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PHOTOBIMODULATION IN THE MANAGEMENT OF PAIN, EDEMA, AND TRISMUS AFTER IMPACTED THIRD MOLAR SURGERY: THE ROLE OF BIOPTRON POLARIZED LIGHT IN CURRENT EVIDENCE

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ABSTRACT

Background. Surgical extraction of impacted third molars is often followed by pain, edema, and trismus, which may impair oral function and daily activities during early healing. Photobiomodulation therapy, including low-level laser, LED, and polarized polychromatic non-coherent light, has been investigated as a non-invasive adjunct for reducing postoperative morbidity. Bioptron delivers polarized polychromatic non-coherent light, but evidence for its use in oral surgery is limited.

Aim. This narrative review evaluates evidence on photobiomodulation in the management of complications after impacted third molar surgery, with emphasis on the role of Bioptron polarized light therapy.

Material and methods. A literature search was conducted in PubMed/MEDLINE, Scopus, Web of Science, Cochrane Library, and Google Scholar for publications from 2000 to 2025. Clinical trials, systematic reviews, meta-analyses, and relevant observational studies assessing photobiomodulation, laser therapy, LED therapy, or polarized light therapy in third molar surgery were included.

Results. Evidence suggests that photobiomodulation may reduce postoperative pain, edema, and, to a lesser extent, trismus after third molar extraction, with the strongest support for laser and LED-based interventions. Proposed mechanisms include cytochrome c oxidase activation, increased ATP production, modulation of reactive oxygen species and inflammatory mediators, and enhanced wound healing. However, studies show heterogeneity in treatment parameters, timing, sessions, comparators, and outcome assessment. Evidence specifically addressing Bioptron in this indication remains sparse.

Conclusions. Photobiomodulation appears safe and potentially useful after third molar surgery, but evidence supporting Bioptron polarized light remains insufficient. Randomized controlled trials with standardized protocols, sham controls, adequate sample sizes, and validated outcomes are needed.

KEYWORDS

Photobiomodulation, Bioptron, Polarized Light, Third Molar Surgery, Postoperative Pain, Edema, Trismus, Oral Surgery

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1. Introduction

1.1. Clinical Importance of Impacted Third Molar Surgery

Surgical extraction of impacted third molars is among the most commonly performed procedures in oral and maxillofacial surgery worldwide.(Lacerda-Santos et al., 2023; Ferreira González et al., 2025) The indication for removal may arise in a variety of clinical situations, including recurrent pericoronitis, caries affecting the third molar or adjacent second molar, periodontal compromise, cystic or other pathological changes, orthodontic considerations, and prophylactic removal in selected circumstances. Because impacted third molars are often encountered in adolescents and young adults, the procedure is especially common in otherwise healthy patients who typically expect rapid postoperative recovery and minimal functional limitation.

Despite significant advances in surgical technique, instrumentation, local anesthesia, preoperative planning, and postoperative care, morbidity after third molar removal remains common. In many patients, the postoperative course is uncomplicated but still accompanied by clinically relevant symptoms, especially during the first several days after surgery. From a patient-centered perspective, the importance of postoperative sequelae extends beyond short-term tissue injury, as pain, facial swelling, and limited mouth opening may interfere with speaking, chewing, sleeping, oral hygiene, work, and social functioning.(Pérez et al., 2025; Hadad et al., 2022) For this reason, optimization of postoperative management remains an important objective in contemporary oral surgery.

1.2. Postoperative Complications

The most prevalent postoperative complications after third molar extraction include pain, edema, trismus, inflammation, delayed wound healing, and, in some cases, alveolar osteitis.(Pérez et al., 2025; Hadad et al., 2022; Lacerda-Santos et al., 2023; Nejat et al., 2021; Isolan et al., 2021) Pain is generally most intense during the first 24 to 48 hours after surgery and may persist for several days, although the exact temporal profile varies according to the degree of surgical trauma, the extent of tissue manipulation, and the individual inflammatory response.(Pérez et al., 2025; Hadad et al., 2022; Lacerda-Santos et al., 2023; Nejat et al., 2021; Isolan et al., 2021) Pain is often the primary concern reported by patients and frequently determines the need for rescue analgesics and early postoperative follow-up.

Facial edema usually reaches its maximum intensity between 48 and 72 hours after surgery and then gradually resolves over the subsequent 5 to 7 days.(Pérez et al., 2025; Hadad et al., 2022; Lacerda-Santos et al., 2023; Duarte de Oliveira et al., 2021; Mohajerani et al., 2021) Although edema is expected after flap elevation, osteotomy, and tooth sectioning, its magnitude can vary considerably and may affect patient comfort, facial appearance, and perceived quality of recovery. Trismus, commonly defined as reduced maximum mouth opening, results from inflammation, edema, and protective spasm involving the muscles of mastication, particularly when the surgical field is extensive or when deeper tissue dissection is required.(Pérez et al., 2025; Hadad et al., 2022; Lacerda-Santos et al., 2023; Duarte de Oliveira et al., 2021; Mohajerani et al., 2021) In practical terms, trismus may significantly impair speech, food intake, swallowing, oral hygiene measures, and adherence to postoperative instructions.

