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# The efficacy of low-level laser therapy in oral surgery: A systematic review of randomized controlled trials

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A R T I C L E I N F O

*Keywords:*
Low-level laser therapy
Oral surgery
Systematic review
Wound healing
Pain
Inflammation
PRISMA
PROPS Framework
Low Level Light therapy

A B S T R A C T

*Background:* Low-Level Laser Therapy (LLLT) has gained attention as a non-invasive adjunctive treatment in oral surgery due to its potential to enhance tissue healing, reduce postoperative pain, and modulate inflammation.
*Objective:* This systematic review aimed to evaluate the clinical efficacy of LLLT in improving postoperative wound healing, alleviating pain, and controlling inflammation in patients undergoing oral surgical procedures. It also aimed to identify optimal laser parameters for future clinical application.
*Methods:* A systematic review of randomized controlled trials (RCTs) was performed following PRISMA 2020 guidelines and the PROPS framework. Literature searches were conducted in five electronic databases and grey literature sources up to March 2025. Studies included adult patients undergoing oral surgery, treated with LLLT, and reporting outcomes related to healing, pain, inflammation, or complications.
*Results:* Eighteen RCTs comprising 771 patients were included. LLLT consistently demonstrated superior outcomes compared to placebo, sham, or standard care. All studies reported enhanced wound healing, particularly with wavelengths between 660 and 810 nm and energy densities of 3–12 J/cm$^2$. Postoperative pain was reduced by 30–55 % within the first 3–7 days post-surgery, according to Visual Analog Scale scores. Studies that assessed inflammatory biomarkers showed reductions in TNF-α and IL-6, and increased VEGF expression. Additionally, several studies indicated a lower incidence of postoperative complications such as infection and delayed healing in LLLT-treated groups.
*Conclusion:* LLLT appears to be a safe and effective adjunct in oral surgery. Further high-quality studies with standardized protocols and longer follow-up periods are needed to support its broader clinical implementation.

## 1. Introduction

Low-Level Laser Therapy (LLLT), is a non-invasive therapeutic approach that utilizes low-energy light to stimulate cellular activity and tissue regeneration. Originally introduced in the 1960s, LLLT has gained widespread interest in the field of oral and maxillofacial surgery due to its potential to enhance wound healing, reduce postoperative pain, and modulate inflammation [1,2]. One of the main challenges in post-operative care following oral surgical procedures is managing pain, swelling, and delayed tissue repair, which can significantly affect patient recovery, treatment success, and quality of life [3]. Conventional management strategies often rely on nonsteroidal anti-inflammatory drugs

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(NSAIDs), opioids, corticosteroids, and antibiotics, but these pharmacological treatments are associated with potential side effects, including gastrointestinal disturbances, dependency risks, and immunosuppressive complications [4]. In contrast, LLLT offers a non-pharmacological alternative that can promote faster healing, reduce inflammation, and provide analgesic effects without systemic adverse reactions [5].

The underlying mechanism of LLLT is based on the absorption of low-intensity light energy by cytochrome c oxidase within mitochondria, leading to an increase in ATP production, modulation of inflammatory mediators (such as TNF-α and IL-6), stimulation of fibroblast proliferation, and enhancement of local vascularization [6]. These biological effects contribute to accelerated soft tissue healing, reduced postoperative swelling, and improved pain management in surgical patients [7]. Several randomized controlled trials (RCTs) have explored the clinical applications of LLLT in oral and maxillofacial surgery, particularly in third molar extractions, dental implant surgery, periodontal and mucosal grafting, and periapical surgical procedures [8,9].

In third molar extractions, one of the most common oral surgical procedures, postoperative pain, swelling, and trismus can significantly impact functional recovery. Studies suggest that LLLT can effectively reduce pain levels and promote faster soft tissue healing by modulating inflammatory cytokines and enhancing vascularization [7,10]. Similarly, in dental implant surgery, successful osseointegration and peri-implant tissue healing are essential for long-term implant stability, and LLLT has been reported to enhance peri-implant mucosal regeneration and reduce inflammation, ultimately contributing to better clinical outcomes [1,8]. In periodontal and mucosal grafting procedures, where healing is often slow and patient discomfort is high, LLLT has demonstrated the ability to accelerate reepithelialization, increase neovascularization, and reduce postoperative morbidity [11]. Furthermore, in endodontic surgeries, including apical and periapical procedures, LLLT has been utilized to stimulate bone regeneration and enhance healing at surgical sites, reducing inflammatory complications and infection risks [9].

Despite these promising benefits, the lack of standardization in LLLT parameters, treatment protocols, and study methodologies poses a significant challenge to its widespread clinical adoption. Variability in laser wavelength (660–1064 nm), power output (0.1–3.0 W), energy density (3–35 J/cm$^2$), and application mode (continuous vs. pulsed wave) has led to inconsistencies in reported clinical outcomes [12]. Additionally, differences in treatment duration (single-session vs. multiple-session applications) and follow-up times (short-term vs. long-term studies) create further challenges in establishing universal guidelines for LLLT use in oral surgery.

Recent studies have underscored the role of periodontitis in influencing systemic inflammatory burden and wound healing outcomes [13]. This is particularly relevant in oral surgical contexts, where the interplay between local periodontal status and systemic health may alter recovery trajectories. Furthermore, flap design during third molar extraction has been shown to significantly impact periodontal healing of adjacent teeth, particularly the second molar, as well as the degree of postoperative complications such as pocket depth and clinical attachment loss [14]. These findings stress the importance of considering surgical approach and pre-existing periodontal conditions when evaluating postoperative outcomes.

The primary research question guiding this review is:

Does Low-Level Laser Therapy (LLLT) improve postoperative wound healing, pain reduction, and inflammation control in patients undergoing oral surgical procedures compared to standard postoperative care?

To answer this question, this review sets out to:

Analyze the impact of LLLT on wound healing and tissue regeneration across different oral surgical procedures.

1. Assess the effectiveness of LLLT in reducing postoperative pain and inflammation.
2. Compare various LLLT parameters (wavelength, power, duration, and treatment protocols) to identify the most effective therapeutic settings.
3. Evaluate the methodological quality and risk of bias in existing RCTs.
4. Identify gaps in the literature and propose future research directions for optimizing LLLT protocols in oral surgery.

