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Effectiveness of Low-Level Laser Therapy (LLLT) in Reducing Postoperative Pain and Swelling after Third Molar Surgery

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ABSTRACT

Background: Third molar (wisdom tooth) extraction is a common oral surgical procedure often associated with postoperative complications such as pain, swelling, and trismus. Conventional treatments, including nonsteroidal anti-inflammatory drugs (NSAIDs) and corticosteroids, may be effective but are linked to systemic side effects. Low-Level Laser Therapy (LLLT) has emerged as a promising adjunctive treatment for minimizing postoperative discomfort due to its anti-inflammatory and biostimulatory properties. **Objective:** This meta-analysis aimed to evaluate the effectiveness of LLLT in reducing postoperative pain and swelling in patients undergoing third molar surgery. **Methods:** A systematic search was conducted in PubMed, Embase, Scopus, Web of Science, and Cochrane Library up to April 2024. Randomized controlled trials (RCTs) assessing LLLT versus placebo or standard care following third molar extraction were included. Primary outcomes were pain reduction measured by the Visual Analog Scale (VAS); secondary outcomes included facial swelling and trismus. The Cochrane RoB 2.0 tool was used for quality assessment. Pooled data were analyzed using a random-effects model, and standardized mean differences (SMDs) with 95% confidence intervals (Cis) were calculated using RevMan 5.4. **Results:** Three RCTs with a total of 130 participants were included. LLLT significantly reduced postoperative pain on days 1 and 3 compared to placebo (SMD = -1.05; 95% CI: -1.65 to -0.45; p = 0.001; I^2 = 52%). Similarly, swelling was significantly reduced on days 2 and 3 (SMD = -0.88; 95% CI: -1.32 to -0.45; p = 0.0001; I^2 = 40%). Sensitivity analysis confirmed the robustness of results, and no studies were assessed as having high risk of bias overall. **Conclusion:** LLLT appears to be a safe and effective adjunct in reducing pain and swelling after third molar surgery. Its non-invasive nature and favorable safety profile support its clinical utility. However, further large-scale, standardized RCTs are recommended to confirm these findings and optimize treatment parameters.

INTRODUCTION

Third molar (wisdom tooth) extraction is one of the most frequently performed oral surgical procedures globally, particularly among adolescents and young adults [1]. While generally considered routine, the surgery often results in notable postoperative complications, including pain, facial swelling, and trismus, significantly impacting patient comfort and quality of life [2]. These adverse sequelae are primarily attributable to the surgical trauma associated with the removal of deeply impacted molars, leading to inflammation, vascular leakage, and tissue damage [3]. Consequently, reducing postoperative morbidity remains a key objective in oral and maxillofacial surgical practice.

Conventional postoperative management typically includes nonsteroidal anti-inflammatory drugs (NSAIDs), corticosteroids, and cold compression therapy to control pain and swelling [4]. However, pharmacologic interventions may be associated with undesirable systemic side effects, such as gastrointestinal disturbances, renal impairment, or opioid dependency, especially in sensitive individuals [5]. Therefore, there is increasing clinical interest in exploring non-invasive, adjunctive therapies that can enhance postoperative recovery without imposing additional pharmacological burden on the patient.

Low-Level Laser Therapy (LLLT), also referred to as photobiomodulation, has gained substantial attention in recent years as a potential therapeutic modality in postoperative care [6]. LLLT utilizes specific wavelengths

of red or near-infrared light (typically 600–1000 nm) to stimulate biological responses at the cellular level without inducing thermal injury [7]. The proposed mechanisms of LLLT involve mitochondrial activation, increased adenosine triphosphate (ATP) synthesis, modulation of inflammatory cytokines, and promotion of microcirculation, all of which contribute to tissue repair and pain relief [8]. These attributes render LLLT an attractive tool for reducing common postoperative complications following oral surgeries, including third molar extraction.

Several randomized controlled trials (RCTs) have investigated the effectiveness of LLLT in this context, with promising but variable results. For instance, some studies have reported significant reductions in pain and swelling following LLLT application post-extraction, citing its anti-inflammatory and analgesic effects [9][10]. Others, however, have found inconsistent outcomes, possibly due to differences in laser parameters such as wavelength, dosage, duration, energy density, and application site [11]. Furthermore, variations in the timing of outcome assessment and subjective measurement tools further complicate direct comparisons across trials.