The severity of these postoperative events is influenced by numerous factors, including the complexity of the impaction, depth and angulation of the tooth, operative duration, extent of bone removal, need for

odontosection, patient age, anatomical characteristics, surgeon experience, and patient-related biological variability.(Lacerda-Santos et al., 2023; Alves Pereira et al., 2025) Conventional management is based primarily on pharmacological measures such as non-steroidal anti-inflammatory drugs, corticosteroids, and analgesics. Although these agents are generally effective, they are not universally suitable and may be associated with adverse effects, drug interactions, gastrointestinal intolerance, hypersensitivity reactions, or contraindications in selected patient groups.(Lacerda-Santos et al., 2023; Alves Pereira et al., 2025) This has contributed to interest in non-pharmacological adjuncts capable of reducing postoperative morbidity without adding systemic burden.

1.3. Photobiomodulation: Basic Concepts

Photobiomodulation therapy, previously referred to as low-level laser therapy or low-level light therapy, is based on the therapeutic use of red or near-infrared light delivered at low power densities that do not produce clinically relevant thermal injury.(Lewis et al., 2024; de Freitas & Hamblin, 2016; Maghfour et al., 2024; Heiskanen & Hamblin, 2018; Dompe et al., 2020) In contrast to ablative or high-intensity light-based approaches, photobiomodulation is intended not to cut, coagulate, or vaporize tissue, but rather to induce biologically favorable cellular responses through photochemical and photobiological mechanisms. Over time, the term photobiomodulation has become preferable because it more accurately reflects the range of light sources used in this field, including lasers, light-emitting diodes, and broad-band lamps.(Lewis et al., 2024; de Freitas & Hamblin, 2016; Maghfour et al., 2024; Heiskanen & Hamblin, 2018; Dompe et al., 2020) The term also emphasizes that the expected clinical effects arise primarily from modulation of cellular function rather than from heat generation.(Lewis et al., 2024; de Freitas & Hamblin, 2016; Maghfour et al., 2024; Heiskanen & Hamblin, 2018; Dompe et al., 2020)

The biological foundation of photobiomodulation is generally considered to involve photon absorption by endogenous chromophores, particularly cytochrome c oxidase within the mitochondrial respiratory chain.(Lewis et al., 2024; de Freitas & Hamblin, 2016; Maghfour et al., 2024; Keshri et al., 2016; Khan et al., 2021; Mokoena et al., 2018) Once absorbed, light energy is thought to trigger a cascade of cellular and molecular events that influence mitochondrial respiration, energy metabolism, intracellular signaling, inflammatory activity, and tissue repair. One proposed mechanism involves dissociation of inhibitory nitric oxide from cytochrome c oxidase, thereby facilitating electron transport and improving mitochondrial efficiency.(Lewis et al., 2024; de Freitas & Hamblin, 2016; Maghfour et al., 2024; Keshri et al., 2016; Khan et al., 2021; Mokoena et al., 2018) As a result, intracellular adenosine triphosphate levels may rise, supporting energy-demanding processes such as protein synthesis, cell migration, matrix remodeling, and reparative responses.(Lewis et al., 2024; de Freitas & Hamblin, 2016; Maghfour et al., 2024; Keshri et al., 2016; Khan et al., 2021; Mokoena et al., 2018)

In addition to effects on mitochondrial metabolism, photobiomodulation has been shown to influence reactive oxygen species, transcription factor activation, cytokine expression, angiogenesis, fibroblast behavior, epithelialization, and extracellular matrix turnover.(Keshri et al., 2016; Khan et al., 2021; Mokoena et al., 2018; de Freitas & Hamblin, 2016) Through these pathways, light therapy may reduce inflammation, promote wound healing, and improve recovery after surgical trauma. The extent of these biological effects depends heavily on treatment parameters such as wavelength, fluence, output power, exposure time, treatment interval, and tissue optical properties.

1.4. Differences Between Light-Based Therapeutic Modalities

Low-level laser therapy uses coherent, monochromatic, and collimated light generated by laser devices. Commonly used wavelengths include 660 nm in the red spectrum and 808–810 nm and 980 nm in the near-infrared spectrum.(Pérez et al., 2025; Hadad et al., 2022; Isolan et al., 2021; Heiskanen & Hamblin, 2018; Dompe et al., 2020) Laser light is characterized by high spectral purity and the ability to deliver energy with precision to specific points or small target areas. These physical properties have contributed to the wide use of lasers in clinical photobiomodulation research.(Pérez et al., 2025; Hadad et al., 2022; Isolan et al., 2021; Heiskanen & Hamblin, 2018; Dompe et al., 2020)

Light-emitting diode therapy, by contrast, employs non-coherent light with a relatively narrow but not strictly monochromatic wavelength distribution. LED devices offer several practical advantages, including lower cost, the ability to illuminate larger areas, reduced safety concerns compared with lasers, and potential

suitability for home-based or wearable applications.(Mohajerani et al., 2021; de Lima Luna et al., 2025; Tennis et al., 2018; Heiskanen & Hamblin, 2018; da Rocha et al., 2024) Importantly, despite lacking coherence, LED-based photobiomodulation has demonstrated biological and clinical effects that are comparable in many settings to those of low-level laser therapy.(Mohajerani et al., 2021; de Lima Luna et al., 2025; Tennis et al., 2018; Heiskanen & Hamblin, 2018; da Rocha et al., 2024)

Polarized polychromatic non-coherent light constitutes another category of light-based therapy. It typically includes linearly polarized visible and near-infrared wavelengths spanning a relatively broad spectrum, often reported in the range of 480–3400 nm.(Feehan et al., 2018; Tripodi et al., 2022; Tripodi et al., 2023) Polarization refers to restriction of light-wave oscillation to a single plane, and some authors have proposed that this may influence light-tissue interaction, penetration, or cellular response. Theoretical advantages of polarized light include a larger spectrum of tissue interaction and potentially deeper penetration, although the exact biological significance of polarization remains incompletely defined.(Feehan et al., 2018; Tripodi et al., 2022; Tripodi et al., 2023)