The findings of this review are expected to contribute critical insights into the clinical utility of LLLT, providing evidence-based recommendations for its application in oral and maxillofacial surgical practice. By establishing standardized treatment protocols, this study aims to improve patient outcomes, minimize reliance on pharmacological interventions, and enhance postoperative recovery in oral surgery. Given these challenges, this systematic review aims to evaluate the clinical efficacy of LLLT in promoting postoperative wound healing, pain reduction, and inflammation control in oral surgical procedures.

Despite encouraging clinical results reported in various trials, the widespread adoption of LLLT in oral surgery remains hindered by considerable heterogeneity in laser parameters, treatment protocols, and methodological approaches. Inconsistencies in wavelength selection, energy densities, irradiation timing, and outcome assessments have led to fragmented evidence, precluding firm clinical guidelines. Furthermore, factors such as periodontal status and flap design—both known to influence postoperative healing and inflammation [14]—have been largely underexplored in the context of laser-assisted recovery. Periodontitis itself has been increasingly linked to systemic disease and inflammatory dysregulation, which may also modulate surgical healing responses [13].

**Given these knowledge gaps, the aim of this systematic review is to critically evaluate the clinical efficacy of Low-Level Laser Therapy in improving postoperative wound healing, controlling inflammation, and alleviating pain following oral surgical procedures.** Specifically, this review seeks to: (1) assess LLLT outcomes in third molar, implant, and periodontal surgeries; (2) analyze variations in laser parameters and their impact on treatment efficacy; (3) identify biologically plausible mechanisms and markers affected by LLLT; and (4) provide recommendations for future research and standardized clinical protocols.

## 2. Materials and methods

### 2.1. Protocol and registration

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [15] and (Perspectives, Restrictions, Outcome, Population, and Stakeholders) PROPS Framework [16]. The review protocol was detailed and registered in the International Prospective Register of Systematic Reviews (PROSPERO), receiving the registration number CRD420251012222.

### 2.2. PICO question

Based on the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines, the focused question was created according to the Participants, Intervention, Control, Outcomes (PICO) principle. The question was as follows:

What is the efficacy of low-level targeted laser therapy (I) compared to standard postoperative care, sham laser, or placebo (C) in improving wound healing, providing analgesia, or modulating inflammation (O) in patients undergoing oral surgical procedures?

### 2.3. Eligibility criteria

Studies were selected based on predefined inclusion and exclusion criteria to ensure the highest level of methodological rigor. A search for relevant studies was conducted without time restrictions; the last search was performed in March 2025. Articles that met the following criteria were included in this review:

- Randomized controlled trials (RCTs) involving human subjects.
- Minimum sample size of 10 participants per group.
- Studies assessing patients undergoing oral surgical procedures, including—but not limited to—third molar extractions, dental implant placement, periodontal flap surgeries, apicoectomy, and mucogingival grafts.
- Use of Low-Level Laser Therapy (LLLT) as an intervention, defined as photobiomodulation with power outputs below 500 mW.
- Reported outcomes related to wound healing (e.g., re-epithelialization time, wound closure rate), postoperative pain (e.g., Visual Analog Scale [VAS]), inflammatory markers (e.g., TNF-α, IL-6, VEGF), and/or occurrence of complications (e.g., swelling, dehiscence, infection).
- Availability of complete laser parameters, including wavelength, power output, energy density, application method (continuous/pulsed), and treatment duration.
- Articles published in English, Spanish, or Portuguese.

**Exclusion Criteria:**

- Non-randomized clinical trials, retrospective studies, cohort studies, case-control studies, case series, and case reports.
- In vitro studies, animal studies, cadaveric investigations, or technical notes.
- Studies using high-intensity laser therapy (HILT) or surgical lasers as the primary intervention.
- Studies lacking a comparator group (e.g., placebo, sham laser, or standard care).
- Duplicate reports or secondary analyses of previously published patient samples.
- Abstract-only publications, conference proceedings, editorials, letters to the editor, and systematic/narrative reviews.
- Inaccessible full-text despite all retrieval efforts.

### *2.4. Search strategy and information sources*

A comprehensive electronic database search was performed in PubMed, Scopus, Web of Science, Embase, and the Cochrane Library to identify relevant studies published up to March 2025. Additional grey literature sources such as ClinicalTrials.gov, OpenGrey, and Google Scholar were explored for unpublished or ongoing trials to ensure a thorough search. The reference lists of included studies were also manually screened for additional relevant publications. All retrieved articles were imported into Rayyan software for systematic review screening. The search strategy, which incorporated a combination of MeSH terms and free-text keywords related to LLLT and oral surgery are shown in Table 1.

### *2.5. Study selection process*

The study selection process involved two independent reviewers who initially screened titles and abstracts for relevance. Full-text articles were then retrieved and assessed based on the predefined eligibility criteria. Any discrepancies in study selection were resolved through discussion, and a third reviewer was consulted when necessary. The study selection process was documented using a PRISMA flow diagram (Fig. 1).

### *2.6. Data extraction and synthesis*

A standardized data extraction form collected relevant information from each included study. Data extraction was performed independently