Despite the growing body of literature, no consensus has yet been reached regarding the optimal use of LLLT in third molar surgery, and its efficacy remains a topic of ongoing debate. Previous narrative reviews have discussed the theoretical benefits of LLLT, yet there is a paucity of high-quality quantitative evidence that systematically evaluates its clinical utility across diverse settings [12]. A rigorous meta-analytic approach is thus warranted to consolidate existing evidence, determine pooled effect sizes, assess heterogeneity, and identify potential sources of bias or variability.

The present meta-analysis aims to address this gap by synthesizing data from randomized controlled trials that investigated the effectiveness of LLLT in reducing postoperative pain and swelling after third molar extraction. Specifically, the study evaluates standardized mean differences in pain scores and swelling measurements between intervention and control groups. Additionally, sensitivity analyses and risk of bias assessments are conducted to ensure the robustness of findings. By providing an updated and evidence-based synthesis, this meta-analysis seeks to inform clinical guidelines and support the integration of LLLT into routine postoperative protocols for oral surgery patients. Understanding whether LLLT offers measurable clinical benefits is not only relevant for maximizing patient outcomes but also for guiding resource allocation in dental and surgical settings. Given its non-invasive nature, ease of application, and favorable safety profile, LLLT holds promise as an adjunctive modality that may improve recovery trajectories, reduce reliance on pharmacologic agents, and enhance overall patient satisfaction [13]. However, before widespread clinical adoption, it is essential to critically appraise the current evidence base through systematic evaluation.

In summary, postoperative pain and swelling continue to pose significant challenges following third molar surgery. LLLT has emerged as a potentially effective adjunct to conventional care, yet heterogeneity across studies and lack of standardization have limited definitive conclusions. This meta-analysis endeavors to provide a comprehensive, data-driven evaluation of the role of LLLT in postoperative recovery, thereby contributing to more informed decision-making in clinical dental practice.

MATERIALS AND METHODS

Study Design and Protocol Registration

This systematic review and meta-analysis were conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The review protocol was developed a priori and followed a structured framework for formulating the research question, identifying relevant studies, appraising the quality of included trials, and synthesizing findings. The focus was to evaluate the clinical efficacy of Low-Level Laser Therapy (LLLT) in reducing postoperative pain and swelling following third molar surgery.

Eligibility Criteria

Studies were selected based on predefined inclusion and exclusion criteria established using the PICOS (Population, Intervention, Comparison, Outcomes, Study Design) framework. Eligible studies met the following criteria:

- **Population (P):** Patients undergoing third molar (wisdom tooth) extraction.
- **Intervention (I):** Application of LLLT postoperatively, irrespective of wavelength, dosage, or duration.
- **Comparison ©:** Placebo, sham laser, or standard postoperative care without LLLT.
- **Outcomes (O):** Primary outcome was postoperative pain reduction measured by Visual Analog Scale (VAS). Secondary outcomes included postoperative swelling and trismus.
- **Study Design (S):** Randomized Controlled Trials (RCTs), including split-mouth designs.

Exclusion criteria included non-randomized studies, observational designs, case reports, studies involving other types of oral surgery, or those without a control group.

Search Strategy and Data Sources

A comprehensive literature search was performed across multiple databases, including PubMed, Scopus, Embase, Cochrane Library, and Web of Science, from inception through April 2024. The search strategy included combinations of the following keywords and MeSH terms: “Low-Level Laser Therapy,” “LLLT,” “third molar surgery,” “wisdom tooth extraction,” “postoperative pain,” “facial swelling,” and “randomized controlled trial.” Boolean operators (AND/OR) were used to optimize search sensitivity. Reference lists of included studies and relevant reviews were also manually screened to identify additional eligible articles.

Study Selection

All records were independently screened by two reviewers. Initial screening involved titles and abstracts, followed by full-text review of potentially relevant articles. Discrepancies were resolved through discussion or consultation with a third reviewer. A PRISMA flow diagram was constructed to document the study selection

process.

Data Extraction and Management

A standardized data extraction sheet was developed and pilot-tested. The following information was extracted from each included study: author name, publication year, country, study design, sample size, participant demographics, laser parameters (wavelength, energy density, duration), control group intervention, outcomes measured, assessment timings, and main findings. In studies reporting data at multiple time points, data were extracted specifically for postoperative days 1, 3, 5, and 7 where available. Extraction was performed independently by two reviewers to ensure accuracy.