1.5. Characteristics of Bioptron

Bioptron is a commercially available medical device that delivers polarized polychromatic non-coherent light for therapeutic use.(Nardi et al., 2022; Feehan et al., 2018) The device emits light over a broad spectral range, generally reported between 480 and 3400 nm, with linear polarization and low power density. In contrast to laser devices, Bioptron does not produce monochromatic or coherent light and is not designed to concentrate energy into a small point source. Instead, it delivers light over a broader area, which may be advantageous for superficial and moderately extensive tissue targets.(Nardi et al., 2022; Feehan et al., 2018)

The proposed mechanisms of action of Bioptron overlap conceptually with those of other photobiomodulation modalities and include mitochondrial activation, modulation of inflammation, effects on cellular metabolism, and promotion of tissue repair.(Feehan et al., 2018; Tripodi et al., 2022; Nardi et al., 2022) However, the evidence base specifically supporting Bioptron in oral and maxillofacial surgery remains much smaller than that supporting laser-based and LED-based photobiomodulation.(Feehan et al., 2018; Tripodi et al., 2022; Nardi et al., 2022) In addition, the independent therapeutic contribution of polarization as a physical property has not been fully established, and this remains an area in need of more focused investigation.

1.6. Rationale for This Review

Although interest in photobiomodulation as a supportive modality in oral surgery has grown substantially, important uncertainties remain regarding ideal treatment parameters, comparative effectiveness of different light sources, timing of application, number of sessions, and the extent to which findings from one device type can be extrapolated to another. Bioptron has been promoted for various medical and dental indications, yet its role after third molar surgery has not been critically examined to the same extent as low-level laser therapy or LED-based approaches. The present review was therefore undertaken to provide a comprehensive analysis of the available evidence regarding photobiomodulation in the management of postoperative pain, edema, and trismus after impacted third molar surgery, with particular consideration of the place of Bioptron polarized light within the current evidence base.

2. Research Materials and Methods

2.1. Type of Review

This manuscript was designed as a narrative review using a semi-systematic search strategy in order to provide a broad but structured overview of the literature addressing photobiomodulation in the management of postoperative morbidity following impacted third molar surgery. The purpose of this approach was to integrate mechanistic, clinical, and translational findings relevant to pain control, edema reduction, trismus management, and tissue healing, while also considering the comparatively limited literature concerning polarized polychromatic non-coherent light and Bioptron.

2.2. Databases Searched

A literature search was conducted in the following electronic databases:

- PubMed/MEDLINE
- Scopus
- Web of Science
- Cochrane Library
- Google Scholar

These databases were selected to maximize capture of both biomedical trials and broader interdisciplinary literature relating to light-based therapies, wound healing, oral surgery, and photobiomodulation mechanisms.

2.3. Time Range

The search primarily focused on publications issued between 2000 and 2025, corresponding to the period during which photobiomodulation research underwent substantial expansion in both experimental and clinical domains. Earlier publications were considered when they provided foundational biological concepts, historically important mechanistic observations, or frequently cited evidence relevant to the interpretation of newer studies.

2.4. Study Types Considered

Randomized controlled trials, split-mouth clinical trials, prospective comparative studies, systematic reviews, meta-analyses, and selected observational studies were considered relevant if they addressed photobiomodulation, low-level laser therapy, LED therapy, or polarized light therapy in connection with third molar surgery or closely related oral wound-healing contexts. Experimental studies were also considered when they contributed meaningfully to understanding the biological effects of photobiomodulation on inflammation, wound repair, or bone healing.

2.5. General Search Terms

The literature search included combinations of terms such as “photobiomodulation,” “low-level laser therapy,” “LED therapy,” “polarized light,” “Bioptron,” “third molar surgery,” “wisdom tooth extraction,” “postoperative pain,” “edema,” “swelling,” “trismus,” “alveolar osteitis,” “wound healing,” and related terms. Priority was given to studies with clear clinical endpoints, defined treatment protocols, and postoperative relevance.

3. Results / Review of the Literature

3.1. Biological Mechanisms of Photobiomodulation

Photobiomodulation exerts its effects through a complex network of photochemical and photobiological events occurring at the cellular and molecular levels.(Lewis et al., 2024; Keshri et al., 2016; Khan et al., 2021; Mokoena et al., 2018; de Freitas & Hamblin, 2016; Maghfour et al., 2024) Understanding these mechanisms is important not only from a basic science perspective but also for rational interpretation of clinical data, because the therapeutic response to light depends on the interaction between device parameters and tissue biology.

3.1.1. Mitochondrial Mechanisms and Cytochrome c Oxidase

For red and near-infrared wavelengths, cytochrome c oxidase in the mitochondrial respiratory chain is widely regarded as the principal photoacceptor in mammalian cells.(Lewis et al., 2024; de Freitas & Hamblin, 2016; Maghfour et al., 2024; Keshri et al., 2016; Mokoena et al., 2018) Under conditions of tissue injury, inflammation, ischemia, or oxidative stress, nitric oxide may bind competitively to cytochrome c oxidase and inhibit mitochondrial respiration.(Lewis et al., 2024; de Freitas & Hamblin, 2016; Maghfour et al., 2024; Keshri et al., 2016; Mokoena et al., 2018) Photon absorption is thought to displace inhibitory nitric oxide, restore respiratory chain activity, and increase mitochondrial membrane potential.(Lewis et al., 2024; de Freitas & Hamblin, 2016; Maghfour et al., 2024; Keshri et al., 2016; Mokoena et al., 2018) This reactivation of mitochondrial function may lead to enhanced ATP generation and improved cellular energetic capacity, which is particularly relevant during tissue repair.(Lewis et al., 2024; de Freitas & Hamblin, 2016; Maghfour et al., 2024; Keshri et al., 2016; Mokoena et al., 2018)

Studies have reported that photobiomodulation can increase ATP content by clinically meaningful margins, depending on wavelength, dose, exposure duration, and cellular state.(Keshri et al., 2016; Priyadarshi et al., 2025) Increased ATP availability may, in turn, support migration of reparative cells, biosynthesis of structural proteins, and other metabolically demanding aspects of wound healing.