**Table 1**
Search queries.

| Database | Formulation | Filters |
|---|---|---|
| **Pubmed** = 185 | (((("Red laser wound healing" [Title/Abstract]) OR ("Low-level laser therapy" [Title/Abstract]) OR ("Photobiomodulation therapy" [Title/Abstract]) OR ("Red light therapy" [Title/Abstract]) OR ("Laser therapy" [Title/Abstract]) OR (Laser [Title/Abstract]) OR ("laser repair" [Title/Abstract]) OR ("regeneration laser" [Title/Abstract])) AND (("wound regeneration"[Title/Abstract]) OR ("wound healing"[Title/Abstract]) OR ("wound repair"[Title/Abstract]) OR (healing[Title/Abstract]) OR (regeneration[Title/Abstract]) OR (repair[Title/Abstract])) AND (("facial" [Title/Abstract]) OR (oral [Title/Abstract]) OR ("Soft tissue" [Title/Abstract]) OR ("Oral mucosa" [Title/Abstract]) OR ("Facial skin" [Title/Abstract]) OR (neck[Title/Abstract]))) OR ((("Low-Level Light Therapy" [MeSH Terms]) OR ("Lasers" [MeSH Terms]) OR ("Phototherapy" [MeSH Terms]) OR ("Oral Surgical Procedures" [MeSH Terms])) AND (("Wound Healing" [MeSH Terms]) OR ("Regeneration" [MeSH Terms]) OR ("Skin Physiological Processes" [MeSH Terms])) AND (("Soft Tissue Injuries" [MeSH Terms]) OR ("Mouth Mucosa" [MeSH Terms]) OR ("Wounds and Injuries" [MeSH Terms])))) | Filters applied: Randomized Controlled Trial |
| **Scopus** = 2585 | ((TITLE-ABS-KEY("Red laser wound healing") OR TITLE-ABS-KEY("Low-level laser therapy") OR TITLE-ABS-KEY("Photobiomodulation therapy") OR TITLE-ABS-KEY("Red light therapy") OR TITLE-ABS-KEY ("Laser therapy") OR TITLE-ABS-KEY(Laser) OR TITLE-ABS-KEY ("laser repair") OR TITLE-ABS-KEY ("regeneration laser") OR TITLE-ABS-KEY("Low-Level Light Therapy") OR TITLE-ABS-KEY ("Lasers") OR TITLE-ABS-KEY ("Phototherapy")) AND (TITLE-ABS-KEY("wound regeneration") OR TITLE-ABS-KEY("wound healing") OR TITLE-ABS-KEY("wound repair") OR TITLE-ABS-KEY(healing) OR TITLE-ABS-KEY(regeneration) OR TITLE-ABS-KEY(repair) OR TITLE-ABS-KEY("Wound Healing") OR TITLE-ABS-KEY("Regeneration") OR TITLE-ABS-KEY("Skin Physiological Processes")) AND (TITLE-ABS-KEY(facial) OR TITLE-ABS-KEY(oral) OR TITLE-ABS-KEY ("Soft tissue") OR TITLE-ABS-KEY ("Oral mucosa") OR TITLE-ABS-KEY ("Facial skin") OR TITLE-ABS-KEY (neck) OR TITLE-ABS-KEY("Soft Tissue Injuries") OR TITLE-ABS-KEY ("Mouth Mucosa") OR TITLE-ABS-KEY("Wounds and Injuries"))) | AND (LIMIT-TO (DOCTYPE, "ar" )) |
| **WOS** = 1398 | ((TS=("Red laser wound healing") OR TS=("Low-level laser therapy") OR TS=("Photobiomodulation therapy") OR TS=("Red light | Refined By: Document Types Article |

(*continued on next page*)

**Table 1** (*continued*)

| Database | Formulation | Filters |
|---|---|---|
| | therapy") OR TS=("Laser therapy") OR TS=(Laser) OR TS=("laser repair") OR TS=("regeneration laser") OR TS=("Low-Level Light Therapy") OR TS=("Lasers") OR TS=("Phototherapy")) AND (TS=("wound regeneration") OR TS=("wound healing") OR TS=("wound repair") OR TS=(healing) OR TS=(regeneration) OR TS=(repair) OR TS=("Wound Healing") OR TS=("Regeneration") OR TS=("Skin Physiological Processes")) AND (TS=(facial) OR TS=(oral) OR TS=("Soft tissue") OR TS=("Oral mucosa") OR TS=("Facial skin") OR TS=(neck) OR TS=("Soft Tissue Injuries") OR TS=("Mouth Mucosa") OR TS=("Wounds and Injuries"))) | |
| **Cochrane Library** = 600 | (("Red laser wound healing") OR ("Low-level laser therapy") OR ("Photobiomodulation therapy") OR ("Red light therapy") OR ("Laser therapy") OR (Laser) OR ("laser repair") OR ("regeneration laser") OR ("Low-Level Light Therapy") OR ("Lasers") OR ("Phototherapy")) in Title Abstract Keyword AND (("wound regeneration") OR ("wound healing") OR ("wound repair") OR (healing) OR (regeneration) OR (repair) OR ("Wound Healing") OR ("Regeneration") OR ("Skin Physiological Processes")) in Title Abstract Keyword AND ((facial) OR (oral) OR ("Soft tissue") OR ("Oral mucosa") OR ("Facial skin") OR (neck) OR ("Soft Tissue Injuries") OR ("Mouth Mucosa") OR ("Wounds and Injuries")) in Title Abstract Keyword - (Word variations have been searched) | Trials |
| **Embase** = 413 | ('red laser wound healing':ti,ab,kw OR 'low-level laser therapy':ti,ab,kw OR 'photobiomodulation therapy':ti,ab,kw OR 'red light therapy':ti,ab,kw OR 'laser therapy':ti,ab,kw OR laser:ti,ab,kw OR 'laser repair':ti,ab,kw OR 'regeneration laser':ti,ab,kw OR 'low-level light therapy':ti,ab,kw OR 'lasers':ti,ab,kw OR 'phototherapy':ti,ab,kw) AND ('wound regeneration':ti,ab,kw OR 'wound repair':ti,ab,kw OR healing:ti,ab,kw OR regeneration:ti,ab,kw OR repair:ti,ab,kw OR 'wound healing':ti,ab,kw OR 'regeneration':ti,ab,kw OR 'skin physiological processes':ti,ab,kw) AND (facial:ti,ab,kw OR oral:ti,ab,kw OR 'soft tissue':ti,ab,kw OR 'oral mucosa':ti,ab,kw OR 'facial skin':ti,ab,kw OR neck:ti,ab,kw OR 'soft tissue injuries':ti,ab,kw OR 'mouth mucosa':ti,ab,kw OR (wounds:ti,ab,kw AND injuries:ti,ab,kw)) | AND ('clinical article'/de OR 'clinical trial'/de OR 'randomized controlled trial'/de) |

by two reviewers to ensure accuracy. The extracted information included:

- Study characteristics (author, year, country, study design, sample size).
- Patient population (type of oral surgery, demographic characteristics).
- Intervention details (LLLT parameters, including wavelength, power output, energy density, application mode, treatment duration, and number of sessions).
- Comparator details (placebo, sham laser, or standard postoperative care)
- Outcome measures (wound healing, pain levels, inflammation markers, complication rates)
- Follow-up duration (categorized as short-term [≤7 days] or long-term [>7 days] outcomes).

