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Review Article

Clinical Outcomes of diode laser therapy in Patients with dental caries

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Abstract

Background: Diode lasers, originally developed for soft-tissue surgery, have accumulated a wide evidence base across cariology, spanning caries detection, cavity disinfection, restorative pretreatment, pulp therapy, and management of postoperative dentin hypersensitivity.

Objective: To synthesize the clinical and closely supporting mechanistic literature on diode laser therapy in patients with dental caries and characterize where genuine clinical benefit is best established.

Methods: Narrative synthesis of randomized controlled trials, meta-analyses, and supporting in vitro and diagnostic-accuracy studies identified through PubMed/MEDLINE, Scopus, and Google Scholar, organized by stage of the caries-management pathway.

Findings: Diode laser fluorescence adds useful adjunctive diagnostic value for cavitated lesions; diode irradiation produces large but generally sub-chlorhexidine bacterial reductions on the cavity floor; diode pretreatment improves dentin sealing and reduces microleakage before adhesive restorations; diode laser pulpotomy achieves clinical and radiographic success comparable to formocresol and other conventional medicaments across two independent meta-analyses; and low-level diode photobiomodulation reduces dentin hypersensitivity and injection-related pain as effectively as established chemical desensitizers.

Conclusions: Diode laser therapy performs reliably as an adjunct across the caries-treatment pathway and outperforms conventional care specifically in patient-reported comfort, but has not yet demonstrated superiority over established methods on hard restorative or pulpal endpoints, positioning it as a versatile complement within minimally invasive caries management rather than a default replacement.

Keywords: diode laser; dental caries; laser dentistry; pulpotomy; minimally invasive dentistry

1. Introduction

Dental caries remains the most common chronic disease encountered in clinical dentistry, and the way it is managed has shifted markedly over the last two decades, away from the reflexive "drill and fill" of a generation ago and toward staged, minimally invasive protocols built around lesion activity and depth [1,2]. That shift has been driven as much by diagnostic refinement, principally the International Caries Detection and Assessment System and its clinical descendant CariesCare International, as by any single new instrument [1]. Diode lasers sit inside that broader movement rather than apart from it. Marketed originally for soft-tissue surgery because their near-infrared wavelength, typically 810-980 nm, is strongly absorbed by haemoglobin and melanin but poorly absorbed by sound enamel and dentin, diode systems have nonetheless accumulated a wide evidence base in cariology: as an adjunct for detecting occlusal and fissure lesions by laser-induced fluorescence, as a chairside disinfectant after mechanical caries excavation, as a pretreatment before pulp-capping and pulpotomy procedures, and as a low-level modality for desensitising exposed dentin once a restoration is placed [3,4,5,6]; a recent comprehensive review situates these caries-specific applications within a wider trend toward energy-based, minimally invasive care across restorative, endodontic, and periodontal dentistry [7].

The appeal is not difficult to state. A diode unit is compact, relatively inexpensive next to erbium hard-tissue lasers, and easy to retrofit into an existing operatory, and its principal biological actions, bactericidal photothermal heating of residual cariogenic flora and photobiomodulation of pulpal and gingival tissue, map directly onto two persistent problems in caries treatment: incomplete cavity-floor disinfection and postoperative pain or pulpal inflammation after deep restorations [8,9]. What is less settled is how consistently those theoretical advantages translate into outcomes a clinician would notice or a patient would report. This review synthesizes the clinical, and where trials are scarce, the closely supporting in vitro literature on diode laser use across the caries-management pathway, and asks where the evidence for genuine clinical benefit is strongest and where it remains provisional.