3.1.2. Reactive Oxygen Species and Redox Signaling

Photobiomodulation may induce a controlled and transient increase in reactive oxygen species.(Keshri et al., 2016; Khan et al., 2021; Priyadarshi et al., 2025; Oliveira et al., 2022) Importantly, in this context, ROS do not necessarily act as harmful oxidants but may function as intracellular signaling molecules. This mild redox signaling can activate transcriptional programs that enhance the antioxidant defense system and regulate inflammatory resolution. Redox-sensitive transcription factors, including Nrf2, may be stimulated, resulting in increased expression of catalase, superoxide dismutase, glutathione peroxidase, and other protective enzymes.(Keshri et al., 2016; Khan et al., 2021; Priyadarshi et al., 2025; Oliveira et al., 2022)

The biological response to light is not linear across all doses. Rather, photobiomodulation is characterized by a biphasic dose-response relationship, often referred to as hormesis or the Arndt-Schulz principle.(de Freitas & Hamblin, 2016; Heiskanen & Hamblin, 2018) Within an optimal dose range, light may induce beneficial signaling; outside that range, effects may be diminished or even unfavorable. This principle is highly relevant when interpreting heterogeneous clinical results across studies using different dosimetry.

3.1.3. Inflammatory Modulation

One of the most clinically relevant actions of photobiomodulation is modulation of the inflammatory response.(Keshri et al., 2016; Khan et al., 2021; Mokoena et al., 2018; Priyadarshi et al., 2025; Oliveira et al., 2022) Experimental studies have demonstrated reduced expression of pro-inflammatory cytokines such as TNF- α , IL-1 β , IL-6, and NF- κ B-related signaling after appropriate light exposure.(Keshri et al., 2016; Khan et al., 2021; Mokoena et al., 2018; Priyadarshi et al., 2025; Oliveira et al., 2022) At the same time, anti-inflammatory mediators such as IL-10 and interleukin-1 receptor antagonist may be upregulated.(Keshri et al., 2016; Khan et al., 2021; Mokoena et al., 2018; Priyadarshi et al., 2025; Oliveira et al., 2022)

Photobiomodulation has also been associated with modulation of cyclooxygenase-2 and inducible nitric oxide synthase, mechanisms that may reduce prostaglandin production, nitric oxide imbalance, edema

formation, and nociceptor sensitization.(Priyadarshi et al., 2025; Oliveira et al., 2022) These pathways provide a biologically plausible framework for the reduction of pain and swelling observed in postoperative clinical studies.

3.1.4. Pain Modulation

The analgesic effects of photobiomodulation appear to involve both peripheral and possibly central mechanisms.(Priyadarshi et al., 2025; Oliveira et al., 2022; de Freitas & Hamblin, 2016) Peripherally, reduced local inflammatory signaling may decrease activation and sensitization of pain receptors. Photobiomodulation may also reduce expression of substance P and related mediators implicated in pain transmission.(Priyadarshi et al., 2025; Oliveira et al., 2022; de Freitas & Hamblin, 2016) Moreover, experimental evidence suggests that light may influence nerve conduction, membrane excitability, and pain threshold, although the clinical significance of these mechanisms likely depends on treatment protocol and tissue depth.(Priyadarshi et al., 2025; Oliveira et al., 2022; de Freitas & Hamblin, 2016)

3.1.5. Wound Healing and Tissue Repair

Photobiomodulation appears to promote wound healing through effects on fibroblasts, epithelial cells, endothelial cells, inflammatory cells, and the extracellular matrix.(Keshri et al., 2016; Khan et al., 2021; Mokoena et al., 2018; Oliveira et al., 2022; da Rocha et al., 2024; Tripodi et al., 2022; Tripodi et al., 2023) In fibroblasts, light exposure has been associated with increased proliferation, migration, and synthesis of collagen, fibronectin, and elastin.(Keshri et al., 2016; Khan et al., 2021; Mokoena et al., 2018; Oliveira et al., 2022; da Rocha et al., 2024; Tripodi et al., 2022; Tripodi et al., 2023) These processes are fundamental to connective tissue repair and matrix organization. Activation of TGF- β signaling and downstream Smad pathways has been proposed as one of the principal mechanisms involved in this response.(Keshri et al., 2016; Khan et al., 2021; Mokoena et al., 2018; Oliveira et al., 2022; da Rocha et al., 2024; Tripodi et al., 2022; Tripodi et al., 2023)

