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Original article

Clinical and Radiographic Evaluation of Diode Laser Pulpotomy in Primary Teeth: A Systematic Review

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Abstract
Pulpotomy remains the most widely accepted vital pulp therapy for carious or traumatically exposed primary teeth. While conventional medicaments such as formocresol and ferric sulfate have shown satisfactory results, concerns regarding cytotoxicity and systemic risks have prompted interest in diode lasers as an alternative. This systematic review aimed to evaluate the clinical and radiographic success of diode laser pulpotomy in primary teeth and compare outcomes with conventional pharmacotherapeutic techniques. Electronic searches were conducted in PubMed, Scopus, Web of Science, Cochrane Library, and Google Scholar for studies published between 2015 and 2025. Studies reporting clinical and radiographic outcomes of diode laser pulpotomy in primary teeth were included. Risk of bias was assessed using the Cochrane Risk of Bias 2.0 tool and the Newcastle–Ottawa Scale. Data were synthesized narratively. Fourteen studies involving over 800 primary molars were included. Diode laser pulpotomy achieved clinical success rates of 90–100%, broadly comparable to those of formocresol, ferric sulfate, and MTA. Radiographic success rates were more variable but were generally comparable to, and in some studies exceeded, those reported for conventional pulpotomy agents, particularly when diode laser treatment was combined with bioactive materials such as MTA or Biodentine. No statistically significant differences were observed in most comparative studies ($p > 0.05$). Diode laser pulpotomy is a safe and effective alternative to conventional agents in primary teeth. Its bactericidal action, immediate hemostasis, and biocompatibility offer tangible clinical advantages. However, the lack of standardized protocols limits definitive recommendations regarding optimal laser parameters.
Keywords. Diode Laser, Pulpotomy, Primary Teeth, Vital Pulp Therapy, Systematic Review.

Introduction

Pulpotomy is the cornerstone of vital pulp therapy in primary teeth affected by deep caries or trauma. The primary objective is to remove the inflamed coronal pulp while preserving the vitality and function of the radicular pulp until physiological exfoliation [1]. For decades, dentists have relied on chemical medicaments—formocresol, ferric sulfate, and mineral trioxide aggregate (MTA)—to fix the remaining pulp tissue. These agents have produced acceptable clinical outcomes, but not without reservations. Formocresol, in particular, has attracted sustained criticism for its cytotoxicity, potential carcinogenicity, and inconsistent long-term performance [1,2]. These concerns have driven the search for safer and more biologically compatible alternatives.

Diode lasers (wavelength 810–980 nm) have emerged as one such alternative. Their near-infrared output is absorbed preferentially by hemoglobin and melanin, with minimal uptake by water and hydroxyapatite [3,7]. In pulpotomy, this translates to precise tissue ablation, rapid hemostasis, bacterial reduction, and limited collateral thermal damage.[4] The avoidance of chemical medicaments with known cytotoxic potential is an important advantage; the potential for photobiomodulation-mediated healing is a promising, if less certain, benefit.[5]

The evidence base, however, remains fragmented. Laser parameters—power, wavelength, exposure time, and application mode—vary considerably between studies, producing inconsistent results [6,7]. Some investigators report complete success; others caution that technique sensitivity demands greater standardization before widespread adoption.

This systematic review was undertaken to clarify the position of diode laser pulpotomy within contemporary pediatric dentistry. Specifically, we aimed to: (i) determine clinical success rates; (ii) evaluate radiographic outcomes, including root resorption, periapical pathology, and dentin bridge formation; and (iii) compare laser outcomes directly with conventional pharmacotherapeutic methods.

Materials And Methods

Search strategy

Five databases were searched: PubMed, Scopus, Web of Science, Cochrane Library, and Google Scholar. The search covered publications from January 2015 to December 2025. Search terms included combinations of "diode laser," "pulpotomy," "primary teeth," "vital pulp therapy," "pediatric dentistry," and specific wavelengths (810 nm, 940 nm, 980 nm). Only English-language full-text articles were considered.