2. Methods

This is a narrative synthesis rather than a registered systematic review, reflecting the heterogeneity of outcome measures across the diode laser literature, which spans diagnostic accuracy studies, randomized clinical trials, split-mouth pulpotomy cohorts, and in vitro microbiological work. PubMed/MEDLINE, Scopus, and Google Scholar were searched for English-language records published through 2026 using combinations of "diode laser," "dental caries," "cavity disinfection," "pulpotomy," "pulp capping," "laser fluorescence," "dentin hypersensitivity," and "minimally invasive dentistry." Priority was given to randomized controlled trials and meta-analyses reporting a clinical or near-clinical endpoint; mechanistic and in vitro studies were retained where they explained a clinical finding or where trial data for a given application were thin. Erbium-family (Er:YAG, Er,Cr:YSGG) laser studies were included only as comparators, since those systems ablate hard tissue by a fundamentally different, photothermal-vaporization rather than sub-ablative mechanism. Twenty-four sources meeting these criteria were synthesized below, organized by stage of the caries-management pathway.

3. Results

Diagnostic use: laser-induced fluorescence for lesion detection

Diode laser fluorescence devices, most widely represented by handheld units projecting 655 nm light onto tooth structure and reading back the fluorescence emitted by bacterial metabolites, were among the earliest cariology applications of the technology and remain the most extensively validated. Kavvadia and Lagouvardos

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evaluated a diode fluorescence device against visual-tactile and radiographic reference standards for occlusal caries in primary teeth and reported clinically useful, though imperfect, diagnostic performance, better at distinguishing frankly cavitated from sound surfaces than at resolving the borderline, early-enamel end of the spectrum [3]. Chu and colleagues reached a similar conclusion comparing visual-tactile fissure caries diagnosis against laser-induced fluorescence, finding the two broadly concordant but neither perfectly sensitive, and recommending fluorescence as an adjunct that refines rather than replaces clinical judgement [10]. More recent work on intra-examiner agreement under magnification loupes versus unaided ICDAS II scoring, while not laser-specific, reinforces the same point: examiner-dependent variability is large enough that any adjunctive device, laser fluorescence included, narrows rather than eliminates diagnostic uncertainty [11].

Table 1: Diode laser therapy across the caries-management pathway, by clinical role and supporting evidence [3,10,4,14,5,20,6,9].

Pathway stage	Diode laser role	Representative evidence	Outcome signal
Detection	Laser-induced fluorescence adjunct	[3,10]	Useful for cavitated lesions; limited at early-enamel boundary
Cavity disinfection	Photothermal bactericidal irradiation	[4,14]	Large CFU reduction; below chlorhexidine/ nanoparticle benchmarks
Restorative pretreatment	Dentin sealing / microleakage reduction	[5]	Improved dentin thickness retention, less discoloration
Pulp therapy	Pulpotomy / pulp-capping adjunct	[20]	Comparable success to conventional medicaments
Postoperative comfort	Photobiomodulation	[6,9]	Reduced hypersensitivity and injection pain

Cavity disinfection and antibacterial effect

The most mechanistically direct clinical application of diode lasers in cariology is bacterial reduction on the cavity floor after excavation, and this is also where the evidence is most quantitatively convergent. Lee and colleagues, working in vitro with Streptococcus mutans irradiated through varying thicknesses of dentin, showed that diode laser energy retains meaningful bactericidal effect even when attenuated by 0.5-1.0 mm of intact dentin, supporting the rationale for irradiating a cavity floor rather than requiring direct line-of-sight to every bacterium [8]. Robati and colleagues extended this to a mixed-flora model, finding low-level diode irradiation suppressed growth of both S. mutans and Lactobacillus acidophilus, the two organisms most implicated in dentin caries progression [12]. Clinical confirmation followed: in a randomized controlled trial comparing diode laser irradiation against zinc oxide nanoparticle disinfection after partial caries removal, Khattab and colleagues measured colony-forming-unit reduction of 93.77% with the diode laser against 97.4% with the nanoparticle suspension, a gap that reached statistical significance in favour of the nanoparticle arm but still left the laser producing a large, clinically meaningful reduction in cavity bioburden on its own [4]. Khafagi and colleagues' in vitro comparison of chlorhexidine, Er:YAG laser, and 980 nm diode laser as dentine disinfectants similarly found all three approaches effective, with the diode performing competitively against chlorhexidine, the longstanding chemical benchmark [13]. A smaller pilot in vitro study by Zotti and colleagues qualified this picture usefully: chlorhexidine achieved complete bacterial suppression in their standardized cavity model, while diode laser irradiation left residual contamination in a subset of samples, a reminder that "large reduction" and "sterilization" are not the same claim and that laser disinfection protocols are better framed as adjuncts to, rather than replacements for, chemical or mechanical debridement [14].