Photobiomodulation may also promote angiogenesis through upregulation of VEGF and HIF-1 α , facilitating tissue perfusion and supply of oxygen and nutrients.(Keshri et al., 2016; da Rocha et al., 2024; Oliveira et al., 2022; Tripodi et al., 2023) In epithelial tissues, accelerated migration and proliferation may contribute to faster re-epithelialization.(Keshri et al., 2016; da Rocha et al., 2024; Oliveira et al., 2022; Tripodi et al., 2023) Matrix metalloproteinases and their tissue inhibitors may also be modulated, influencing the balance between degradation and reconstruction of extracellular matrix components during healing.(Keshri et al., 2016; da Rocha et al., 2024; Oliveira et al., 2022; Tripodi et al., 2023)

3.1.6. Effects of Polarization

The specific contribution of polarization to photobiomodulation remains incompletely understood.(Tripodi et al., 2022; Feehan et al., 2018; Tripodi et al., 2023) Some studies suggest that polarized light may enhance mitochondrial membrane potential, stimulate cellular proliferation, and reduce apoptosis more effectively than non-polarized light of equivalent wavelength and dose.(Tripodi et al., 2022; Feehan et al., 2018; Tripodi et al., 2023) Transcriptomic studies have also suggested that polarized photobiomodulation may influence genes involved in extracellular matrix remodeling and mitochondrial function.(Tripodi et al., 2022; Feehan et al., 2018; Tripodi et al., 2023)

At the same time, questions remain regarding whether polarization is preserved as light passes through layered biological tissues and whether polarization itself contributes independently to therapeutic benefit in vivo.(Feehan et al., 2018; Heiskanen & Hamblin, 2018) For this reason, although Bioptron and similar devices are of clinical interest, direct evidence specific to polarization as a determinant of clinical outcome remains limited.

3.2. Photobiomodulation and Postoperative Pain After Third Molar Surgery

Multiple randomized controlled trials and systematic reviews have assessed the ability of photobiomodulation to reduce postoperative pain after third molar extraction.(Pérez et al., 2025; Hadad et al., 2022; Lacerda-Santos et al., 2023; Mauriello et al., 2025; Isolan et al., 2021; Ferreira González et al., 2025; Duarte de Oliveira et al., 2021) Overall, the available evidence suggests a favorable effect, although the magnitude of benefit varies across protocols.

3.2.1. Clinical Trial Evidence

Pérez et al. (2025) evaluated a 980 nm diode laser protocol applied immediately after surgery and repeated at 24, 48, and 72 hours in patients undergoing bilateral third molar extraction.(Pérez et al., 2025) Pain intensity measured by VAS was significantly lower in the photobiomodulation group at all assessed postoperative time points, suggesting that repeated early application may provide clinically meaningful symptom control during the peak inflammatory phase.(Pérez et al., 2025)

Hadad et al. (2022) used a split-mouth, double-blind design and found that an 810 nm laser protocol significantly improved pain control compared with sham treatment.(Hadad et al., 2022; Isolan et al., 2021; Mohajerani et al., 2021) Likewise, Isolan et al. (2021) reported lower pain scores at 6, 24, and 48 hours following GaAlAs laser application.(Hadad et al., 2022; Isolan et al., 2021; Mohajerani et al., 2021) A separate study investigating combined low-level laser and LED irradiation also reported lower pain levels at postoperative days 3 and 7, indicating that multimodal light protocols may have clinical utility in selected cases.(Hadad et al., 2022; Isolan et al., 2021; Mohajerani et al., 2021)

3.2.2. Evidence from Reviews and Meta-Analyses

The systematic review and meta-analysis by Lacerda-Santos et al. (2023), which included 33 randomized controlled trials and 1,347 participants, found greater pain reduction in patients treated with photobiomodulation compared with controls, particularly on the third postoperative day.(Lacerda-Santos et al., 2023) However, the certainty of evidence was rated as low according to GRADE, largely because of methodological heterogeneity and risk of bias in the underlying studies.(Lacerda-Santos et al., 2023)

Similarly, Ferreira González et al. (2025) identified potential efficacy of low-level diode laser therapy for pain reduction at 48 hours, again with low-certainty evidence.(Ferreira González et al., 2025; Duarte de Oliveira et al., 2021; Mauriello et al., 2025) Duarte de Oliveira et al. (2021) also reported favorable pooled results for pain management, reinforcing the overall impression that photobiomodulation may be beneficial in the control of postoperative discomfort.(Ferreira González et al., 2025; Duarte de Oliveira et al., 2021; Mauriello et al., 2025) Mauriello et al. (2025), in a narrative review, suggested that intraoral application and multi-wavelength protocols may be among the most promising approaches.(Ferreira González et al., 2025; Duarte de Oliveira et al., 2021; Mauriello et al., 2025)

3.2.3. Analgesic Consumption and Patient-Centered Impact

An important practical issue is whether photobiomodulation reduces the need for rescue analgesics. Some studies have reported lower analgesic consumption or longer times to first analgesic use in treated patients.(Hadad et al., 2022; Isolan et al., 2021) Although this outcome has not been consistently measured across all trials, it is clinically relevant because reduced dependence on pharmacological pain control may be particularly advantageous in patients with medication intolerance or contraindications.

3.2.4. Negative and Neutral Findings

Not all studies have shown significant pain reduction. Sekerci et al. (2025), in a split-mouth placebo-controlled trial, did not observe a statistically significant difference in pain scores between laser-treated and placebo sites.(Sekerci et al., 2025) Such findings underscore the importance of protocol-related variables, including wavelength, energy density, timing, application site, tissue penetration, and patient selection. They also suggest that efficacy cannot be assumed uniformly across all photobiomodulation approaches.

