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Photobiomodulation for Acute Dental Pain: Evidence-Based Applications for Local Anesthesia, Endodontic Treatment and Oral Surgery

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Abstract

Photobiomodulation (PBM), also called low-level laser therapy, is increasingly used as a non-pharmacologic adjunct for acute dental pain. This review synthesizes current clinical evidence for PBM in three settings relevant to general practice: pain during local anesthetic injection (including its emerging use to increase anesthesia depth and reduce the need for supplemental injections), postoperative pain after endodontic treatment and pain and analgesic use following extractions and minor oral surgery. Randomized trials and recent systematic reviews report that PBM applied to the mucosa before injection modestly but significantly reduces reported injection pain, with the most consistent signal in pediatric patients and separately improves anesthesia success during inferior alveolar nerve block in symptomatic irreversible pulpitis. For postoperative endodontic pain, most systematic reviews describe a favorable trend, but certainty is limited by small samples and heterogeneous laser parameters and at least one recent well-controlled trial found no benefit. The most consistent evidence supports PBM after third-molar extraction and other oral surgery, where multiple trials and meta-analyses report reduced pain, edema, trismus and analgesic consumption, generally graded low-to-moderate certainty. Across all three applications, wavelength, dose, timing and delivery technique vary considerably between studies, limiting direct comparison and protocol standardization. This review summarizes the reported parameters, the strength and limitations of the evidence base and offers practical recommendations for general dentists considering PBM as an adjunct-not a replacement-for established pharmacologic pain control.

Keywords: Photobiomodulation; Low-Level Laser Therapy; Dental Pain; Local Anesthesia; Endodontics; Third Molar Surgery

Introduction

Injection-related pain and anxiety, postoperative endodontic discomfort and pain after extractions and minor oral surgery remain among the most common sources of acute pain encountered in general dental practice and unmanaged pain is a well-documented contributor to dental avoidance [4]. While local anesthesia, nonsteroidal anti-inflammatory drugs, and, when indicated, opioid analgesics remain the foundation of dental pain management, non-pharmacologic adjuncts have drawn growing clinical interest and Photobiomodulation (PBM) is now one of the more extensively studied of these adjuncts [1].

PBM refers to therapeutic irradiation with red or near-infrared light, typically in the 600-1000 nm range, delivered at power levels low enough to avoid a significant thermal effect on tissue [1,2]. The World Association for Laser Therapy's 2026 position paper on PBM for orofacial pain describes low-level laser therapy and light-emitting-diode devices as sharing this common non-thermal mechanism, distinguishing PBM from ablative or surgical laser use [2]. Rather than cutting or coagulating tissue, PBM is proposed to act by absorption of light in mitochondrial chromophores, principally cytochrome c oxidase, which increases adenosine triphosphate production and modulates downstream inflammatory signaling [1]. For pain specifically, proposed mechanisms include a reversible slowing of nerve conduction in myelinated Aδ and unmyelinated C fibers, changes in local microcirculation and reductions in pro-inflammatory mediators, with some clinical studies also reporting reduced salivary markers of mucosal inflammation after PBM application [26]. These mechanisms are grounded largely in laboratory and translational work; the question for general dentistry is whether they produce a reproducible, clinically meaningful benefit.

This review addresses that question for three sources of acute dental pain encountered daily in general practice: pain associated with local anesthetic injection (including PBM's role in anesthesia depth and success), postoperative endodontic pain and pain and analgesic use following extractions and minor oral surgery. It also summarizes the wide variability in wavelength, dose and technique reported across the literature, discusses the resulting limitations of the evidence base and closes with practical guidance for general dentists.

Photobiomodulation for Local Anesthetic Injection Pain and Anesthesia Success

Reducing injection-related discomfort has particular value in pediatric and injection-anxious patients and PBM has been evaluated both as a stand-alone comfort measure and as an adjunct that improves anesthesia performance during endodontic access.

A 2025 split-mouth, placebo-controlled trial in adults found that a 980-nm diode laser applied to the mucosa before infiltration anesthesia produced significantly lower Visual Analogue Scale (VAS) pain scores than a sham application, with the benefit consistent across age and sex subgroups [5]. In children undergoing pulpotomy and stainless-steel crown placement, PBM used as a pre-anesthetic tissue-management technique reduced injection pain without compromising anesthetic efficacy [6]. In a triple-blind, split-mouth trial in 6- to 9-year-olds undergoing bilateral pulpotomy, an 808-nm diode laser (250 mW, 16.25 J, 32.5 J/cm²) produced significantly lower injection pain and smaller heart-rate changes than a 20% benzocaine topical gel, although the two methods did not differ significantly on postoperative pain at 1 or 24 hours [7].

