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Photobiomodulation Therapy In Oral Medicine-A Narrative Review

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Abstract:
Photobiomodulation (PBM) therapy is a non-invasive form of therapy used across the fields of medicine and dentistry for therapeutic efficacy. In general, photobiomodulation therapy uses low-level lasers for the treatment and management of various odontogenic and non-odontogenic diseases and lesions. Recent studies have shown that PBM is highly effective and has fewer adverse effects. This article focuses on the use of PBM in the field of Oral Medicine for the management of the following lesions: oral mucositis, oral potentially malignant disorders, other mucosal lesions such as ulcers, orofacial pain such as trigeminal neuralgia and burning mouth syndrome, infectious diseases of the oral cavity such as herpes and candidal infections, and postoperative wound healing. Emerging evidence suggests that PBM is a promising adjunctive therapy in Oral Medicine, offering effective symptom relief and improved healing outcomes with minimal side effects.

Keywords: *Photobiomodulation therapy, PBM, LLLT, Low-Level Laser therapy*

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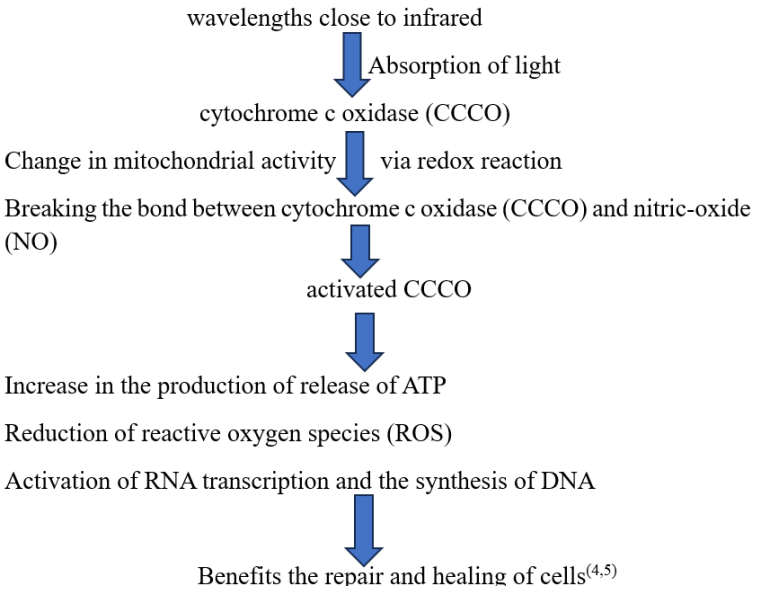
I. Introduction

The technique of Photobiomodulation(PBM) was discovered by Endre Mester in 1965, As a definition PBM is "the use of non-ionizing optical radiation in the visible and near-infrared spectral range is absorbed by endogenous chromophores to elicit photophysical and photochemical events at various biological scales without eliciting thermal damage, leading to physiological changes and therapeutic benefits"[(1)]. It's commonly known as low-level laser therapy[(2)] Recognized organizations like The World Association of Photobiomodulation Therapy [WALT] and The International Society of Oral Oncology and The Multinational Society for Supportive Care in Cancer (MASCC/ISOO) were they demonstrated the PBM's therapeutic and prophylactic prospects for cancer therapy[(3)]. In dentistry due to its promising adjuvant therapeutics, effective symptom relief, and improved healing outcomes with minimal side effects it gained its attention in the field of Oral Medicine(OM) in treating and managing orofacial disorders, such as mucocutaneous lesions, potentially malignant disorders, orofacial pain, burning mouth syndrome, infectious diseases like oral herpes infection ,oral candidiasis etc, Autoimmune disorders like pemphigus, temporomandibular joint disorders, and post-surgical management of the orofacial region. This article will explain the mechanism, operation of PBM with respective to various lesion, it's limitations and what all can be in-corporate to make it a definitive therapy in oral medicine

