Photobiomodulation: A promising adjunct in periodontal therapy (Review)

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Abstract. Wound healing is a biological process that requires a well-coordinated sequence of events, including clot formation, inflammatory response, tissue proliferation and remodeling. In the oral cavity, periodontal wounds face additional challenges due to the presence of bacteria, constant mechanical stress and inflammatory conditions such as periodontitis. While conventional treatments, such as scaling and root planing (SRP) and surgical interventions, such as flap surgery help manage periodontal disease, optimal healing outcomes are not always achieved. Photobiomodulation (PBM), formerly referred to as low-level laser therapy, has gained recognition as a potential approach for promoting periodontal wound healing. PBM utilizes non-ionizing light to stimulate cellular and molecular processes, accelerating tissue repair, reducing inflammation and improving overall treatment outcomes. The mechanism of action of PBM involves mitochondrial activation, increased ATP production, reactive oxygen species modulation, and the activation of growth factors, such as TGF-β, which collectively promote angiogenesis, fibroblast proliferation and extracellular matrix synthesis. In periodontal therapy, PBM has demonstrated beneficial effects in post-surgical healing following gingivectomy, flap surgery and grafting procedures. It also plays a crucial role in periodontal regeneration by influencing osteoblasts, fibroblasts, periodontal ligament cells and endothelial cells, fostering bone formation and connective tissue repair. Given its non-invasive nature, ability to enhance cellular response and potential to reduce post-operative discomfort, PBM represents an innovative strategy for improving periodontal wound healing. The present review discusses the mechanisms, applications and clinical implications of PBM in periodontology, highlighting its potential as a valuable therapeutic modality in periodontal management. Relevant literature was sourced through searches in databases including PubMed, Google Scholar, Scopus and Web of Science. The focus was on clinical and experimental studies published recently that evaluated PBM in periodontal wound healing. The selection included randomized controlled trials, clinical trials and well conducted narrative reviews. The search strategy included the use of the following MeSH terms: Photobiomodulation Therapy; Lasers; Periodontal Diseases; Wound Healing; Periodontal Surgery; Light Therapy.

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Contents

1. Introduction

The biological process of wound healing is intricate and entails a well-coordinated series of events, such as hemostasis, inflammation, proliferation and remodeling. The disruption of any of these stages may attenuate or compromise the process (1). Hence, uninterrupted wound healing is always desirable to ensure speedy recovery without complications. Oral wounds, particularly those linked to periodontal disease, face distinct challenges during healing due to the increased risk of infection attributed to the moist and warm environment of the oral cavity combined with its continuous exposure to bacteria. Moreover, dental plaque and calculus further impede the healing process (1).

Periodontal disease is a chronic inflammatory condition characterized by the breakdown of the tissues supporting the teeth (2). It is also recognized as one of the non-communicable diseases with established links to systemic conditions, such as diabetes and cardiovascular diseases. Scaling and root planing (SRP) and surgical procedures such as flap surgery are the cornerstones to addressing the underlying cause and for the effective treatment of periodontal disease (3). A meticulous removal of plaque and calculus and smoothening of the root surface can create an environment conducive to healing post-treatment and reduce the risk of disease recurrence. Although the healing process following these procedures is favorable, the individual responses may vary and, in some cases, optimal wound healing may not be achieved (4).

Therefore, additional measures to promote wound healing are essential for enhancing recovery and reducing patient discomfort. Several strategies, such as maintaining proper oral hygiene, utilizing antiseptic rinses, such as chlorhexidine and applying regenerative materials such as enamel matrix derivatives or collagen membranes, may be employed to promote periodontal wound healing. Advanced techniques include platelet-rich plasma (PRP), growth factors and low-level laser therapy (LLLT) (1). Customized treatment plans according to the specific needs of the patient can significantly enhance outcomes and patient comfort.

Notably, LLLT is a non-invasive technique that uses low-intensity light to stimulate cellular processes at a molecular level, promoting tissue repair and regeneration (5). Its ability to accelerate healing, reduce inflammation and improve patient comfort renders it a valuable tool in periodontal therapy. Several clinical studies have proven the advantages of LLLT, particularly when used as an adjunct to conventional periodontal treatment, demonstrating its significant improvements in periodontal healing outcomes: Reduced probing depths, improved clinical attachment levels, more rapid epithelialization and decreased postoperative discomfort (6,7). In addition, LLLT also has applications in other areas of dentistry, such as in the management of temporomandibular joint disorders, the reduction of dentinal hypersensitivity, relief from oral mucositis and the enhancement of orthodontic tooth movement (8). The underlying mechanisms, therapeutic parameters and clinical applications of LLLT in periodontal therapy are discussed in the following sections.