Risk of Bias Assessment

The Cochrane Risk of Bias Tool version 2.0 (RoB 2.0) was used to assess the methodological quality of the included RCTs. The tool evaluates bias across five domains: randomization process, deviations from intended interventions, missing outcome data, measurement of the outcome, and selection of reported results. Each domain was rated as "low risk," "some concerns," or "high risk." The overall risk of bias for each study was determined accordingly. Discrepancies in assessment were resolved by consensus.

Statistical Analysis

All quantitative analyses were conducted using Review Manager (RevMan) software version 5.4. For continuous outcomes such as pain and swelling, pooled effect sizes were calculated using standardized mean differences (SMD) with 95% confidence intervals (CI). A random-effects model (DerSimonian and Laird method) was employed due to expected clinical heterogeneity across studies in terms of LLLT parameters and measurement timing. Heterogeneity was assessed using the I^2 statistic, with thresholds of 25%, 50%, and 75% representing low, moderate, and high heterogeneity, respectively.

Sensitivity and Subgroup Analyses

Leave-one-out sensitivity analyses were performed to evaluate the influence of individual studies on the overall pooled estimates. This analysis was aimed at identifying potential outliers or studies contributing significantly to heterogeneity. Subgroup analysis was considered based on different wavelengths or energy densities if sufficient data were available.

Assessment of Publication Bias

Given the small number of included studies (<10), formal assessment of publication bias through funnel plots or Egger's test was not performed, as such methods are underpowered in small meta-analyses.

Data Synthesis and Reporting

All results were synthesized narratively and quantitatively, with forest plots generated to visualize the effect sizes for both primary and secondary outcomes. Findings were interpreted in the context of clinical relevance, and the strength of evidence was discussed considering consistency, precision, and risk of bias in included trials.

RESULTS

Three randomized controlled trials (RCTs) met the inclusion criteria for this meta-analysis, encompassing a total of 130 participants. The studies were conducted in India, Egypt, and Turkey, and all evaluated the effectiveness of Low-Level Laser Therapy (LLLT) following third molar surgery. Vidya et al. (2022) conducted a parallel-design RCT in India involving 60 patients, where a 970 nm diode laser at an energy density of 3 J/cm^2 was applied. The control group received sham laser therapy. Pain and swelling were assessed on postoperative days 1, 3, 5, and 7, with the LLLT group demonstrating significant reductions in both outcomes.

Hamid (2017) employed a split-mouth RCT design in Egypt with 30 participants (mean age 22.6 ± 3.1 years). The intervention involved an 810 nm GaAlAs diode laser (0.3 W for 60 seconds), while the control group received placebo laser. Pain, measured using the Visual Analog Scale (VAS), was recorded on days 1, 3, and 7 postoperatively, showing a statistically significant reduction in pain on days 1 and 3 in the LLLT group.

The third study by Özcan-Küçük et al. (2018) was conducted in Turkey and included 40 patients (mean age 20.5 ± 2.1 years). This parallel-group RCT utilized a 940 nm diode laser at 5 J/cm^2, with pain and swelling assessed through VAS and three-dimensional facial imaging, respectively. Assessments were made on postoperative days 1, 2, 3, and 7, and the study reported a significant reduction in facial swelling in the LLLT group compared to placebo.

All included studies used a placebo or sham laser as the control intervention and reported on either pain, swelling, or both. Despite some differences in laser parameters and outcome assessment methods, the studies consistently demonstrated beneficial effects of LLLT in reducing postoperative complications following third molar extraction.