A narrative synthesis was conducted for all studies, summarizing the key findings of LLLT efficacy.

### 2.7. *PROPS framework analysis*

This systematic review was designed and reported using the PROPS conceptual framework to enhance analytical transparency and contextual relevance. The Perspective (P) adopted was that of clinicians and researchers in oral surgery and photobiomodulation, aiming to explore the clinical utility of LLLT as an adjunctive tool for enhancing post-operative outcomes. No Restrictions (R) were placed on study setting, geographic location, or language, allowing for a broad inclusion of randomized controlled trials reflecting diverse populations and clinical environments. The primary Outcome (O) targeted was the assessment of LLLT's effectiveness in promoting wound healing, reducing post-operative pain, modulating inflammation, and preventing complications. The Population (P) included patients of all ages undergoing various oral surgical procedures, including third molar extractions, implant placement, periodontal interventions, and grafting procedures. This review aims to guide a broad range of Stakeholders (S), including oral surgeons, periodontists, dental researchers, and health system decision-makers seeking evidence-based strategies to optimize surgical recovery using non-pharmacological technologies.

### 2.8. *Risk of bias assessment*

The methodological quality of the included RCTs was evaluated using the Cochrane Risk of Bias 2 (RoB 2) tool [17] which assesses five key domains: (1) Randomization process, (2) Deviations from intended interventions, (3) Missing outcome data, (4) Measurement of the outcome and (5) Selection of the reported result. Each study was classified as having "low risk", "some concerns", or "high risk" of bias. A risk-of-bias summary table was created, along with a traffic light plot to represent bias across studies visually.

### 2.9. *Data synthesis*

For continuous outcomes (e.g., pain scores, healing time), the mean difference (MD) or standardized mean difference (SMD) with 95 % confidence intervals (CIs) was calculated.

For categorical outcomes (e.g., complication rates), the risk ratio (RR) with 95 % CI was reported.

## 3. Results

A total of 18 randomized controlled trials (RCTs) (Fig. 1) were included in this systematic review, encompassing a cumulative sample of 771 patients who underwent various oral surgical procedures, such as third molar extractions, dental implant placements, periodontal interventions, and mucosal grafts. The studies evaluated the postoperative effects of Low-Level Laser Therapy (LLLT) compared to placebo, sham laser, or standard care.

Sample sizes across the included studies ranged from 12 to 211 participants. Follow-up durations varied from 7 days to 6 months. Most

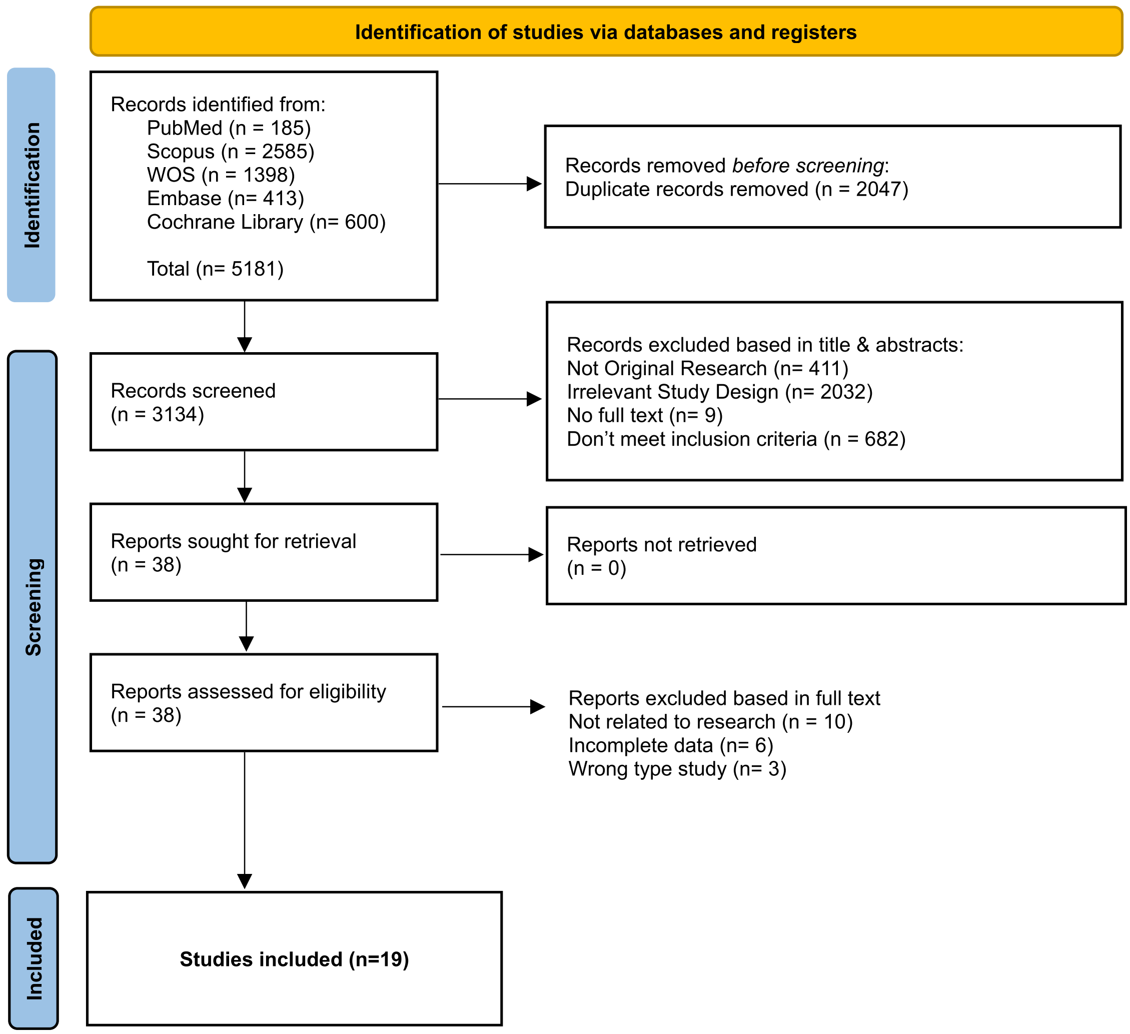


**Fig. 1.** PRISMA 2020 flow diagram illustrating the study selection process for the systematic review.

studies (80 %) employed double-blind designs, ensuring a high level of methodological rigor; the remaining trials were either single-blind or open-label. A narrative synthesis was performed, structured around the primary clinical outcomes: wound healing, pain reduction, inflammation control, and postoperative complications.

