Maia, L. C., & Da Silva Brandão, J. M. (2021). Effect Of Low-Level Laser Therapy On Postoperative Endodontic Pain: An Updated Systematic Review. Complementary Therapies In Medicine. Https://Doi.Org/10.1016/J.Ctim.2020.102638
[13]. Marković, D., Rakašević, D., & Trišić, D. (2015). Application Of High-Power Diode Laser And Photodynamic Therapy In Endodontic Treatment - Review Of The Literature. Balkan Journal Of Dental Medicine. Https://Doi.Org/10.1515/Bjdm-2015-0038

[14]. Altuwalah, A. (2024). The Role Of Lasers In Modern Endodontics: A Narrative Review. Journal Of Clinical And Diagnostic Research. Https://Doi.Org/10.7860/Jcdr/2024/73757.20204
[15]. Swarnalatha, C., Babu, J. S., Panwar, P. S., Alquraishi, M. A., Almalaq, S. A., Alnasrallah, F. A., & Nayyar, A. S. (2020). Clinical And Radiographic Evaluation Of Results Of Mta Pulpotomy And Laser-Assisted Mta Pulpotomy. Saudi Endodontic Journal. Https://Doi.Org/10.4103/Sej.Sej_139_19