The review question was structured using the PICO framework:

- Population: Children requiring pulpotomy for vital primary molars
- Intervention: Diode laser pulpotomy
- Comparison: Conventional pulpotomy agents (formocresol, MTA, ferric sulfate)

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- Outcome: Clinical success (absence of pain, swelling, pathological mobility) and radiographic success (absence of internal/external root resorption, furcation radiolucency, periapical pathology)

The study selection process is illustrated in (Figure 1).

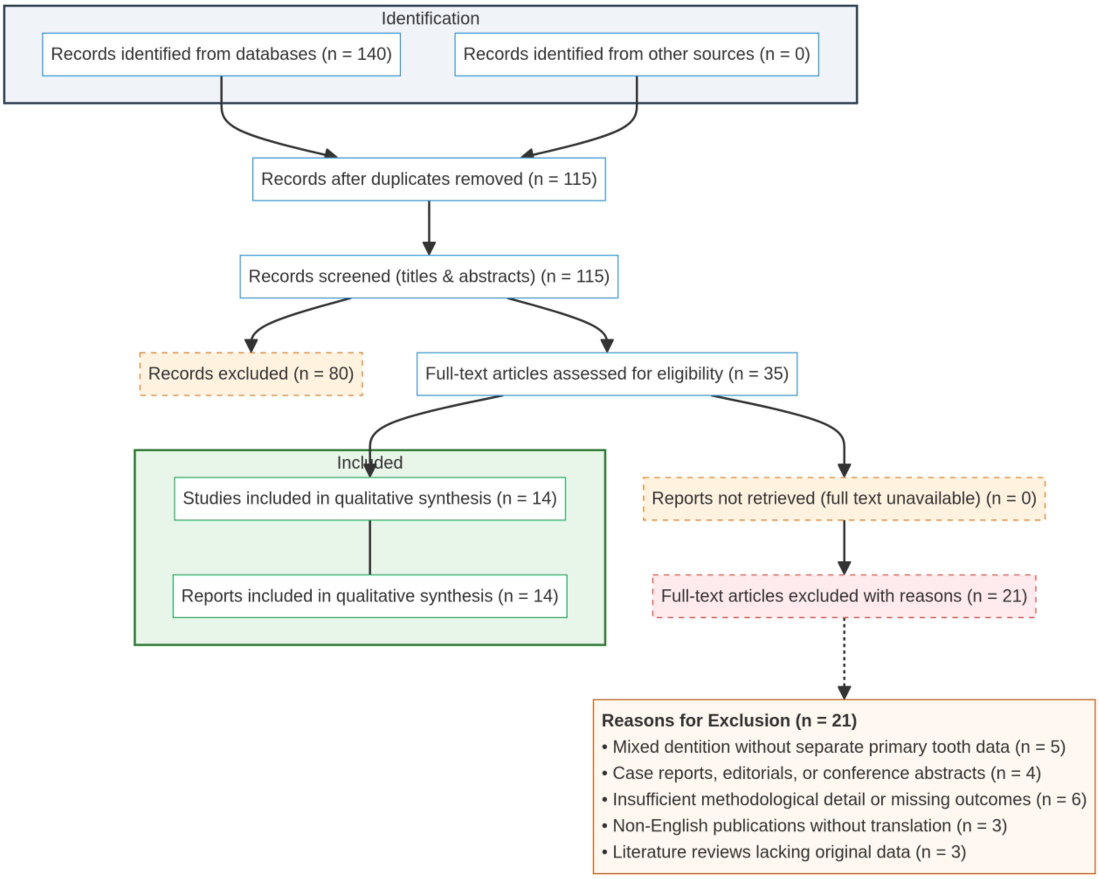

Figure 1. Study selection process

Study selection

Selection followed PRISMA guidelines. Two reviewers independently screened titles, abstracts, and full texts. Disagreements were resolved by consensus.