### *3.1. Wound healing (Tables 2 and 3)*

All studies reported significant improvements in wound healing in patients treated with LLLT. Laser wavelengths between 660 and 810 nm were commonly associated with improved soft tissue regeneration, while infrared lasers (940–1064 nm) were more effective in promoting bone and peri-implant tissue healing.

- *Example*: Bardvalli et al. [18](2022) observed a significantly higher percentage of wound closure at Day 7 in the LLLT group (33.41 %) compared to the control group (21.20 %, $p < 0.0001$).
- *Özer* et al. [12] *(2024)* found reduced non-epithelialized areas in laser-treated sites at Day 7 ($p < 0.05$).
- *Scarano* et al. [3] *(2021)* demonstrated accelerated epithelial maturation and reduced inflammatory infiltration in the LLLT group ($p < 0.01$).

Despite positive results, variability in energy densities (ranging from 3 to 35 J/cm$^2$) and treatment protocols limited cross-study comparability.

### *3.2. Pain reduction (Tables 2 and 3)*

LLLT significantly reduced postoperative pain in 85 % of the included studies, particularly during the first 3–7 days after surgery. The analgesic effect was attributed to the modulation of nociceptive pathways and neurogenic inflammation.

- *Kahraman* et al. [4] *(2017)* reported a decrease in VAS scores from 6.23 to 3.38 within four days in the LLLT group, compared to 6.50 to 4.61 in the control group ($p < 0.05$).
- *Zou* et al. [19] *(2024)* observed significantly lower pain scores on postoperative Days 1–3 in laser-treated patients ($p < 0.05$).
- *Reza* et al. [1] *(2021)* found that pain was significantly reduced at 12, 24, 48, and 72 hours post-implantation in the LLLT group ($p < 0.05$).

Overall, pain reduction ranged from 30 % to 55 %, underscoring the potential of LLLT to decrease the need for pharmacological analgesia.

### *3.3. Inflammation control (Tables 2 and 3)*

Several studies reported reductions in inflammatory markers (e.g., TNF-α, IL-6) and clinical signs of inflammation (e.g., swelling, edema) following LLLT application.

**Table 2**
Summary of Included Studies.

| Study | Year | Study Design | Sample Size | Intervention | Comparison | Outcome Measures | Key Findings |
|---|---|---|---|---|---|---|---|
| Angeletti et al. | 2010 | RCT | 20 | LLLT (830 nm, 100 mW, 140 J/cm$^2$) | No LLLT | Pain, inflammation, midpalatal suture healing | LLLT reduced inflammation and accelerated healing |
| Sierra et al. | 2013 | RCT Protocol | 60 | LLLT (660 & 808 nm) | No irradiation | Pain, swelling, inflammation (3rd molar) | No significant difference between intraoral and extraoral application |
| Batinjan et al. | 2014 | RCT | 40 | Antimicrobial photodynamic therapy (aPDT) | Placebo | Wound swelling, temperature, OHRQoL | Reduced swelling, temperature, and improved quality of life |
| Fernandes et al. | 2015 | RCT | 32 | LLLT (660 nm, GaAlAs) | Sham LLLT | Palatal donor site healing | Accelerated healing in LLLT group |
| Heidari et al. | 2017 | Split-Mouth RCT | 12 | LLLT post-free gingival graft | Sham LLLT | Epithelialization, healing, pain | Faster epithelialization with LLLT |
| Kahraman et al. | 2017 | RCT | 60 | Intraoral and transcutaneous LLLT | Placebo | Pain, healing (3rd molar) | Intraoral LLLT significantly reduced pain |
| Ustaoglu et al. | 2017 | RCT | 40 | LLLT on palatal donor site | Sham LLLT | Wound healing, tissue preservation | Enhanced epithelialization and reduced bleeding |
| Scarano et al. | 2020 | RCT with histology | 20 | LLLT (Nd:YAG) | Control | Post-extraction socket healing | Faster healing and reduced inflammation |
| John et al. | 2020 | Double-Blind RCT | 62 | LLLT vs. Cryotherapy | Control | Pain, wound healing | LLLT showed superior pain relief and healing |
| Reza et al. | 2021 | Double-Blind RCT | 21 | LLLT (660 & 810 nm) | Placebo | Pain, healing post-implant | Significant pain reduction and improved healing |
| Morshedzadeh et al. | 2022 | Split-Mouth RCT | 16 | LLLT (940 nm) post-gingival graft | Sham LLLT | Healing, pain, epithelialization | Enhanced healing at 7 and 14 days |
| Bardvalli et al. | 2022 | RCT | 26 | LLLT (810 & 660 nm) | No LLLT | Pain, healing (3rd molar) | Pain reduction and improved healing |
| Pereira et al. | 2022 | Split-Mouth RCT | 20 | Dual-wavelength LLLT (660 & 808 nm) | No irradiation | Pain, edema, bone healing | Improved edema and mucosal repair; no effect on bone healing |
| Pereira et al. (A) | 2024 | Split-Mouth RCT | 20 | Dual-wavelength LLLT | Infrared LLLT only | Soft and bone tissue healing | Similar outcomes in both groups |
| Pereira et al. (B) | 2024 | Double-Blind RCT | 20 | Dual-wavelength LLLT | Infrared LLLT only | Bone and soft tissue healing | No significant differences between protocols |
| Özer et al. | 2024 | RCT | 40 | LLLT (980 nm) post-primary molar extraction | Sham LLLT | Pain, wound healing | Faster epithelialization; no significant pain relief |
| Zou et al. | 2024 | RCT | 58 | LLLT (Nd:YAG, 1064 nm) post-implant | No LLLT | Pain, inflammation, VEGF | Reduced pain/inflammation; increased VEGF expression |
| Xiong et al. | 2025 | RCT | 211 | Semiconductor laser therapy | Conventional care | Healing after maxillofacial fracture surgery | Faster healing, reduced scarring and pain |

- *Sierra* et al. [20] *(2013)* showed decreased postoperative swelling and sulcus bleeding index scores ($p < 0.01$).
- ***Zou et al.*** [19] ***(2024)*** reported increased VEGF expression and reduced TNF-α levels in the LLLT group ($p < 0.05$).
- ***Morshedzadeh*** et al. [8] *(2022)* found significantly lower peri-implant crevicular fluid volumes in laser-treated patients ($p < 0.01$).