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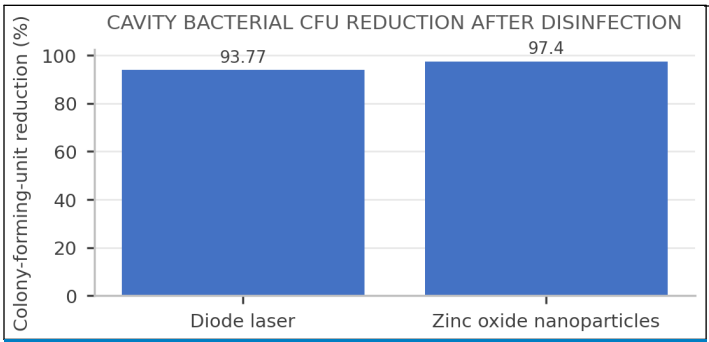

Figure 1: Cavity-floor bacterial colony-forming-unit reduction after partial caries removal, diode laser irradiation versus zinc oxide nanoparticle disinfection, from a randomized controlled clinical trial [4].

Cavity preparation, restoration integrity, and adjunctive pretreatment

Diode lasers have made comparatively less headway in direct hard-tissue ablation, a role for which erbium-family lasers remain far better suited given their strong absorption by water and hydroxyapatite. Esteves-Oliveira and colleagues' meta-analysis of laser-assisted caries removal and hard-tissue preparation, pooling 20 studies across roughly 2,260 teeth, found that laser-assisted techniques (predominantly erbium-family, with diode systems used as an adjunct in a subset) reduced reported pain and anaesthesia requirements relative to conventional bur preparation, but took significantly longer chair time, and produced no significant difference in restoration survival or pulp vitality at follow-up [15]. Dipalma and colleagues' systematic review comparing Er:YAG laser against the conventional dental turbine in paediatric patients reported the same pattern of reduced pain and anxiety scores at the cost of longer procedure time, findings that likely generalize qualitatively to diode-assisted protocols even though the ablative mechanism differs [16]. Diode lasers have instead found a more specific restorative niche as a pretreatment step. Elgamily and colleagues' randomized trial of diode laser pretreatment before biodentine placement in deep caries found laser-irradiated cavities retained greater residual dentin thickness and showed less discoloration at follow-up than non-irradiated controls, attributing the effect to mild coagulative sealing of exposed dentinal tubules ahead of the bioactive cement [17]. Oskoee and colleagues, comparing Nd:YAG laser, diode laser, and photodynamic therapy as adjuncts before Class V composite placement, found all three reduced microleakage relative to untreated controls, with the diode laser comparable to the other two energy-based approaches [18]. Where diode lasers substitute for chemical caries-removal agents rather than the bur itself, Salem and colleagues' trial comparing diode laser, silver diamine fluoride, and a combined protocol as a modification of the Hall technique in primary molars found the laser arm performed comparably to silver diamine fluoride in arresting lesion progression, offering an alternative where the black staining of silver diamine fluoride is a barrier to acceptance [19].