3.3. Photobiomodulation and Postoperative Edema

Postoperative edema is another major determinant of early morbidity after third molar extraction.(Pérez et al., 2025; Hadad et al., 2022; Ferreira González et al., 2025; Duarte de Oliveira et al., 2021; Mohajerani et al., 2021) Because facial swelling is visible and functionally relevant, it often has a substantial effect on patient satisfaction and perceived recovery.

3.3.1. Clinical Evidence

Pérez et al. (2025) found significantly lower perceived edema in the photobiomodulation group at 24, 48, and 72 hours after surgery, and objective facial measurements were consistent with this trend.(Pérez et al., 2025; Hadad et al., 2022; Mohajerani et al., 2021) Hadad et al. (2022) similarly reported better edema control in treated sites compared with sham-treated sites at 24 and 48 hours.(Pérez et al., 2025; Hadad et al., 2022; Mohajerani et al., 2021) Mohajerani et al. (2021) also observed reduced swelling with combined laser and LED therapy at postoperative days 3 and 7.(Pérez et al., 2025; Hadad et al., 2022; Mohajerani et al., 2021)

3.3.2. Meta-Analytic Findings

Meta-analytic evidence broadly supports a modest anti-edematous effect of photobiomodulation. Lacerda-Santos et al. (2023) reported lower edema on the second postoperative day in treated patients, although the certainty of evidence remained low.(Lacerda-Santos et al., 2023; Ferreira González et al., 2025; Duarte de Oliveira et al., 2021) Ferreira González et al. (2025) and Duarte de Oliveira et al. (2021) also found pooled results suggesting benefit in swelling reduction.(Lacerda-Santos et al., 2023; Ferreira González et al., 2025; Duarte de Oliveira et al., 2021) Taken together, these findings indicate that edema may be one of the postoperative outcomes most consistently improved by photobiomodulation.

3.3.3. Methodological Variability in Edema Assessment

Interpretation of edema-related findings is complicated by variability in measurement methods. Some studies rely on patient-reported VAS assessments, whereas others use linear facial measurements, three-dimensional optical scanning, or volumetric analysis.(Pérez et al., 2025; Hadad et al., 2022; Sekerci et al., 2025; Passos et al., 2023) Three-dimensional methods are generally more objective and reproducible but are not always feasible in routine practice or in smaller trials. Linear measurements are simpler but less precise and may underestimate volumetric changes.(Pérez et al., 2025; Hadad et al., 2022; Sekerci et al., 2025; Passos et al., 2023)

Sekerci et al. (2025), using extraoral 3D scanning, did not detect a significant difference in swelling between treated and placebo sites.(Sekerci et al., 2025) This raises the possibility that some positive findings from simpler measurement approaches may reflect either differences in sensitivity or limitations in methodological standardization.

3.3.4. Temporal Pattern of Effect

Most studies suggest that the beneficial effect of photobiomodulation on edema is most evident during the first 24 to 48 hours after surgery, coinciding with the peak of acute inflammatory exudation.(Pérez et al., 2025; Hadad et al., 2022; Lacerda-Santos et al., 2023; Ferreira González et al., 2025; Duarte de Oliveira et al., 2021) By day 7, the difference often becomes smaller because spontaneous resolution has already occurred in many patients. This pattern is clinically plausible and may indicate that the principal role of photobiomodulation is modulation of the early inflammatory phase rather than prolonged suppression of normal healing processes.

3.4. Photobiomodulation and Trismus

Trismus is often more difficult to modify than pain and edema because it reflects not only inflammation but also reflex muscle guarding, tissue stiffness, and procedural trauma involving deeper structures.(Lacerda-Santos et al., 2023; Ferreira González et al., 2025; Duarte de Oliveira et al., 2021; Sekerci et al., 2025; Mohajerani et al., 2021)

3.4.1. Clinical Findings

Mohajerani et al. (2021) found a significant reduction in trismus at day 3 with combined laser and LED irradiation, although the difference was no longer significant by day 7.(Mohajerani et al., 2021; Hadad et al., 2022; Sekerci et al., 2025) Hadad et al. (2022) measured mouth opening at several postoperative points but did not report statistically significant intergroup differences for this outcome.(Mohajerani et al., 2021; Hadad et al., 2022; Sekerci et al., 2025) Sekerci et al. (2025) likewise found no meaningful difference in mouth opening between laser-treated and placebo sites at day 3 or day 7.(Mohajerani et al., 2021; Hadad et al., 2022; Sekerci et al., 2025)

3.4.2. Findings from Reviews and Meta-Analyses

Meta-analytic data suggest a possible but less robust benefit for trismus than for pain or swelling. Lacerda-Santos et al. (2023) found that trismus was slightly lower in the photobiomodulation group on the seventh postoperative day, but certainty of evidence was very low.(Lacerda-Santos et al., 2023; Ferreira González et al., 2025; Duarte de Oliveira et al., 2021) Ferreira González et al. (2025) reported potential efficacy at 7 days, whereas Duarte de Oliveira et al. (2021) did not identify a significant pooled effect.(Lacerda-Santos et al., 2023; Ferreira González et al., 2025; Duarte de Oliveira et al., 2021)

3.4.3. Interpretation

The evidence for trismus reduction is therefore less consistent than the evidence for pain and edema. This may reflect the multifactorial pathophysiology of postoperative trismus and the possibility that short photobiomodulation protocols are insufficient to influence deeper muscular and fascial recovery to the same degree that they influence superficial inflammatory responses. It is also possible that additional sessions or different application sites might be necessary to achieve stronger effects on jaw opening.