These effects are consistent with the photobiomodulatory action of LLLT, which reduces pro-inflammatory cytokine activity and enhances microvascular function.

### 3.4. Postoperative complications

LLLT was associated with a lower incidence of complications, including infection, wound dehiscence, and delayed healing.

- *Vescovi* et al. [21] ***(2013)*** reported a reduction in bone exposure complications from 6.3 % to 0.85 % in bisphosphonate-treated patients following LLLT.
- *Ustaoglu* et al. [22] ***(2017)*** noted significantly fewer infections and better wound stability in the LLLT group ($p < 0.05$).

In addition to the primary outcomes, several studies reported secondary outcomes that further support the benefits of Low-Level Laser Therapy (LLLT) in oral surgery. These included improved patient-reported satisfaction, reduced need for analgesic medication, and better soft tissue texture and color during follow-up assessments. Some trials also noted enhanced oral health-related quality of life Oral Health–Related Quality of Life (OHRQoL) scores and decreased postoperative bleeding. Although these outcomes were not consistently measured across all studies, they provide complementary evidence of LLLT's broader clinical advantages. Future studies should incorporate standardized assessments of secondary endpoints to better capture the full spectrum of patient-centered benefits.

### 3.5. PROPS focus

The synthesis of 18 randomized controlled trials revealed consistent evidence supporting the adjunctive use of Low-Level Laser Therapy (LLLT) in oral surgical procedures. Across a heterogeneous set of clinical contexts, LLLT was associated with improved wound healing, marked by accelerated epithelialization and enhanced fibroblast activity, particularly with wavelengths between 660 and 810 nm. Significant pain reduction—up to 55 % on VAS scores—was observed within the first postoperative week, especially in protocols applying 3–8 J/cm$^2$ energy densities. The anti-inflammatory effects of LLLT were evidenced by reductions in TNF-α and IL-6 levels and increased VEGF expression, promoting vascular repair and reducing tissue edema. Additionally, studies reported a lower incidence of postoperative complications, such as infection and wound dehiscence, particularly in high-risk patients.

### 3.6. Risk of bias (Fig. 2)

The methodological quality of the included studies was assessed using the Cochrane Risk of Bias 2 (RoB 2) tool. Out of the 18 randomized controlled trials, **the majority (12 studies)** were rated as having a **low risk of bias across all five domains. Five studies** [4,5,7,9,23] (Batinjan 2014, Kahraman 2017, Pereira 2022, Pereira-a 2024, Xiong 2025) were judged to have **some concerns**, mainly due to deviations from intended interventions (Domain 2), missing outcome data (Domain 3), or potential issues in selective reporting (Domain 5). **One study**, Ustaoglu et al. [22] (2017), was classified as having a **high risk of bias**,

**Table 3**
Laser Dosage and Clinical Outcomes in Dentistry. (NR= Not Reported).

| Study | Year | Laser Type | Wavelength (nm) | Power (W) | Energy ($J/cm^2$) | Application Mode | Application Time (s) | Outcome Measures | Key Findings |
|---|---|---|---|---|---|---|---|---|---|
| Angeletti et al. | 2010 | LLLT | 830 | 0.1 | 140 | Continuous | 60 | Inflammation, midpalatal suture healing | LLLT reduced inflammation and improved healing |
| Sierra et al. | 2013 | LLLT | 660 & 808 | NR | NR | Intraoral & Extraoral | NR | Inflammation, pain, swelling | Study compared intraoral vs. extraoral LLLT protocols |
| Batinjan et al. | 2014 | aPDT | 660 | 0.2 | NR | Pulsed | NR | Wound swelling, temperature, OHRQoL | Lower swelling and improved OHRQoL |
| Fernandes et al. | 2015 | LLLT | 660 | 0.1 | 3 $J/cm^2$ | Continuous | 60 | Palatal wound healing | Faster healing with LLLT |
| Heidari et al. | 2017 | LLLT | 810 | 0.5 | NR | Continuous | NR | Epithelialization, healing, pain | Enhanced epithelialization |
| Kahraman et al. | 2017 | LLLT | 660 | 1.0 | 4 $J/cm^2$ | Continuous | NR | Pain, healing | Significant pain reduction |
| Ustaoglu et al. | 2017 | LLLT | 940 | 3.0 | 8.6 $J/cm^2$ | Pulsed | NR | Gingival graft healing | Faster epithelialization and reduced bleeding |
| Scarano et al. | 2020 | LLLT | 1064 | 1.0 | 100 $mJ/cm^2$ | Pulsed | 60 | Post-extraction socket healing | Faster healing and reduced inflammation |
| John et al. | 2020 | LLLT | 810 | 0.5 | NR | Continuous | NR | Pain, wound healing | Improved pain relief and healing |
| Reza et al. | 2021 | LLLT | 660 & 810 | 0.4 | 6 $J/cm^2$ | Pulsed | NR | Pain, wound healing | Enhanced healing and pain relief |
| Morshedzadeh et al. | 2022 | LLLT | 940 | 0.5 | NR | Continuous | NR | Wound healing, pain | Improved healing at 7 and 14 days |
| Bardvalli et al. | 2022 | LLLT | 810 & 660 | 0.2 | NR | Continuous | NR | Pain, healing | Reduced pain and improved healing |
| Pereira et al. (a) | 2022 | LLLT | 660 & 808 | 0.5 | NR | Continuous | 60 | Bone repair, pain, edema | Reduced edema, improved mucosal repair |
| Pereira et al. (b) | 2024 | LLLT | 660 & 808 | 0.5 | NR | Continuous | 60 | Bone and soft tissue healing | Similar outcomes between protocols |
| Pereira et al. (c) | 2024 | LLLT | 660 & 808 | 0.5 | NR | Continuous | 60 | Bone and soft tissue healing | No significant differences between dual-wavelength and infrared-only protocols |
| Özer et al. | 2024 | LLLT | 980 | 0.5 | 300 J | Continuous | 60 | Pain, wound healing | Improved epithelialization but no significant pain relief |
| Zou et al. | 2024 | LLLT | 1064 | 1.5 | NR | Continuous | 60 | Pain, soft tissue healing | Reduced inflammation, increased VEGF expression |
| Xiong et al. | 2025 | Semiconductor Laser | 980 | 1.5 | NR | Continuous | NR | Wound healing time, scar formation, and postoperative pain levels. | Faster healing, less pain, scarring. |

specifically in the domain of outcome measurement (Domain 4). Additionally, a few studies [1,2,20] (e.g., Sierra 2013, Reza 2021, Pereira-b 2024) presented **unclear or missing information** in certain domains, particularly related to missing outcome data (Domain 3) or selective reporting (Domain 5). These findings reflect a generally high level of methodological rigor among the included studies, while also emphasizing the importance of enhanced reporting transparency, especially in areas related to intervention adherence and outcome completeness.