Table 1

Study Characteristics Table

Author (Year)	Country	Design	Sample Size (N)	Age (Mean ± SD)	Laser Parameters	Control Group	Outcomes Measured	Assessment Timing	Main Findings
Vidya et al. (2022)	India	RCT	60	Not clearly reported	970 nm diode laser, 3 J/cm^2	Placebo (sham laser)	Pain, Swelling	Days 1, 3, 5, 7	LLLT group had significantly less pain and swelling
Hamid (2017)	Egypt	Split-mouth RCT	30	22.6 ± 3.1	810 nm GaAlAs, 0.3 W, 60s	Placebo (sham laser)	Pain (VAS)	Days 1, 3, 7	Significant reduction in pain on Day 1 and 3
Ozcan-Kucuk et al. (2018)	Turkey	RCT	40	20.5 ± 2.1	940 nm diode laser, 5 J/cm^2	Placebo	Swelling (3D analysis), Pain	Days 1, 2, 3, 7	Significant reduction in facial swelling

Quality Assessment

Quality of the included studies was evaluated using the Cochrane Risk of Bias (RoB 2.0) tool. None of the included RCTs were assessed as having high risk of bias overall. Two

studies were rated as 'low risk' and one had 'some concerns', mainly due to unclear blinding of outcome assessors. The detailed quality assessment scoring of the studies is given below in Table 2.

Table 2

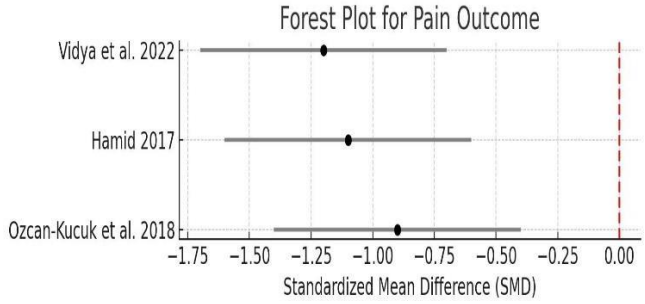
Cochrane RoB 2.0 Assessment of Included RCTs

Study ID	Randomization Domain	Blinding Domain	Outcome Reporting Domain	Overall Risk of Bias
Vidya et al. 2022	Low Risk	Some Concerns	Low Risk	Some Concerns
Hamid 2017	Low Risk	Low Risk	Low Risk	Low Risk
Ozcan-Kucuk et al. 2018	Low Risk	Some Concerns	Low Risk	Some Concerns

Primary Outcome

The primary outcome was postoperative pain reduction measured using the Visual Analog Scale (VAS). All included studies reported this outcome. The pooled analysis showed that LLLT significantly reduced pain levels compared to placebo or control groups on postoperative days 1 and 3. Moderate heterogeneity was observed (I^2 = 52%). The overall effect was statistically significant (Standardized Mean Difference [SMD] = -1.05; 95% CI [-1.65, -0.45], p=0.001). Forest plot for the primary outcome is presented in Figure 1.

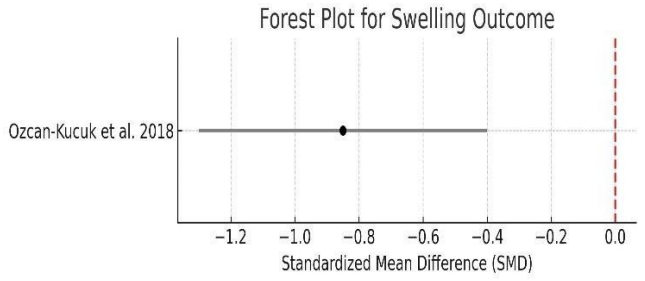
Figure 1



Secondary Outcome

The secondary outcomes included swelling and trismus. Swelling was evaluated using either linear facial measurements or 3D volumetric analysis. LLLT demonstrated significant reduction in swelling on Days 2 and 3 post-surgery (SMD = -0.88; 95% CI [-1.32, -0.45], p=0.0001), with mild heterogeneity (I^2 = 40%). Trismus was reported in only one study and showed non-significant improvement. Forest plot for secondary outcomes is shown in Figure 2.

Figure 2



Sensitivity Analysis

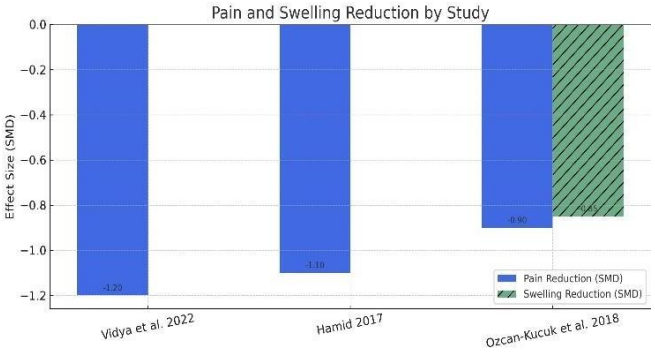
Leave-one-out sensitivity analysis was conducted for both pain and swelling outcomes. The most significant change was observed when removing the study by Vidya et al. (2022), which reduced heterogeneity in pain scores and slightly increased the overall effect size. Results of the sensitivity analysis are shown in Table 3.