Pulp therapy: pulp capping and pulpotomy

The largest concentration of diode-laser randomized trial evidence in cariology concerns pulp therapy following deep, pulp-adjacent or pulp-exposing caries. Yazdanfar and colleagues' randomized trial of diode laser combined with resin-modified tricalcium silicate for direct pulp capping of carious exposures in permanent teeth reported favourable short-term clinical and radiographic success, consistent with the rationale that irradiation before placing the capping agent reduces residual bacterial load and promotes a more favourable healing response at the exposure site [5]. In primary teeth, where pulpotomy rather than pulp capping is the dominant approach, the evidence now supports meta-analysis. Gao and colleagues pooled 17 randomized controlled trials totalling 1,018 primary teeth and found diode laser pulpotomy achieved clinical and radiographic success statistically comparable to conventional pulpotomy medicaments, concluding it is a viable alternative rather than a clearly superior one [20]. Cao and colleagues' independent systematic review and meta-analysis reached a concordant safety and efficacy conclusion [21]. Individual trials sit comfortably within that pooled picture: Ansari and colleagues' split-mouth

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comparison of diode laser pulpotomy against formocresol found 100% clinical success in both arms at six and twelve months, with the laser arm showing 95% and 90% radiographic success at those same intervals and no statistically significant difference from formocresol, evidence that laser pulpotomy performs on par with an established medicament while avoiding its tissue-fixative drawbacks [22]. Haghgoo and colleagues extended follow-up to three years in a split-mouth trial pairing diode laser pulpotomy with one of three capping agents, mineral trioxide aggregate, calcium-enriched mixture cement, or calcium hydroxide, and found MTA and CEM produced significantly better radiographic outcomes than calcium hydroxide by 36 months, though clinical success remained comparable across all three; the finding locates the capping agent, not the laser step, as the dominant determinant of long-term radiographic outcome once diode pulpotomy is used [23].

Table 2: Diode laser pulpotomy outcomes in primary teeth across two independent meta-analyses and two primary randomized trials [20,21,22,23].

Study	Design	Comparator	Key finding
[20]	Meta-analysis, 17 RCTs, 1018 teeth	Conventional pulpotomy medicaments	Comparable clinical/radiographic success
[21]	Systematic review and meta-analysis	Conventional pulpotomy	Concordant efficacy and safety
[22]	Split-mouth RCT, 6-12 months	Formocresol	100% clinical success both arms; 95%/90% laser radiographic success
[23]	Split-mouth RCT, 36 months	MTA vs CEM vs calcium hydroxide capping	MTA/CEM superior to calcium hydroxide radiographically

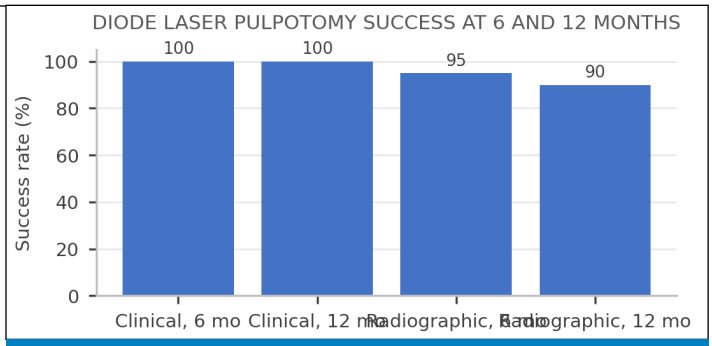

Figure 2: Clinical and radiographic success of diode laser pulpotomy in primary molars at 6 and 12 months in a split-mouth randomized trial against formocresol, with 100% clinical success in both arms at both intervals [22].

Postoperative sensitivity and patient-reported comfort

Diode lasers also carry a low-level, sub-ablative application distinct from disinfection and pulpotomy: photobiomodulation for dentin hypersensitivity and procedural discomfort. Orhan and colleagues' trial comparing low-level diode laser therapy against a glutaraldehyde-based desensitizer for cervical dentin hypersensitivity found both active treatments significantly reduced visual-analogue sensitivity scores within seven days relative to placebo, with no significant difference between them, positioning photobiomodulation as a non-pharmacological alternative for patients intolerant of topical desensitizers [6]. In a paediatric context further removed from restorative treatment but mechanistically related, Seraj and colleagues' double-blind randomized trial found photobiomodulation with an 810 nm diode laser reduced children's reported pain during local-anaesthetic injection, consistent with diode lasers' broader capacity to modulate peripheral nociceptor signalling independent of any bactericidal or restorative action [9].