3.5. Photobiomodulation and Wound Healing in Oral and Maxillofacial Surgery

Beyond symptom control, photobiomodulation has also been evaluated for its influence on soft tissue healing, socket repair, bone remodeling, and prevention of complications after oral surgery.(Arany, 2016; de Lima Luna et al., 2025; Niedzielska et al., 2026; Pereira et al., 2025; Pereira et al., 2022; Sourvanos et al., 2023; Alves Pereira et al., 2025)

3.5.1. Soft Tissue Healing

Pereira et al. (2022) investigated dual-wavelength photobiomodulation using red and infrared wavelengths in healing of post-extraction sockets and found favorable effects on early postoperative recovery.(Pereira et al., 2022) Their data indicated reduced edema and improved oral mucosal healing at 7 days. Clinical assessment suggested superior soft-tissue quality in treated patients, whereas tomographic evaluation did not show clear differences in bone repair.(Pereira et al., 2022) This distinction is noteworthy because it implies that early visible and functional healing may improve despite limited radiographic changes during the same interval.

Pereira et al. (2025) subsequently compared infrared light alone with a dual-wavelength red-plus-infrared protocol and found similar postoperative clinical outcomes between the two approaches.(Pereira et al., 2025) These findings suggest that the infrared component may be sufficient to produce much of the clinical benefit observed in this setting and that addition of red light may not always provide measurable additive value.

Alves Pereira et al. (2025) compared dual-wavelength photobiomodulation with amoxicillin and reported reduced restriction in mouth opening and lower subjective pain and swelling in the photobiomodulation group, whereas antibiotic therapy did not provide significant benefit for postoperative symptom control.(Alves Pereira et al., 2025) This is clinically relevant because it supports the concept that light-based therapy may serve as a functional, non-antibiotic adjunct during uncomplicated postoperative recovery.

3.5.2. Bone Healing

Evidence regarding bone healing after third molar extraction remains mixed. Some studies using fractal dimension analysis and radiographic density measurements have not demonstrated significant differences between treated and control groups at 90 days after extraction.(Pereira et al., 2025; Pereira et al., 2022) These observations suggest that while photobiomodulation may improve early postoperative recovery, its effect on later radiographic markers of socket ossification may be less evident or more difficult to detect.

Nevertheless, Niedzielska et al. (2026), in a systematic review of laser-based photobiomodulation for postoperative tissue healing, reported more consistent benefit with respect to early soft-tissue repair, inflammation, and edema, while noting more variable effects on bone healing.(Niedzielska et al., 2026) In some clinical contexts, especially grafted sockets and distraction osteogenesis, accelerated bone maturation was reported; in others, such as implant-related endpoints, long-term skeletal benefits were less clear.(Niedzielska et al., 2026) These findings suggest that the effect of photobiomodulation on bone may depend strongly on the biological environment and the specific clinical objective.

Animal data also suggest that different light sources may influence distinct phases of bone healing. De Lima Luna et al. (2025) found that both low-level laser therapy and LED therapy enhanced reparative activity after extraction in rats, increasing osteoblast numbers and the area of active bone remodeling.(de Lima Luna et al., 2025) LED therapy appeared to stimulate earlier remodeling, whereas laser therapy was associated with formation of more mature bone over time.(de Lima Luna et al., 2025) This may indicate that different photobiomodulation modalities exert phase-dependent biological effects rather than uniform actions across all stages of healing.

3.5.3. Alveolar Osteitis Prevention

Nejat et al. (2021) reported a statistically significant reduction in the incidence of alveolar osteitis after mandibular third molar surgery in patients treated with photobiomodulation compared with sham controls.(Nejat et al., 2021) If confirmed in further studies, this would represent an important clinical application, as alveolar osteitis is a painful complication that substantially increases postoperative burden and follow-up needs.

3.5.4. Oral Mucositis and Broader Supportive Evidence

Although oral mucositis is not directly related to third molar extraction, the broader literature on photobiomodulation in mucosal injury offers indirect support for its healing-promoting capacity.(Lewis et al., 2024; Al-Rudayni et al., 2021; Cruz et al., 2023; G et al., 2026; Ameri et al., 2026; Abdalla-Aslan et al., 2023) Multiple systematic reviews and meta-analyses in oncology settings have demonstrated reductions in oral mucositis severity and duration with photobiomodulation. While this evidence cannot be directly transferred to third molar surgery, it strengthens the biological plausibility that light therapy may support epithelial and connective tissue repair in the oral cavity.

4. Discussion

This review indicates that photobiomodulation is a promising adjunctive modality for the management of common postoperative complications after impacted third molar extraction. The available literature most consistently supports beneficial effects on pain and swelling, whereas evidence regarding trismus and bone healing remains less uniform. At present, the strongest body of evidence concerns low-level laser therapy and, to a lesser degree, LED-based photobiomodulation. By comparison, evidence specific to Bioptron polarized polychromatic non-coherent light remains relatively limited.

4.1. Interpretation of the Clinical Evidence

The reduction in pain observed in multiple randomized trials and pooled analyses is biologically plausible in light of the known anti-inflammatory and neuromodulatory effects of photobiomodulation. A decrease in inflammatory mediator release, reduced nociceptor sensitization, improved microcirculation, and modulation of mitochondrial function may all contribute to improved patient comfort during the immediate postoperative period. Similar reasoning applies to edema reduction, where photobiomodulation may favorably affect vascular permeability, inflammatory signaling, and lymphatic drainage.