Inclusion criteria

- Primary teeth treated with diode laser pulpotomy
- Both clinical and radiographic outcomes reported
- Publication between 2015 and 2025
- Pediatric population

Exclusion criteria

- Mixed dentition studies without separate primary tooth data
- Case reports, editorials, conference abstracts, narrative reviews
- Insufficient methodological detail or missing outcome data
- Non-English publications without an available translation

Quality assessment

Randomized controlled trials were assessed using the Cochrane Risk of Bias 2.0 tool, whereas observational studies were evaluated using the Newcastle–Ottawa Scale. Two reviewers independently assessed study quality, and disagreements were resolved through discussion. The results of the quality assessment were considered during data interpretation.

Data extraction

A standardized form captured: author/year, design, sample size, laser parameters (wavelength, power, duration, mode), comparison group, follow-up period, and clinical/radiographic outcomes. Two reviewers extracted data independently, then sat down together to iron out any disagreements.

Given the heterogeneity in study designs, laser parameters, and outcome definitions, a narrative synthesis was performed. Studies were grouped thematically for comparison.

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Ethical considerations
This review did not involve primary human or animal research. All included clinical studies reported institutional ethics approval and parental informed consent. Our review adhered to principles of transparency, objectivity, and respect for intellectual property.

Results and discussion

Study characteristics
Fourteen studies met the inclusion criteria: randomized controlled trials, clinical trials, and comparative observational studies. Collectively, they followed over 800 primary molars with follow-up ranging from 6 to 24 months. Ten studies were judged to be at low risk of bias, three at moderate risk, and one at high risk. The findings of the high-risk study were interpreted cautiously during the narrative synthesis.

Clinical success rates
Diode laser pulpotomy consistently produced clinical success rates between 90% and 100% (Table 1). These outcomes were generally comparable to those reported for conventional pulpotomy agents. In direct comparisons, most studies found no statistically significant difference between laser and control groups ($p > 0.05$). A few studies reported 100% success, occasionally surpassing the comparison arm. However, low-level laser therapy (LLLT) showed less consistent durability, with one study documenting a decline over follow-up.[4] This suggests that application mode and parameters meaningfully influence outcomes. Notably, protocols combining a diode laser with MTA or a calcium-enriched mixture (CEM) reported particularly favorable results, suggesting a potential synergistic effect between laser energy and bioactive capping materials.

Table 1. Clinical success rates of diode laser pulpotomy in primary teeth.

Study	Diode laser success (%)	Comparison success (%)	Follow-up	p-value
Fadhil & Noori, 2024 [10]	100	FC 96; NaOCl 88	12 mo	>0.05
Uloopi et al., 2016 [4]	95→80 (LLLT)	MTA 94.7	12 mo	>0.05
Aripirala et al., 2021 [11]	81.6→76.1	Simvastatin 82.6→80.4	12 mo	0.499
Yavagal et al., 2021 [12]	94.1 (LPBM)	Formocresol 97.05	9 mo	0.55
Nadhreen et al., 2021 [13]	98 (LLLT)	Formocresol 98	9 mo	1.0
Krothapalli et al., 2015 [14]	90	MTA 100; Biodentine 90	6 mo	>0.05
Shaikh et al., 2019 [15]	94.2	Formocresol 92.8	9 mo	>0.05
Kuo et al., 2017 [16]	100	NaOCl 100; none 87.5	24 mo	>0.05
Joshi et al., 2017 [17]	100	Formocresol 100	12 mo	>0.05
Ansari et al., 2018 [18]	100	Formocresol 100	12 mo	>0.05
Simonoska et al., 2023 [19]	90 (Laser+MTA)	Conventional 80–90	6 mo	>0.05
Ansari et al., 2017 [20]	100 (CEM+LLLT)	FC 100; FS 95; CEM 97.5	12 mo	>0.05
Alamoudi et al., 2020 [21]	96.1 (LLLT)	Formocresol 96.1	12 mo	>0.05
Roy et al., 2023 [22]	100 (LLDL)	Electrosurgery 100	12 mo	>0.05

FC, formocresol; MTA, mineral trioxide aggregate; NaOCl, sodium hypochlorite; FS, ferric sulfate; CEM, calcium-enriched mixture; LLLT, low-level laser therapy; LPBM, laser photobiomodulation; LLDL, low-level diode laser.