2. History and evolution

The therapeutic use of light has roots in the ancient medicine of Egyptians and Indians, who recognized and utilized the healing properties of sunlight therapy to promote health and overall well-being. However, it gained recognition and appreciation only in the late 19th century (9). Theodore Maiman's development of light amplification by stimulated emission of radiation (LASER) in 1960 marked a significant technological breakthrough that was grounded in Albert Einstein's theoretical work from 1917, a significant milestone. This innovation reignited interest in the therapeutic applications of light energy, further advancing the field (10). Endre Mester, a Hungarian physician and scientist, discovered that low-dose laser therapy could promote hair growth and improve wound healing in mice [Mester *et al* (11)]. He coined the term photostimulation to describe this effect and later demonstrated its effectiveness in treating skin ulcers in humans (12).

Although cold laser therapy and LLLT have emerged to describe low-dose light treatments, these terms are misleading as no actual cooling occurs, and labels such as 'low' and 'level' are vague and imprecise. Additionally, evidence supports the effectiveness of non-laser devices, rendering 'laser' an inaccurate term. In order to address these issues, the North American Association for Light Therapy and the World Association for Laser Therapy agreed in 2014 to adopt the term photobiomodulation (PBM) therapy (13).

3. PBM in periodontology

The integration of laser therapy in periodontology dates back to the 1980s when Pick *et al* employed CO_2 laser for the gingivectomy of hyperplastic gingiva (14). PBM was first introduced in periodontal therapy in the early 2000s, yielding promising results that marked the beginning of its widespread adoption and continuous advancements in the field (15). Lasers used in periodontal therapy are classified into two categories: High-power lasers (HPLs) and low-level lasers (LLLs). HPLs are commonly employed in periodontal treatments, including soft tissue and bone surgeries, sulcular debridement of periodontal pockets, root decontamination and as a part of SRP techniques. These include Nd:YAG (1,064 nm), Er:YAG (2,940 nm), Er,Cr:YSGG (2,780 nm) and high-power semiconductor diode laser (808-904 nm), commonly employed for non-surgical periodontal therapy, whereas CO_2, Nd:YAG, diode laser, and Er:YAG are employed on the root surface (16).

By contrast, LLLs are commonly used for their PBM effects (17). PBM is a therapeutic approach that employs non-ionizing light sources, such as lasers and light-emitting diodes, to trigger biological processes at the cellular level. PBM involves low-level light therapy, typically in the red or near-infrared wavelength (600-1,000 nm), referred to as the optical window of PBM that triggers photochemical reactions without generating significant heat (16). The most commonly employed lasers are Ruby (694 nm), Argon (488 and 514 nm), Helium-Neon (632 nm), Krypton (521, 530, 568 and 647 nm), and low-level diode lasers in the form of Ga-Al-As (780-890 nm) or In-Ga-AlP (630-700 nm) and Ga-As (904 nm) (18).

4. Mechanisms of action

The therapeutic effects of PBM are deeply rooted in its ability to modulate the inflammatory response of the body following tissue injury. In the event of acute injury, the body initiates a complex inflammatory response to address tissue damage. This response involves the release of mediators, such as prostaglandins and bradykinins, leading to symptoms such as pain, swelling and impaired function. PBM therapy provides a non-invasive approach which can be used to alleviate inflammation and its associated symptoms. The underlying mechanism of action is elaborated below, explaining the ability of PBM to modulate the inflammatory response and promote healing.

Mechanistically, the effects of PBM can be broadly categorized as primary and secondary phases. The primary phase comprises direct and indirect events. Direct events include photochemical reactions and photoacoustic-photochemical effects. Photochemical reactions occur when light is absorbed by chromophores within cells, which in turn triggers a series of redox reactions that lead to the generation of reactive oxygen species (ROS). Although ROS are associated with oxidative stress, they can function as signaling molecules at optimal levels, triggering beneficial cellular responses. On the other hand, light absorption in the photoacoustic-photochemical effects can induce physical changes in tissues, such as a slight increase in temperature and mechanical stress. These physical effects can influence cellular processes and promote healing. Indirect events begin with mitochondrial activation via light absorption by cytochrome *c* oxidase, a vital enzyme in the electron transport chain. This feedback loop boosts the mitochondrial function, resulting in the increased production of ATP, which in turn stimulates the synthesis of DNA, RNA, protein, and enzymes that support and accelerate tissue repair and regeneration (19). Other key events include the release of nitric oxide (NO), a potent vasodilator and signaling molecule, which can be stimulated by PBM. NO improves blood supply, reduces inflammation and promotes tissue healing. Another main event is kinase activation, wherein the generated ROS activate Src kinase, an enzyme involved in numerous cellular processes, promoting cell survival, proliferation and migration, ultimately contributing to tissue repair and regeneration (19,20). Additionally, PBM can influence hormone release, which plays a vital role in stimulating tissue growth and repair. Another critical mechanism involves the activation of growth factors, such as transforming growth factor-beta (TGF-β), a multifunctional cytokine involved in various cellular processes, including wound healing. PBM therapy generates ROS that activate latent TGF-β, in turn triggering tissue repair by stimulating migration, proliferation and matrix synthesis. Hence, PBM-mediated TGF-β activation provides a promising therapeutic approach for wound healing applications (19,21).