A separate and clinically distinct body of work has examined whether PBM applied before or during Inferior Alveolar Nerve Block (IANB) can increase anesthesia depth in teeth with symptomatic irreversible pulpitis, where block anesthesia often under-performs. In a double-blind randomized trial, a 980 nm diode laser (15 J/cm², 20 seconds) applied to the buccal mucosa before IANB significantly reduced the need for supplemental injection and lowered pain scores during dentin cutting and pulp exposure compared with placebo [8]. A similarly designed trial in mandibular molars with symptomatic irreversible pulpitis found that 980 nm PBM before anesthesia significantly reduced pain during dentin cutting and pulp exposure, with 0% of the laser group requiring supplemental anesthesia compared with 40% of the placebo group [9]. A four-arm randomized trial comparing ibuprofen premedication, PBM, their combination and placebo before IANB found that both ibuprofen and PBM alone significantly improved anesthesia success compared with placebo, with no significant difference between the two active treatments and the combination performed best of all [10].

Systematic reviews help contextualize these individual trials. A 2025 systematic review and meta-analysis of 14 studies (6 pediatric, 8 adult) found that PBM tends to reduce reported injection pain, with a significant benefit in children on the self-reported Wong-Baker FACES scale but not on the observer-rated FLACC behavioral scale-an important distinction, since self-report and observer-rated outcomes do not always align [11]. A separate systematic review and meta-analysis focused on infiltration-injection pain reached a similarly favorable conclusion while noting the limited number of pooled trials [12]. A broader systematic review of PBM, vibration and phentolamine mesylate for reducing injection pain and reversing local anesthesia likewise supports a role for PBM among these non-pharmacologic adjuncts [13]. Additional pediatric trials comparing PBM with topical anesthetic spray, evaluating a 915 nm diode for maxillary infiltration and examining PBM for accelerating anesthesia reversal after treatment add further support, as does a split-mouth trial in patients with molar-incisor hypomineralization, a population in which injection pain and behavior management are particularly challenging [14-17].

Taken together, PBM applied to the mucosa around the time of injection appears to modestly reduce reported injection pain for many patients and may also improve the depth and success of block anesthesia in inflamed pulps-an application distinct from, but related to, simple injection-pain reduction. The evidence is more consistent in pediatric populations and self-report pain scales than in observer-rated outcomes and clinicians should view PBM as an adjunct to, not a substitute for, sound injection technique and topical anesthetic.

Photobiomodulation for Postoperative Endodontic Pain

Postoperative pain after root canal therapy is common even when treatment is technically successful and PBM has been studied as an adjunct to reduce it, sometimes in direct comparison with analgesic medication. A 2024 systematic review of 12 randomized trials using diode lasers in the 808-970 nm range found that most included studies demonstrated a significant benefit of PBM for postoperative endodontic pain, while cautioning that heterogeneous laser parameters and a lack of sample-size calculations in most trials preclude a firm clinical recommendation [18]. A 2024 systematic review and meta-analysis in the International Endodontic Journal reached a similarly favorable but cautious conclusion regarding laser adjuvant therapy for postoperative endodontic pain [19]. A 2024 systematic review and meta-analysis in Scientific Reports focused specifically on pain after primary and secondary (retreatment) endodontic procedures likewise reported a benefit for laser-based adjuncts, again with variable certainty across outcomes [20]. A further systematic review and meta-analysis focused specifically on retreatment cases found comparable support for laser therapy in reducing postoperative pain [21] and an earlier systematic review of low-level laser therapy after root canal treatment or retreatment reported a generally favorable, though methodologically heterogeneous, evidence base [22].