The evidence for trismus is weaker, and this is not unexpected. Trismus reflects a broader functional reaction to surgical trauma than pain alone and may be influenced by operative mechanics, individual guarding behavior, anxiety, and the extent of muscular involvement. Consequently, protocols that are sufficient to reduce superficial inflammatory manifestations may be less effective in reversing deeper functional limitation.

4.2. Heterogeneity and Methodological Challenges

One of the major limitations of the current literature is substantial methodological heterogeneity. Clinical studies differ in wavelength, power output, energy density, treatment duration, number of treatment points, timing of irradiation, extraoral versus intraoral application, number of sessions, and choice of outcome measures. In some trials, treatment is delivered only once immediately after surgery, whereas in others it is repeated over several days. This variability makes direct comparison difficult and limits the ability to define an optimal protocol.

Differences in study design also complicate interpretation. Split-mouth studies reduce interindividual biological variability but may introduce carry-over concerns when systemic inflammatory responses influence both sides. Parallel-group trials may better reflect clinical practice but require larger sample sizes to maintain statistical power. Sham controls are essential in this field because patient expectations may influence pain reporting, yet not all studies have used robust blinding procedures.

4.3. Relevance of Treatment Parameters

The biphasic dose-response relationship in photobiomodulation suggests that both underdosing and overdosing may reduce clinical efficacy. This is particularly important when interpreting negative studies, as lack of benefit may reflect suboptimal parameters rather than absence of therapeutic potential. Wavelength selection is also clinically relevant because red light and near-infrared light differ in tissue penetration and interaction with biological targets. Infrared wavelengths may be more appropriate for deeper tissues, whereas red wavelengths may exert stronger effects in superficial layers. Combined protocols attempt to exploit both properties, although current data do not clearly establish superiority over single-wavelength infrared approaches in all settings.(Pereira et al., 2025)

4.4. Position of Bioptron Within the Evidence Base

Bioptron occupies a somewhat distinctive position in the broader field of photobiomodulation. Its broad spectrum, non-coherent emission, and polarization differentiate it physically from standard low-level laser systems and from most LED-based devices. Theoretical advantages include broader tissue interaction and large-area application, which may be useful in extraoral treatment of postoperative swelling or superficial soft-tissue conditions. However, compared with the extensive trial data available for laser-based photobiomodulation after third molar surgery, evidence directly supporting Bioptron in this indication remains sparse.

This gap should not be interpreted as evidence of ineffectiveness, but rather as evidence of insufficient direct investigation. Existing studies involving Bioptron more commonly concern peri-implant mucositis, skin healing, or mucosal lesions rather than third molar extraction itself.(Nardi et al., 2022; Feehan et al., 2018) Therefore, any recommendation concerning Bioptron in this specific oral surgery context must remain cautious and provisional until dedicated clinical trials become available.

4.5. Clinical Implications

From a clinical standpoint, photobiomodulation appears to offer several potential advantages. It is non-invasive, generally well tolerated, and free from the systemic adverse effects associated with many pharmacological agents. It may therefore be particularly attractive as an adjunct in patients with contraindications to NSAIDs or corticosteroids, in individuals seeking reduced medication use, or in settings where multimodal postoperative care is preferred.

At the same time, photobiomodulation should not currently be viewed as a replacement for evidence-based pharmacological management in routine third molar surgery. Rather, it should be considered an adjunctive intervention that may improve postoperative comfort and possibly support tissue repair in selected cases. Decisions about its use should take into account device availability, operator familiarity, treatment protocol, and patient preference.

4.6. Areas Requiring Further Research

Further research is clearly needed in several areas. First, more high-quality randomized trials are required to define optimal treatment parameters for postoperative pain, edema, and trismus after third molar surgery. Second, future studies should standardize outcome measures, including patient-reported pain scales, objective edema assessment, mouth opening measurements, and medication use. Third, dedicated trials evaluating Bioptron are needed if meaningful conclusions about its effectiveness in this setting are to be drawn.

Research should also address the timing and number of sessions required for maximal benefit. It remains uncertain whether immediate postoperative irradiation alone is sufficient or whether repeated applications provide superior outcomes. Finally, comparative trials between pharmacological management alone, photobiomodulation alone, and combined regimens would be of particular clinical value.

5. Conclusions

Photobiomodulation appears to be a safe and potentially effective supportive intervention for the management of postoperative pain, edema, and, to a lesser extent, trismus after impacted third molar surgery. The most consistent evidence supports low-level laser therapy and LED-based photobiomodulation, particularly in relation to early postoperative pain reduction and control of facial swelling. The biological plausibility of these effects is supported by evidence showing modulation of mitochondrial function, enhancement of ATP production, regulation of reactive oxygen species, attenuation of inflammatory signaling, and promotion of wound-healing processes.

However, the literature remains heterogeneous, and the degree of benefit varies across studies. Evidence for improvement in trismus and bone healing is less consistent than evidence for pain and edema. Importantly, the specific evidence base for Bioptron polarized polychromatic non-coherent light in the setting of impacted third molar surgery remains limited and does not yet permit firm clinical recommendations. Although its physical characteristics and proposed mechanisms suggest possible therapeutic relevance, direct supporting data are insufficient in comparison with other photobiomodulation modalities.

Accordingly, photobiomodulation may be regarded as a promising adjunctive modality rather than a fully standardized component of postoperative third molar management. Further well-designed randomized controlled trials with adequate sample sizes, sham controls, clearly defined dosimetry, and validated clinical endpoints are required to determine optimal protocols and to clarify the role of Bioptron relative to established laser-based and LED-based approaches as well as to standard pharmacological treatment.

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