Radiographic success rates
Radiographic outcomes were more variable than clinical results (Table 2). Several studies approached 100% radiographic success; others reported substantially lower figures, especially when laser parameters deviated from established ranges. This divergence highlights an important clinical reality: a tooth may be asymptomatic while harboring subclinical radiographic changes. In head-to-head comparisons, the diode laser frequently outperformed formocresol radiographically. Yavagal et al. [12] reported 94.1% versus 58.8%—a striking difference suggesting superior biological compatibility. Protocols incorporating MTA, CEM, or optimized laser settings achieved the highest radiographic success rates.

Table 2. Radiographic success rates of diode laser pulpotomy in primary teeth.

Study	Diode laser success (%)	Comparison success (%)	Follow-up	p-value
Fadhil & Noori, 2024[10]	98→95	FC 92→85	12 mo	>0.05
Uloopi et al., 2016[4]	93.2	MTA 94.7	12 mo	>0.05
Aripirala et al., 2021[11]	56.5→52.1	Simvastatin 67.4→65.2	12 mo	0.304
Yavagal et al., 2021[12]	94.1 (LPBM)	Formocresol 58.82	9 mo	0.001*
Nadhreen et al., 2021[13]	100 (LLLT)	Formocresol 98	9 mo	0.317
Krothapalli et al., 2015[14]	90	MTA 100; Biodentine 90	6 mo	>0.05
Shaikh et al., 2019[15]	91.7	Formocresol 90.2	9 mo	>0.05
Kuo et al., 2017[16]	90.9	NaOCl 100; none 87.5	24 mo	>0.05

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Joshi et al., 2017[17]	78.8	Formocresol 57.8	12 mo	>0.05
Ansari et al., 2018[18]	90	Formocresol 100	12 mo	>0.05
Simonoska et al., 2023[19]	90 (Laser+MTA)	Conventional 80–90	6 mo	>0.05
Ansari et al., 2017[20]	100 (CEM+LLLT)	FC 100; FS 92.5; CEM 95	12 mo	>0.05
Alamoudi et al., 2020[21]	100 (LLLT)	Formocresol 98	12 mo	>0.05
Roy et al., 2023[22]	100 (LLDL)	Electrosurgery 96.8	12 mo	>0.05

**Statistically significant. Other abbreviations as in (Table 1).*

Comparative efficacy

Versus formocresol: Clinical equivalence was the norm, with occasional radiographic superiority for the laser. The elimination of formaldehyde exposure is an additional, non-trivial benefit.

Versus MTA: Short-term outcomes (6–12 months) were comparable. MTA maintained a marginal advantage in long-term radiographic stability, though laser–MTA combination protocols produced excellent results.

Versus ferric sulfate: Similar success profiles, with the laser offering more predictable hemostasis.

Versus sodium hypochlorite and electrosurgery: Comparable or marginally favorable outcomes for the laser.

The principal advantages of the diode laser across comparisons were biocompatibility, bactericidal action, and hemostatic control. Barriers to adoption included equipment cost, training requirements, and the absence of standardized protocols.

Interpretation of key findings

The evidence assembled in this review supports diode laser pulpotomy as a clinically viable alternative to conventional chemical medicaments. Clinical success rates of 90–100% recur across independent studies and patient cohorts, matching the performance expected from established protocols.

Radiographic outcomes may represent an important advantage of diode laser pulpotomy, although the available evidence remains heterogeneous. Several studies documented healthier periapical and furcation architecture following laser treatment compared with formocresol.[12,17] This likely reflects the combined effects of bacterial load reduction, minimal collateral tissue damage, and possible photobiomodulation-mediated healing.