Against this generally favorable trend, a rigorously designed 2025 randomized, double-blind trial in maxillary molars undergoing single-visit treatment found no significant difference between PBM and control at 4, 8, 12 or 24 hours postoperatively, nor on palpation, percussion or the OHIP-14 quality-of-life measure, explicitly concluding that current evidence for PBM in reducing postoperative endodontic pain should be considered low or very low certainty [23]. More recent work has explored PBM against other physical adjuncts, such as a 2025 randomized trial comparing PBM with intracanal cryotherapy for post-endodontic pain [24]. A 2026 review of lasers in general dental practice similarly frames PBM for endodontic pain as a plausible but not yet standardized adjunct [25]. For general practice, this body of evidence suggests PBM may reduce postoperative endodontic pain for some patients, particularly as a complement to standard postoperative analgesic guidance, but a recent, well-controlled negative trial is an important counterweight to earlier, more optimistic reports and clinicians should not assume a guaranteed benefit.

Photobiomodulation After Extractions and Minor Oral Surgery

The most extensive and reproducible evidence for PBM in acute dental pain comes from third-molar extraction and other minor oral surgery, where several randomized trials and meta-analyses have evaluated its effect on pain, edema, trismus and analgesic consumption.

A split-mouth randomized trial of bilateral impacted mandibular third-molar removal found that an 810 nm PBM protocol (4 J/cm^2, applied immediately postoperatively and on days 1 and 2) significantly reduced pain and swelling within the first 48 hours compared with the ibuprofen-only side and also reduced postoperative salivary IgA, a biomarker of mucosal inflammation-evidence of an effect at both the clinical and molecular level [26]. A randomized clinical trial in 44 patients (101 extractions) using an 808 nm diode laser (50 mW, 11 J/point, six points) applied after extraction found significantly lower VAS pain scores in the PBM group at 6, 24 and 48 hours, with the effect consistent across different impaction positions and classifications [27]. A split-mouth pilot trial using an 830 nm laser applied both intraorally and extraorally at multiple postoperative time points found significantly reduced pain and swelling on postoperative days 2, 4 and 7, along with a significantly lower number of analgesics taken in the PBM group compared with placebo [28].

A 2025 multicenter, triple-blind randomized trial conducted across five Italian centers (the BIOSTOTT study) reinforced this pattern in a large, well-controlled sample: the PBM group showed significantly reduced pain, edema and trismus on postoperative days 2 and 7, along with decreased analgesic use on nearly every measured day [29]. These individual trials are consistent with pooled findings: a 2021 systematic review and meta-analysis of low-level laser therapy for postoperative morbidity after third-molar surgery found a favorable effect on pain, swelling and trismus, graded low certainty [30]; a 2023 systematic review and meta-analysis reached similar conclusions and a 2024 systematic review and meta-analysis specifically addressing post-surgical side effects after mandibular third-molar extraction found that PBM combining intraoral and extraoral application in a single postoperative session was effective for reducing both pain and edema [31,32].

Evidence of PBM's analgesic effect after oral surgery extends beyond third-molar extraction. A split-mouth trial of periodontal flap surgery using a 940 nm diode laser found significantly less pain on postoperative days 2 through 7 and significantly fewer analgesics used on days 3 through 7 in the laser-treated side [33]. A double-blind randomized trial of dental implant placement found that concurrent 660 nm and 810 nm PBM significantly reduced pain at 12, 24, 48 and 72 hours and improved wound healing scores at 3, 7 and 14 days compared with a placebo side [34]. In a more specialized population, a double-blind randomized pilot study of dental extraction after head and neck radiation therapy found that PBM led to faster alveolar mucosal healing and significantly lower postoperative pain and analgesic use at day 7 [35]. While these implant, periodontal and post-radiotherapy studies fall outside the strict scope of third-molar extraction, they reinforce that PBM's postsurgical analgesic effect is not specific to a single procedure.

Overall, PBM after extraction and minor oral surgery has the broadest and most reproducible support of the three applications reviewed here, with multiple independent trials and meta-analyses converging on reduced pain, edema, trismus and analgesic use, particularly in the first 48 hours to 7 days postoperatively. "Low certainty" remains the recurring GRADE-type descriptor across meta-analyses, reflecting protocol heterogeneity rather than a clearly negative signal.