Mechanism of Action of PBM

PBM is based on the photochemical reaction stimulated by the non-ionizing light which is near infrared spectrum. PBM has nonthermal effects cells and tissues which aids in healing, reducing inflammation, and relieving pain[(4)], irradiation with certain wavelengths of red or near-infrared light produces many physiological effects in cells, and tissues which form the core[(4)]



It also has some indirect effects on the blood vessels which aids to above discussed mechanism by increase in nitrous oxide and increases the dilation of local blood vessels which increases the available oxygen and cell permeability which favours cell division and ultimately it helps in modify cell self-degradation(5)

PBM Devices and Parameters

Photobiomodulation (PBM) employs a wide range of light-emitting devices, primarily low-level lasers and light-emitting diodes (LEDs), to deliver therapeutic effects through non-ionizing light at specific parameters. The therapeutic efficacy of PBM is closely linked to its physical parameters, including wavelength, power density, fluence, beam profile, pulse mode, and treatment duration.

Types of PBM Devices

The most commonly used PBM devices in oral medicine are diode lasers (e.g., GaAlAs, InGaAlP) and LEDs.

- Lasers provide monochromatic, coherent light that allows precise dosimetry and penetration depth.
- LEDs offer broader spectral outputs, lower cost, and feasibility for home-based devices, but often show variability in dose delivery compared to lasers (8).

Key Parameters in PBM

1. Wavelength
   - Typically ranges between 600–1100 nm, for proper light penetration into biological tissues is optimal (9).
   - Red light (630–700 nm) often used because penetrates superficially and hence employed in treating in oral mucosal lesions.
   - Near-infrared light (780–940 nm) ha the ability to penetrates deeper tissues, hence employed in trating neuropathic pain and bone healing(6).
2. Power Output and Power Density
   - PBM devices usually operate within 10–500 mW power range.
   - Power density (irradiance) between 5–150 mW/cm² shows to enhance wound healing, and reduce inflammation due to stimulation of fibroblast activity, (6).
3. Fluence (Energy Density)
   - Optimal fluence generally used are 1–10 J/cm², but therapeutic windows can vary depending on tissue and clinical condition (7).
   - Lower fluences may produce insufficient stimulation, while higher doses may inhibit cellular activity, demonstrating the biphasic dose response (9).
4. Beam Spot Size and Optical Delivery
   - Larger spot sizes, uniformly distribute energy, while smaller beams allow targeted treatment.
   - Home LED PBM devices are inconsistencies in irradiance due to divergence and beam distribution, without any proper standardized calibration (8).
5. Mode of Operation (Continuous vs Pulsed)
   - In dentistry continuous wave delivery is commonly applied, but using pulsed modes can improve therapeutic outcomes by reducing tissue heating and promoting specific cellular signaling (9).

6. Treatment Time and Frequency
- Generally the treatment session durations range from 30 seconds to several minutes per site, but most treatment frequency depends on the pathology.

Clinical Considerations

The absence of universally standardized protocols remains a limitation in PBM therapy. Different devices report varying energy outputs despite similar specifications, complicating reproducibility [8]. To address this, recent guidelines emphasize the importance of accurate reporting of all PBM parameters, including device type, wavelength, power, irradiance, fluence, beam profile, and duration, to ensure clinical safety and reproducibility [10]

Applications of PBM in Oral Medicine

Photobiomodulation (PBM) has emerged as a valuable adjunctive therapy in oral medicine due to its anti-inflammatory, analgesic, and bio-stimulatory effects. By modulating cellular activity through low-intensity red and near-infrared light, PBM promotes tissue repair, reduces oxidative stress, and accelerates wound healing. Its non-invasive and drug-free nature makes it particularly suitable for managing multiple oro-facial diseases.

Oral Mucositis

Photobiomodulation (PBM) has shown effective non-invasive therapy for the prevention and management of oral mucositis (OM) associated with chemotherapy and radiotherapy. PBM promotes tissue [11,12].