Several biological mechanisms may explain these findings. Immediate hemostasis creates a clean operative field, reducing the risk of bacterial contamination and blood clot entrapment. The bactericidal effect of laser irradiation lowers the residual microbial burden in the pulp chamber. Photobiomodulation at appropriate parameters may stimulate cellular metabolism and dentin bridge formation, though this mechanism requires further elucidation.

The variability in reported outcomes is likely attributable to heterogeneity in laser parameters, application techniques, and study methodology. Wavelength, power density, exposure duration, and application mode (contact versus non-contact) varied widely across studies. Without standardization, clinicians cannot know whether a reported failure reflects an inherent limitation or suboptimal technique.

The marked radiographic superiority observed in the study by Yavagal et al. [12] (94.1% versus 58.8% for formocresol) warrants cautious interpretation. This substantial divergence may reflect differences in radiographic assessment criteria between the laser and control groups, operator-dependent technique sensitivity, or potential ascertainment bias favoring the laser arm. The single-study nature of this finding and the absence of independent replication underscore the need for standardized radiographic protocols in future trials.

From a clinical perspective, diode laser pulpotomy offers several practical advantages. It reduces postoperative discomfort, eliminates chemical toxicity concerns, and shortens operative time through rapid hemostasis. For pediatric patients—who often experience significant dental anxiety—these translate to calmer appointments and fewer return visits. For parents, the absence of formocresol is frequently decisive.

Limitations of the reviewed evidence

The limitations of this review mirror those of the underlying literature. Study designs, laser parameters, and follow-up durations were heterogeneous. Most studies tracked outcomes for 12 months or less, leaving long-term behavior near exfoliation uncertain. Radiographic success criteria were not uniform. Restriction to English-language publications may have excluded relevant non-English research.

Recommendations for clinical practice

Based on the most robust evidence, we propose the following practical parameters for clinicians considering diode laser pulpotomy (Table 3). The combination of laser application with MTA or Biodentine capping appears optimal, leveraging bactericidal preparation with bioactive sealing.

Common errors to avoid include using LLLT as a standalone treatment, insufficient exposure duration (<10 seconds per canal), direct fibre-to-tissue contact, and cutting corners on the coronal seal.

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Table 3. Proposed parameters for diode laser pulpotomy in primary teeth.

Parameter	Recommended setting
Laser type	High-power diode laser
Wavelength	810–980 nm
Power output	1.5–2.0 W
Mode	Continuous or pulsed
Fibre diameter	400 µm
Exposure time	10–15 seconds per canal

Recommendations for future research
Future research priorities include: large randomized trials with uniform parameters and ≥24-month follow-up; histological characterization of laser-induced dentin bridges; cost-effectiveness analyses; direct wavelength comparisons; and patient-reported outcome measures, including pain and anxiety scores.

Conclusion
Diode laser pulpotomy is a safe, effective, and biologically favorable alternative to conventional chemical medicaments in primary teeth. Clinical success is reliably high; radiographic outcomes are frequently equivalent or superior, particularly when combined with bioactive capping materials. Although MTA may demonstrate slightly superior long-term radiographic performance, diode laser therapy offers additional advantages, including rapid hemostasis, antimicrobial activity, and improved patient comfort. Current evidence supports the combination of diode laser pulpotomy with bioactive materials such as MTA or Biodentine to achieve optimal clinical and radiographic outcomes, although further standardization is required.

Authors' contributions
- **Amal Mohammed Abdlsadeg:** Conceptualization, methodology, formal analysis, writing—original draft.
- **Rowida Miftah Aween:** Investigation, data curation, visualization, writing—review and editing.
- **Nadin Hussein Elgandouz:** data curation, writing, review, editing, Supervision, validation, and final approval.

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Conflicts of interest
The author declares no conflict of interest.

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Availability of Data and Materials
All data generated or analyzed during this study are included in this published article and its supplementary information files. The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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