These primary phase events trigger a cascade of secondary responses, including the activation of transcription factors, such as NF-κB, AP-1 and hypoxia-inducible factor-1α, which regulate gene expression and control cellular response. It can induce a variety of cellular responses, including proliferation, migration, differentiation, and matrix synthesis. It can also accelerate healing by promoting inflammation resolution, angiogenesis, and tissue remodeling (19) (Fig. 1).

Previous studies have stated that PBM can lead to increased collagen production, a key component of tissue repair (22-24). PBM can initiate an early proliferation phase by modulating the inflammatory response, further enhancing healing.

5. Applications in periodontal therapy

The therapeutic applications of PBM span a range of periodontal procedures. One of its key benefits is enhancing post-surgical healing, where it significantly reduces healing time and reduce patient discomfort after periodontal surgery. By reducing inflammation, stimulating cellular processes and promoting tissue regeneration, PBM can accelerate wound healing and promote a more rapid recovery. Various periodontal surgical procedures using PBM have yielded promising results (25). These include gingivectomy, an invasive procedure that often leads to delayed healing and increased discomfort. Typically, wound healing occurs through secondary intention, requiring ~5 weeks for complete surface healing and 7 weeks for full tissue maturation (26). However, PBM has emerged as a promising adjunct therapy to accelerate healing and discomfort after gingivectomy.

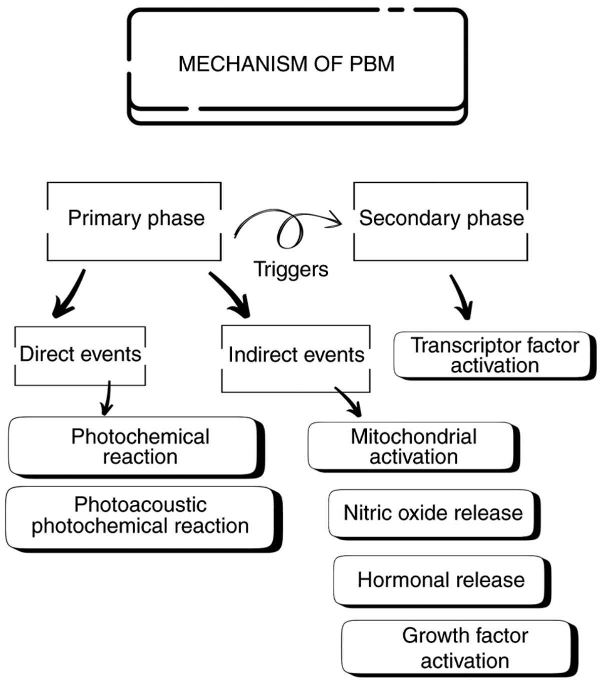

Figure 1. Mechanisms of photobiomodulation.

Flap surgeries are an integral component of periodontal therapy that are designed to access and treat deeper periodontal structures that cannot be adequately managed through non-surgical means. These procedures include surgically raising a flap that allows for the debridement of subgingival deposits, root modification and the correction of osseous defects. Flap surgeries aim to eliminate periodontal pockets, reduce inflammation and restore periodontal health (27). Flap surgeries can also be performed for recession coverage, with techniques such as coronally advanced flap being widely used to restore gingival tissue over the exposed root surfaces, enhancing both function and esthetics. Some studies have consistently demonstrated that PBM plays a crucial role in improving post-surgical wound healing and accelerating recovery following flap surgeries; some of these studies are listed in Table I (28-36).

Gingival tissue augmentation through free gingival grafts and connective tissue grafts also improves healing outcomes with PBM both at donor sites and recipient sites. These techniques are vital for addressing gingival recession and ensuring stable soft tissue architecture.

The key studies highlighting the application of PBM in various periodontal surgical procedures, including grafting, are summarized in Table I (28-36). A flow diagram outlining the screening and inclusion process for the studies in the present review is illustrated in Fig. 2. Since this article is a narrative review and not a systematic review or meta-analysis, the PRISMA guidelines were not applied.