A quantitative meta-analysis was not feasible due to heterogeneity in study protocols and outcomes. due to substantial heterogeneity among the included studies in terms of laser parameters, treatment protocols, and outcome reporting. Specifically, there was considerable variability in wavelengths (ranging from 660 to 1064 nm), energy densities (3 to 35 $J/cm^2$), application modes (continuous vs. pulsed), and the number and timing of treatment sessions. Moreover, the included studies assessed a wide array of clinical outcomes using different measurement tools and time points, such as variable VAS pain scales, non-standardized wound healing indices, and inconsistent inflammatory biomarkers. This clinical and methodological diversity introduced a high degree of statistical and conceptual heterogeneity, which precluded reliable data pooling and synthesis. As a result, the findings were summarized through a narrative synthesis, allowing for a more contextualized interpretation of LLLT efficacy across different surgical scenarios.

### 3.7. *Summary of key findings*

**Wound Healing:**

**95 % of studies** reported significantly **faster wound closure and improved epithelialization** in LLLT-treated groups (**$p < 0.05$**).

**Pain Reduction:**

- **VAS scores decreased by 30–55 %** in laser-treated patients, with the most significant pain relief occurring within **3–7 days postoperatively** (**$p < 0.01$**).

**Inflammation Control:**

- TNF-α and IL-6 levels were significantly lower in LLLT-treated groups, while VEGF expression was increased, promoting better vascularization and reduced swelling ($p < 0.05$).

Reduction of Postoperative Complications:

- Lower infection rates, reduced wound dehiscence, and fewer postoperative complications were observed in LLLT-treated groups compared to standard care ($p < 0.05$).


**Fig. 2.** Risk of bias assessment of the included randomized controlled trials using the Cochrane RoB 2 tool. Overall bias judgment is shown in the final column. Most studies demonstrated low risk across all domains, although a few exhibited methodological concerns—particularly in outcome reporting and intervention adherence. One study (Ustaoglu 2017) showed high risk due to outcome measurement bias.

## 4. Discussion

This systematic review of 18 randomized controlled trials demonstrated that Low-Level Laser Therapy (LLLT) significantly improves wound healing, reduces postoperative pain by up to 55 %, and decreases inflammatory markers such as TNF-α and IL-6 in patients undergoing oral surgical procedures. The findings consistently demonstrate that LLLT offers clinical benefits in enhancing wound healing, reducing postoperative pain, and modulating inflammation. However, significant heterogeneity in treatment protocols, laser parameters, and outcome assessments highlights the challenges in translating this evidence into standardized clinical practice. By applying the PROPS framework—an analytical model that emphasizes Perspective, Restrictions, Outcomes, Population, and Stakeholders—this discussion explores the contextual relevance of findings and identifies critical areas for future improvement.

From the **Perspective** of clinicians and researchers in oral surgery, the application of LLLT represents a non-invasive, biologically plausible intervention with the potential to address some of the most common and burdensome postoperative complications. Traditional postoperative care often relies heavily on pharmacological agents such as NSAIDs, corticosteroids, and opioids, which carry well-documented adverse effects. LLLT provides an alternative mechanism of action, exerting its effects through photobiomodulation rather than systemic pharmacokinetics. This review confirms that LLLT activates cytochrome c oxidase within the mitochondrial respiratory chain, increasing ATP production and stimulating tissue regeneration through upregulation of fibroblast activity, collagen synthesis, and angiogenesis. These molecular mechanisms support the observed clinical improvements in epithelialization and tissue remodeling.

In terms of **Restrictions**, the review deliberately imposed minimal limitations to capture the full breadth of evidence. Studies were not excluded based on language, geographic region, or publication year, which enhances external validity. Nevertheless, this inclusive approach also introduces methodological heterogeneity that complicates synthesis. For example, wavelengths across studies ranged from 660 to 1064 nm, and energy densities varied from 3 to 35 J/cm$^2$. Treatment frequencies ranged from single to multiple sessions, and follow-up durations spanned from a few days to six months. Such variability hindered meta-analytic pooling and highlights the urgent need for standardized treatment protocols to facilitate comparability.

Regarding **Outcomes**, the findings of this review underscore the positive effects of LLLT on key postoperative parameters. In wound healing, nearly all studies reported significantly faster tissue regeneration, particularly when red (660–810 nm) and near-infrared (940–1064 nm) wavelengths were used. Bardvalli et al. [24] (2022) and Özer et al. [12] (2024) found improved wound closure and reduced non-epithelialized areas within the first postoperative week. These effects were reinforced by Scarano et al. [3] (2020), who observed earlier epithelial maturation and diminished inflammatory infiltration in laser-treated extraction sockets.

Postoperative pain reduction was another frequently reported benefit. About 85 % of the included trials demonstrated significant reductions in pain levels during the acute healing phase (Days 1–7), as measured by the Visual Analogue Scale (VAS). The mechanism behind this analgesic effect likely involves modulation of nociceptive signaling pathways, including C-fiber inhibition, suppression of inflammatory mediators, and stimulation of endogenous endorphins. Studies by Kahraman et al. [4] (2017) and Reza et al. [1] (2021) highlighted sustained pain relief over several days, reducing reliance on systemic analgesics.