Recent studies confirm PBM's efficacy in reducing OM severity, pain, and duration, while improving patients' quality of life. A 2025 randomized controlled trial reported that preconditioning PBM prevented mucositis in up to 80% of chemotherapy patients, with significant improvement in oral function and comfort [8]. Systematic reviews and umbrella reviews further validate PBM as the most reliable supportive care strategy, though variability in device parameters highlights the need for standardized protocols [25]. PBM is now widely recognized as a first-line supportive intervention for OM and is increasingly incorporated into oncology oral care guidelines [13].

Oral Candidiasis

PBM demonstrates antifungal and immunomodulatory potential in managing oral candidiasis, particularly in immunocompromised patients. It enhances epithelial repair, reduces inflammation, and synergistically increases antifungal drug efficacy. Clinical studies show PBM decreases fungal colony counts and improves symptomatic relief compared with antifungals alone [14].

2. Oral Herpes Infection

PBM is effective in reducing pain, frequency, and healing time of recurrent herpes labialis and intraoral lesions. Low-level laser therapy (LLLT) at 660–830 nm accelerates epithelialization and reduces viral replication through immune modulation. A recent RCT confirmed shortened lesion duration and longer remission periods with PBM [15].

3. Temporomandibular Joint Disorders (TMDs)

PBM reduces pain, muscle spasm, and joint inflammation in TMDs by modulating inflammatory mediators and improving microcirculation. Meta-analyses suggest significant improvements in maximal mouth opening and pain scores compared with placebo. PBM is a safe adjunct to conventional physiotherapy [16].

4. Myofascial Pain Dysfunction Syndrome (MPDS)

PBM provides analgesia and muscle relaxation in MPDS through modulation of nociceptors and endorphin release. Clinical trials show significant pain reduction and improved mandibular movements with PBM, making it a valuable adjunct in conservative therapy [17].

5. Oral Lichen Planus (OLP)

PBM is effective in reducing pain, erythema, and ulceration in erosive OLP. It modulates T-cell activity and reduces cytokine-driven inflammation. RCTs have demonstrated PBM to be comparable or superior to corticosteroids in symptom management, without adverse effects [18].

6. Leukoplakia and Erythroplakia

PBM is mainly explored for symptom relief and adjunctive healing post-surgical excision of leukoplakia/erythroplakia rather than direct lesion regression. It promotes epithelial repair, reduces postoperative discomfort, and enhances mucosal healing [19].

7. Oral Submucous Fibrosis (OSMF)

PBM helps reduce burning sensation, trismus, and fibrotic pain in OSMF by enhancing vascularity and reducing oxidative stress. Small-scale studies show improvements in mouth opening and quality of life, making PBM a promising non-invasive adjunct [20].

8. Burning Mouth Syndrome (BMS)

PBM offers significant symptomatic relief in BMS by modulating peripheral nerve sensitivity and improving neurovascular response. Clinical trials show reduced pain intensity and burning sensation, with benefits sustained for months post-therapy [27].

Trigeminal Neuralgia (TN)

PBM has shown promise as a supportive therapy in TN by modulating nerve conduction and reducing neurogenic inflammation. Clinical reports suggest PBM decreases paroxysmal pain frequency and intensity, offering a non-invasive alternative or adjunct to pharmacological therapy [21].

Neuropathic Pain

PBM exerts analgesic effects in neuropathic pain conditions by altering sodium-potassium pump activity, improving mitochondrial function, and modulating inflammatory pathways. RCTs in post-radiotherapy neuropathy and peripheral nerve injuries demonstrate reduced pain scores and improved neural recovery [22].

3. Recurrent Aphthous Ulcer (RAU)

PBM is effective in accelerating ulcer healing, reducing pain, and prolonging recurrence intervals in RAU. Low-level laser at 660–830 nm promotes epithelial regeneration and reduces inflammatory mediators. Clinical trials confirm faster symptom relief compared to topical corticosteroids[23].