Differences in Wavelength, Dose, Timing and Application Technique

A consistent theme across all three applications is the absence of a standardized PBM protocol. In a comprehensive review of 46 clinical trials in oral surgery, the most effective physical parameters identified for pain reduction after tooth extraction were wavelengths of 650-980 nm, power of 4-300 mW and energy density of 3-85.7 J/cm²; parameters of 660-910 nm, 4-500 mW and 2-480 J/cm² were most associated with reduced facial swelling; and 4-106 J/cm² was most associated with reduced trismus, though the same review noted that studies using nearly identical nominal parameters have produced both positive and null results [1]. A dedicated systematic review and meta-analysis of PBM dosimetry in dentistry similarly found no consensus on wavelength or delivery methodology and highlighted that spot size, contact versus non-contact technique and tissue optical properties can each substantially affect how much energy actually reaches the target tissue-meaning two protocols reporting the same nominal dose may deliver meaningfully different biological exposure [3]. Table 1 summarizes representative parameter ranges by clinical application, drawn from the trials and reviews cited above. Beyond wavelength and dose, delivery technique varies meaningfully across studies: contact versus non-contact application, single-point versus multi-point protocols and intraoral-only versus combined intraoral/extraoral delivery. Several of the trials reviewed above used repeated sessions (e.g., immediately postoperative plus days 1-2 or days 2, 4 and 7) rather than a single application, which may partly explain why some single-application protocols have produced null results while multi-session protocols targeting the same procedure have shown benefit. The WALT 2026 position paper on PBM for orofacial pain likewise calls for standardized dosimetric reporting to allow meaningful comparison across future trials [2].

Application	Wavelength	Power / dose	Delivery	Timing
Injection pain reduction	660-980 nm (diode)	40 mW-300 mW; ~4-35 J single application (contact)	Mucosa at planned injection site, single point or small area	Immediately before infiltration/block
Anesthesia depth / IANB success	808-980 nm	0.3-0.8 W; 15 J/tooth or 4 J/cm²	Buccal crown/periapical area, single or repeated application	Before or at time of block injection
Postoperative endodontic pain	660-980 nm (diode/InGaAlP)	10-500 mW; 2-106 J/cm² typical range	Periapical intraoral, sometimes + extraoral over apex	Immediately after obturation; some repeat at 24-72 h
Post-extraction / third-molar surgery	637-980 nm (single or multiband)	4-500 mW; 2-480 J/cm² (swelling); 4-106 J/cm² (trismus); 3-85.7 J/cm² (pain)	Combined intraoral + extraoral, multiple points	Immediately postoperative; repeated on days 1-2 and/or 7

IANB: Inferior Alveolar Nerve Block. Ranges reflect representative protocols reported in the cited trials and reviews; they illustrate the range of parameters in current use and are not a validated standard dosing protocol

Table 1: Representative photobiomodulation parameters reported by clinical application.

Limitations and Inconsistencies in Evidence

Several recurring limitations temper enthusiasm for PBM as a reliable, protocol-driven adjunct in general practice:

- Small sample sizes. Most individual randomized trials cited in this review enroll fewer than 100 participants and several systematic reviews explicitly note the absence of sample-size calculations in included trials [18]
- Heterogeneous or incompletely reported parameters. Wavelength, power, energy density, spot size and number of treatment points vary widely across studies, a problem specifically documented in dosimetry-focused reviews [1,3]
- Inconsistent outcome measures. Trials mix VAS, numeric rating scales, Wong-Baker FACES and observer-rated scales such as FLACC; these do not always agree, particularly in pediatric populations [11]
- Certainty ratings remain low. Where systematic reviews formally grade evidence certainty, the recurring conclusion across all three applications reviewed here is low-to-moderate certainty, even when point estimates favor PBM [18,23,30,31]
- Conflicting individual trials. A recent, well-controlled endodontic trial found no benefit for postoperative pain, underscoring that PBM's effect is not uniform even within a single clinical application [23]
- Single-session versus multi-session protocols. Trials using a single postoperative application have sometimes produced weaker or null results compared with trials repeating PBM over several days, complicating direct comparison across the literature
- Limited head-to-head comparison with standard care. Relatively few trials directly compare PBM against or in combination with, first-line pharmacologic care (e.g., NSAIDs) using equivalent outcome measures and time points [10]
- None of these limitations negate the plausibility of a real, mechanism-based analgesic effect and the third-molar and oral-surgery literature in particular shows a fairly consistent direction of effect across independent research groups and countries. But the evidence base as a whole is better described as promising and mechanistically plausible than as definitive or standardized

Practical Recommendations for General Dentists

Based on the evidence reviewed, general dentists considering PBM for acute dental pain may find the following practical points useful:

- Treat PBM as an adjunct, not a replacement. Sound anesthesia technique, appropriate NSAID-based postoperative regimens and standard surgical protocol remain the foundation of dental pain management
- Expect the most consistent benefit after third-molar and minor oral surgery. This application has the largest and most convergent body of randomized and meta-analytic evidence, including reduced analgesic consumption in large, well-controlled multicenter trials [29]
- Consider PBM for injection-anxious patients, especially children and consider it as an option to improve anesthesia depth in symptomatic irreversible pulpitis when block anesthesia is likely to be difficult [8-10]
- Set realistic expectations for endodontic postoperative pain. The literature is mixed, with a recent rigorous trial showing no benefit; patients should still receive standard postoperative pain guidance regardless of whether PBM is used [23]
- If adopting PBM, follow a validated protocol for the specific device and indication rather than assuming parameters are interchangeable across devices, wavelengths or single- versus multi-session regimens [1,3]
- Document parameters and outcomes. Because published protocols are heterogeneous, practices that adopt PBM are well positioned to track their own outcomes (pain scores, analgesic use, need for supplemental anesthesia) to evaluate real-world effectiveness with their specific device and patient population
- Confirm device safety classification and staff training. PBM devices used in dentistry are generally low-risk lasers or LED systems, but manufacturer instructions and appropriate eye protection should still be followed
- Stay alert to new evidence. This field is publishing rapidly-many of the trials and reviews cited here appeared in 2024 and 2025 and a formal position paper on PBM for orofacial pain was published in 2026 [2]-and protocol standardization efforts are ongoing.

Conclusion

Photobiomodulation is a biologically plausible, generally safe, non-pharmacologic adjunct for acute dental pain, with the strongest and most reproducible evidence supporting its use after third-molar extraction and other minor oral surgery, more mixed evidence for postoperative endodontic pain and evidence for both reducing local anesthetic injection pain and improving anesthesia depth during endodontic treatment of inflamed pulps. Across all three applications, considerable variability in wavelength, dose and technique-combined with small trial sizes and low-to-moderate certainty ratings in most systematic reviews-means PBM should currently be positioned as a complement to, not a substitute for, established pharmacologic and technique-based pain control. Table 2 summarizes the direction and certainty of evidence from the major systematic reviews discussed in this article. General dentists interested in incorporating PBM should select an evidence-informed protocol for their specific application, set realistic patient expectations and track outcomes as the supporting literature continues to mature.

Application	Source (year)	Scope	Direction of Effect	Certainty / Caveat
Injection pain	Shekarchi, et al., 2025	14 RCTs (6 pediatric, 8 adult)	Favors PBM; significant on Wong-Baker FACES in children	FLACC (observer-rated) not significant in children
Injection pain	Hakimiha, et al., 2025	Systematic review + meta-analysis	Favors PBM for infiltration injection pain	Limited number of pooled trials
Anesthesia depth/IANB	Olszewska, et al., 2025	Systematic review (PBM, vibration, phentolamine)	PBM supports anesthesia reversal/pain reduction	Heterogeneous comparators
Endodontic postop pain	Kadam, et al., 2024	12 RCTs, diode 808-970 nm	Majority of studies favor PBM	Heterogeneous parameters; no power calculations in most trials
Endodontic postop pain	Luo, et al., 2024	Systematic review + meta-analysis	Favors PBM as adjuvant	Certainty downgraded for risk of bias
Endodontic postop pain	Elmsmari, et al., 2024	SR + meta-analysis, primary and secondary tx	Favors laser adjuncts	Certainty variable across outcomes
Third-molar/extraction	Domah, et al., 2021	Systematic review + meta-analysis	Favors PBM for pain/swelling/trismus	Low certainty (GRADE)
Third-molar/extraction	Lacerda-Santos, et al., 2023	Systematic review + meta-analysis	Favors PBM for pain, edema, trismus	Low certainty (GRADE)
Third-molar/extraction	J Evid Based Dent Pract, 2024	Systematic review + meta-analysis	Favors PBM (infrared, combined intra/extraoral)	Low-to-moderate certainty
RCT: Randomized Controlled Trial; SR: Systematic Review; GRADE: Grading of Recommendations Assessment, Development and Evaluation. "Certainty" reflects the certainty-of-evidence rating reported by each source, where stated.				

Table 2: Selected systematic reviews and large randomized trials by clinical application.

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The project did not meet the definition of human subject research under the preview of the IRB according to federal regulations and therefore was exempt.

Informed Consent Statement
Not applicable.

Authors' Contributions

All authors contributed equally to this paper.

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