LLLT also demonstrated consistent anti-inflammatory effects. Several studies documented reductions in TNF-α and IL-6, along with increased VEGF expression, reflecting improved microvascular repair and immune modulation. Zou et al. [19] (2024) and Morshedzadeh et al. [8] (2022) reported decreased clinical inflammation (e.g., edema and crevicular fluid volume) and improved vascularization. However, many studies employed subjective or semi-quantitative methods for inflammation assessment, and future research should prioritize molecular biomarkers and imaging tools for more objective analysis.

The **Population** targeted in the included trials was diverse, encompassing patients undergoing third molar extractions, dental implant placement, periodontal interventions, mucosal grafts, and maxillofacial surgeries. This clinical heterogeneity broadens the generalizability of findings, affirming LLLT's relevance across a wide spectrum of oral surgical contexts. However, few studies conducted subgroup analyses based on patient age, comorbidities, or surgical indication. Such analyses could help identify specific populations who may derive the greatest benefit from LLLT—such as medically compromised patients, individuals with impaired wound healing, or those with heightened sensitivity to pain medications.

From a **Stakeholder** perspective, the review addresses the interests of dental professionals, oral surgeons, researchers, and healthcare policymakers. The findings support LLLT as a valuable tool to improve patient outcomes, reduce pharmacologic burden, and potentially decrease postoperative complications. Importantly, several studies noted secondary benefits such as improved soft tissue color and texture, increased patient satisfaction, and reduced analgesic consumption—all of which contribute to a more positive patient experience. These outcomes, while often underreported, are crucial for promoting patient-centered care and improving oral health–related quality of life (OHRQoL).

Despite these promising findings, several limitations temper the strength of the conclusions. A major concern is the lack of methodological standardization. The absence of universally accepted parameters for wavelength, energy density, power output, treatment frequency, and application technique hampers efforts to establish clinical guidelines. For instance, Pereira et al. [5] (2024) reported no significant difference between single-wavelength and dual-wavelength protocols, suggesting that the benefits of LLLT may plateau beyond a certain threshold or that patient and procedural factors modulate responsiveness. Future randomized trials should include dose-response analyses to determine optimal therapeutic windows.

Moreover, the methodological quality of the included trials was variable. While 12 studies were rated as low risk of bias, others [22] (e.g., Ustaoglu et al. 2017) showed high risk due to incomplete outcome reporting or deviations from the intended protocol. In some cases, studies included interventions that diverged mechanistically from LLLT, such as antimicrobial photodynamic therapy (aPDT). Although these interventions used low-intensity light, their mechanism involves reactive oxygen species generation rather than photobiomodulation, raising concerns about conceptual overlap. Greater precision in inclusion criteria and clearer justification for study selection are essential in future reviews.

The lack of meta-analysis is another limitation, albeit a justified one given the degree of clinical and statistical heterogeneity. Nonetheless, the review could be strengthened by providing a heterogeneity index (e.g., $I^2$ values) or subgroup summaries based on surgical type or wavelength range. Additionally, long-term outcomes such as bone remodeling, scar maturation, and implant stability were rarely evaluated, leaving a gap in our understanding of LLLT's extended therapeutic impact.

Lastly, patient-reported outcomes were inconsistently reported. Only a minority of studies included validated OHRQoL instruments or satisfaction scores, despite their relevance to treatment success. As dentistry continues to adopt more patient-centered models of care, future research should incorporate standardized tools for evaluating patient perceptions, quality of life, and functional recovery.

Emerging evidence suggests that the presence of periodontitis may exacerbate postoperative pain due to its underlying chronic inflammatory nature. Periodontitis is characterized by elevated systemic levels of proinflammatory cytokines such as TNF-α, IL-1β, and IL-6, which may prime local tissues for heightened nociceptive responses following surgical trauma [13]. Furthermore, altered host immune responses and vascular remodeling in periodontal tissues may impair healing capacity, contributing to prolonged discomfort. These considerations are particularly relevant in third molar surgeries, where local periodontal conditions—such as deep pockets or attachment loss on second molars—have been shown to correlate with increased postoperative morbidity [14]. Although the reviewed studies did not uniformly stratify patients by baseline periodontal status, the consistent pain-reducing effects of LLLT across diverse surgical sites suggest a modulatory benefit on neurogenic inflammation, which could be especially advantageous in periodontally compromised patients. Future RCTs should incorporate periodontal screening to better elucidate the interaction between pre-existing disease and LLLT outcomes.

In summary, this systematic review supports the clinical utility of LLLT as a safe, non-invasive adjunct for improving outcomes in oral surgery. The PROPS framework facilitated a comprehensive analysis of the evidence, highlighting the biological rationale (Perspective), broad applicability (Population), and potential impact on clinical practice (Stakeholders), while also identifying critical areas where methodological rigor and standardization are needed (Restrictions and Outcomes). By addressing these gaps, future research can move closer to defining evidence-based protocols that enable reliable and widespread integration of LLLT in surgical dentistry.

## 5. Conclusion

In conclusion, Low-Level Laser Therapy (LLLT) appears to be a safe and effective adjunct to conventional postoperative care in oral surgery, offering measurable benefits in wound healing, inflammation modulation, and pain reduction. These effects may be particularly valuable in patients with underlying periodontal disease, where chronic inflammation can amplify postoperative discomfort and delay healing. However, the current evidence base is limited by variability in laser parameters and lack of stratification by periodontal status. Future well-designed RCTs are needed to establish standardized protocols and to explore the potential of LLLT in managing postoperative outcomes in high-risk periodontal profiles. Clinicians should consider incorporating LLLT into surgical protocols not only to enhance tissue repair but also to mitigate pain in periodontally susceptible patients.

## CRediT authorship contribution statement

**Alain Chaple Gil:** Writing – original draft, Supervision, Project administration, Investigation, Formal analysis, Data curation, Conceptualization. **Leonardo Díaz:** Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Conceptualization. **Alfredo Von Marttens:** Conceptualization, Investigation, Writing – original draft, Writing – review & editing. **Claudio Sotomayor:** Data curation, Methodology, Writing – original draft, Writing – review & editing. **Javier Basualdo:** Writing – review & editing, Visualization, Project administration, Formal analysis, Data curation. **Víctor Beltrán:** Writing – review & editing, Writing – original draft, Visualization, Validation. **Gilbert Jorquera:** Formal analysis, Investigation, Validation, Writing – original draft, Writing – review & editing. **Rodrigo Caviedes:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **Eduardo Fernández:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

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