4. Pemphigus Vulgaris (PV)

PBM has been applied as an adjunct in PV management, especially for painful oral erosions resistant to conventional therapy. Studies report enhanced wound healing, pain reduction, and improved patient comfort when PBM is combined with systemic corticosteroids [24].

Healing Of Post-Surgical Wounds

PBM accelerates post-surgical wound healing by stimulating fibroblast proliferation, angiogenesis, and collagen synthesis. Studies in third molar extractions and biopsy sites report faster healing, less postoperative pain, and reduced edema in PBM-treated patients [25].

Advantages of PBM in Oral Medicine

1. **Non-invasive and Safe** – PBM is a non-thermal, painless therapy with minimal reported adverse effects, making it suitable even for medically compromised patients [29].
2. **Analgesic and Anti-inflammatory Effects** – PBM reduces pain by modulating nociceptor activity and decreasing pro-inflammatory cytokines, which is beneficial in conditions like oral mucositis, burning mouth syndrome, and TMDs [28,29]).
3. **Accelerated Healing and Tissue Regeneration** – PBM stimulates fibroblast proliferation, angiogenesis, and collagen deposition, resulting in faster healing of surgical wounds, ulcers, and erosive lesions [25].
4. **Adjunct to Conventional Therapies** – PBM can complement pharmacological treatments, reducing the required drug dosage and associated side effects, e.g., in oral lichen planus or pemphigus [18].
5. **Broad Range of Applications** – Effective in diverse oral conditions: mucositis, OSMF, leukoplakia (symptom relief), candidiasis, neuralgias, and postoperative recovery, highlighting its versatility in oral medicine [20].

Disadvantages / Limitations of PBM in Oral Medicine

1. **Lack of Standardized Protocols** – Variation in **wavelengths, power densities, fluence, and treatment schedules** across studies limits reproducibility and clinical adoption [30].
2. **Dose-dependent Response** – PBM follows a biphasic dose–response curve (Arndt–Schulz law), where both under- and over-irradiation may be ineffective or even inhibitory to healing [29].
3. **Limited Long-term Evidence** – While short-term benefits are well-documented, long-term outcomes, recurrence prevention, and effects on potentially malignant disorders remain underexplored [14].
4. **Device and Operator Dependence** – Variability in laser/LED devices, operator expertise, and treatment settings can affect outcomes, leading to inconsistent clinical results [16].
5. **Cost and Accessibility** – High-quality PBM devices may be expensive, limiting widespread use in resource-constrained clinical setups, especially in developing countries [20].

II. Future Perspectives

Despite extensive evidence supporting the therapeutic benefits of photobiomodulation (PBM) in oral medicine, several gaps remain. A major limitation is the lack of standardized treatment protocols, particularly regarding wavelength, power density, fluence, and treatment intervals, which results in variability across clinical studies [30]. Future research must focus on multicenter randomized controlled trials (RCTs) with standardized dosimetry to establish reproducible outcomes.

Emerging directions include the integration of PBM with nanotechnology, photodynamic therapy, and regenerative medicine, which may enhance its efficacy in managing resistant oral lesions and potentially malignant disorders [14].Advances in portable and cost-effective PBM devices could further improve accessibility, especially in low-resource settings. Furthermore, the application of artificial intelligence (AI) and radiomics to optimize treatment planning and predict therapeutic response represents a promising frontier [20].

III. Conclusion

PBM has established itself as a safe, non-invasive, and versatile adjunct in the management of diverse oral conditions, ranging from mucosal lesions (oral lichen planus, recurrent aphthae, mucositis) to chronic pain disorders (TMDs, burning mouth syndrome, neuropathic pain) and post-surgical healing. Its analgesic, anti-inflammatory, and biostimulatory effects offer a valuable alternative or complement to conventional therapies, often with fewer side effects [28,29].

However, to transition PBM from an adjunctive therapy to a mainstream clinical tool, further long-term, high-quality RCTs are essential, alongside the development of standardized clinical guidelines

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