4. Discussion

Taken as a whole, the clinical outcomes literature on diode laser therapy in dental caries management describes a technology that performs reliably well in several well-defined roles and remains, at best, an equal alternative rather than a clear advance in others. The

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strongest evidence sits at two ends of the caries-treatment pathway. At the front end, diode fluorescence devices add real, if modest, diagnostic value, catching frankly cavitated lesions reliably while contributing less at the ambiguous, early-lesion boundary [3,10,11]. At the back end, low-level diode photobiomodulation performs on par with established chemical desensitizers and reduces injection discomfort in children [6,9]. In between, the picture is more nuanced. Diode-mediated cavity disinfection produces large, biologically meaningful bacterial reductions that remain a step behind chlorhexidine or, in the one head-to-head trial available, zinc oxide nanoparticles [4,13,14]. And in pulp therapy, where the trial base now supports two independent meta-analyses, diode laser pulpotomy has cleared the bar of statistical non-inferiority against formocresol and other conventional medicaments repeatedly, without yet demonstrating clear superiority on any hard endpoint [20,21,22].

Two structural limitations temper all of the above. First, almost none of the RCTs identified compared diode laser protocols against every relevant conventional alternative in the same trial; most compare a single laser protocol against a single, often already-favoured comparator, which makes cross-study synthesis, and the meta-analyses built on it, dependent on assumptions about comparator equivalence that the primary literature was not designed to test. Second, chair time is the outcome least favourable to laser-assisted protocols and the most consistently reported: both the Esteves-Oliveira and Dipalma meta-analyses found laser preparation measurably slower than bur preparation even where pain and anxiety scores improved, a trade-off that matters for practice economics in a way pain scores alone do not capture [15,16]. Set against the wider minimally invasive dentistry literature, where emphasis has shifted from removing all discoloured tissue to preserving remineralizable dentin and prioritising a durable adhesive seal, diode laser therapy fits best as one of several tools, alongside selective excavation, silver diamine fluoride, and bioactive restorative cements, deployed depending on lesion depth, patient tolerance, and operator preference [1,24,2].

5. Conclusion

Across detection, disinfection, restorative pretreatment, pulp therapy, and postoperative comfort, diode laser therapy in patients with dental caries produces outcomes that are consistently comparable to, and in the specific domains of dentin hypersensitivity and injection pain measurably better tolerated than, conventional treatment, without yet establishing decisive superiority on hard clinical endpoints such as restoration survival or long-term pulpotomy success [15,20,6]. Its most defensible current uses are as a diagnostic adjunct for occlusal and fissure lesions, a disinfecting adjunct after mechanical caries excavation, a pretreatment step before adhesive or bioactive restorations, and a comfort-oriented modality for dentin hypersensitivity and local-anaesthetic discomfort, each supported by trial or meta-analytic evidence rather than mechanistic plausibility alone. What the literature does not yet support is treating diode laser therapy as a wholesale replacement for conventional excavation, chemical disinfection, or established pulpotomy medicaments; the realistic clinical role, consistent with the broader shift toward minimally invasive, lesion-staged caries management, is as a versatile adjunct chosen case by case rather than a default substitute for the tools it has so far only matched.

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8. Conflict of Interest

The authors declare no conflict of interest.

9. Author Contributions

S.A. conceived the review and drafted the manuscript; K.M. conducted the literature search and prepared the tables and figures; C.B. critically revised the manuscript for intellectual content. All authors approved the final version.

10. Ethics Statement

This is a narrative literature synthesis and did not involve human participants, patient data, or animal subjects requiring institutional ethics approval.

11. Data Availability

No new datasets were generated; all data discussed are drawn from the cited published sources.

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