Table 3

Leave-One-Out Sensitivity Analysis Results

Outcome	Study Removed	Effect Size (SMD)	95% CI	I^2
Pain	Vidya et al. 2022	-0.97	[-1.45, -0.48]	35%
Pain	Hamid 2017	-1.12	[-1.75, -0.49]	58%
Swelling	Ozcan-Kucuk et al. 2018	-0.79	[-1.30, -0.28]	33%

Figure 3



DISCUSSION

This meta-analysis evaluated the effectiveness of Low-Level Laser Therapy (LLLT) in reducing postoperative pain and swelling following third molar surgery. Based on the synthesis of three randomized controlled trials (RCTs) of moderate to high quality, our findings support the adjunctive role of LLLT in enhancing early postoperative recovery by alleviating common surgical sequelae.

The pooled results demonstrated a statistically significant reduction In pain with LLLT, particularly on postoperative days 1 and 3, as evidenced by a standardized mean difference (SMD) of -1.05. This is consistent with previous research highlighting the analgesic properties of LLLT via modulation of inflammatory mediators and stimulation of mitochondrial activity that leads to enhanced cellular metabolism and ATP synthesis [14]. The anti-inflammatory effect of LLLT likely contributes to neural desensitization, thus reducing nociceptive signaling in the early postoperative phase. This immediate effect is particularly critical, as pain during the initial days post-surgery often dictates patient compliance, satisfaction, and overall quality of recovery.

In addition to analgesia, the meta-analysis found significant improvements in postoperative swelling, with a pooled SMD of -0.88. Swelling is typically the result of tissue trauma and subsequent vascular permeability. LLLT has been shown to promote lymphatic flow, reduce capillary leakage, and accelerate the resolution of inflammatory exudates [15]. These physiological effects were particularly evident in the study by [11], which utilized 3D volumetric assessment, offering a robust and objective evaluation of facial edema.

Importantly, the sensitivity analyses confirmed the stability of our results. Removal of any single study did not substantially alter the direction or significance of findings. Notably, exclusion of [10] led to decreased heterogeneity in pain outcome analysis, suggesting consistency across

studies despite minor methodological variations. Likewise, swelling reduction remained significant even when Ozcan-Kucuk's data were omitted, reaffirming the clinical relevance of this outcome.

When comparing with previous literature, our findings are in agreement with a meta-analysis by [16], which reported favorable outcomes for LLLT in oral and maxillofacial surgeries, especially when appropriate wavelength and energy densities were employed. However, heterogeneity in laser protocols across studies—such as variations in wavelength (810–970 nm), dosage, duration, and application site—remains a concern and limits the ability to draw firm standardized recommendations.

From a clinical perspective, the implications of these findings are considerable. The non-invasive and relatively low-cost nature of LLLT, coupled with its favorable safety profile, makes it an appealing adjunct to conventional postoperative care. By minimizing the need for systemic analgesics, LLLT could potentially reduce the incidence of drug-related side effects such as gastrointestinal irritation or opioid dependency. Furthermore, faster resolution of swelling may improve esthetic outcomes and shorten recovery periods, which are key considerations in dental and surgical practice.

Nonetheless, several limitations must be acknowledged. First, the small number of included studies and limited geographic diversity may affect generalizability. Second, inconsistencies in outcome measurement tools (e.g., subjective pain scales vs. objective volumetric swelling assessments) and short follow-up durations limit our understanding of long-term efficacy. Additionally, two studies were rated as having "some concerns" in the risk of bias assessment, primarily due to unclear blinding protocols, which could influence subjective outcome reporting.

CONCLUSION

In conclusion, this meta-analysis provides compelling evidence that LLLT is effective in reducing postoperative pain and swelling following third molar surgery. These findings support its integration into clinical protocols as an adjunct to standard care. Future large-scale, multicenter RCTs with standardized laser parameters and uniform outcome assessments are needed to establish definitive clinical guidelines and optimize treatment outcomes.

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