Periodontal regeneration refers to the process of rebuilding or restoring lost or damaged tissue to recover the original form and function of the affected structures (37). PBM therapy contributes to periodontal regeneration by influencing cellular and molecular processes by facilitating tissue repair and bone formation. The subsequent section describes how PBM contributes to periodontal regeneration.

Table I. Procedural details of periodontal therapy in recent years that incorporated PBM.

First author, year of publication	Procedure	Study type	Type of laser used	Methodology	Outcome	(Refs.)
Madi, 2020	Gingivectomy	Randomized case control	Diode	10 out of 20 patients with inflammatory gingival enlargement (test group) were irradiated with laser at baseline,3,5 days post-surgery, while the control group did not receive laser treatment. Laser parameters: Wavelength, 660 nm; duration, 3 min; power, 50 mW; technique, the laser tip was positioned perpendicular to gingival tissue, 1 cm away.	Significant improvement in wound healing scores observed.	(28)
Uslu, 2020	Gingivectomy	Randomized single blind case-control study.	Diode (GaAiAs)	The study included 36 patients with inflammatory gingival enlargement, with 12 receiving laser irradiation, 12 undergoing ozone application at baseline, 3rd and 7th days and 12 others were controls. Laser parameters: Wavelength, 810 nm; duration, 1 min; power, 200 mW; technique,the Laser tip was positioned perpendicular to gingival tissue.	Oral health impact factor was assessed, which was lower in laser group compared to ozone group.	(29)
Misra, 2023	OFD	Randomized controlled trial.	Diode	A total of 240 sites from 40 patients with bilateral attachment loss were included; 120 sites from the test group were irradiated with laser and the other 120 sites were control sites. Laser parameters: Wavelength, 890 nm; duration, 30 sec; power, 1.5 W; technique, sweeping movements of tip in apico-coronal direction were carried out.	Inflammatory mediators were evaluated to assess wound healing and, significant wound healing observed at sites irradiated with laser.	(30)
Shakoush, 2023	OFD	Split mouth randomized clinical trial.	Diode	10 patients with stage III periodontitis were included, where test sites were irradiated with laser. Laser parameters: Wavelength, 808 nm; duration, 12 sec; power, 250 mW.	Improved clinical indices and post-operative pain observed in the PBM group.	(31)
Silviya, 2022	Single-flap periodontal surgery	Randomized controlled clinical trial.	Diode	Of the 40 intrabony defects included, 20 were treated with laser following surgery and remaining 20 served a control group. Laser parameters: Wavelength, 790-810 nm; duration-4-5 min; power, not reported;	Exhibited a decrease in pocket probing depth. However, the results were not significant.	(32)

Table I. Continued.

First author, year of publication	Procedure	Study type	Type of laser used	Methodology	Outcome	(Refs.)
				technique, probe tip was placed perpendicular in contact of defect area.		
Kolamala, 2022	OFD	Split mouth randomized clinical trial.	Diode	15 participants with periodontitis were included, with 30 sites in total. 15 sites received laser assisted surgery (test sites), and another 15 were control sites. Laser parameters: Wavelength, 980 nm; duration, 30 sec; power, 3 W; technique, inflamed soft tissue pocket wall was removed.	Significant reduction in pocket depth, bleeding on probing and improved healing was observed.	(33)
Guimarães, 2024	CTG procedure	Randomized controlled clinical trial.	Diode (GaAiAs)	Out of a total of 40 class I and II gingival recession cases, 20 test sites were treated with the tunneling technique followed by laser irradiation; the remaining 20 were control sites. Laser parameters: Wavelength, 660 nm; duration, 20 sec; power, 30 mW; technique, laser tip was in contact with tissue at donor and recipient area.	Significant difference was notedas regards post-operative discomfort in patients treated with laser.	(34)
Morshedzadeh, 2022	FGG procedure	Split mouth randomized controlled clinical trial.	Diode (GaAiAs)	16 patients were treated with FGG as a part of split mouth surgery, one site was irradiated with laser. Laser parameters: Wavelength, 940 nm; duration, 30 sec; power, 0.21 W; technique, was employed at wound site in non-contact mode.	Remaining wound area was assessed to be much smaller in the region irradiated with laser as compared to non-irradiated site.	(35)
Lavu, 2022	FGG procedure	Randomized controlled clinical trial.	Diode	A total of 38 patients with isolated gingival recession were treated using the laterally closed tunnel technique. 19 of control group received sham laser application, while the other 19 underwent laser application. Laser parameters: Wavelength, 660 nm; duration, 5 sec; power, 50 mW; technique, laser was directed perpendicularly with slight contact to tissue at both donor and recipient area.	PBM led to the more rapid healing of the wound site and improved patient comfort.	(36)

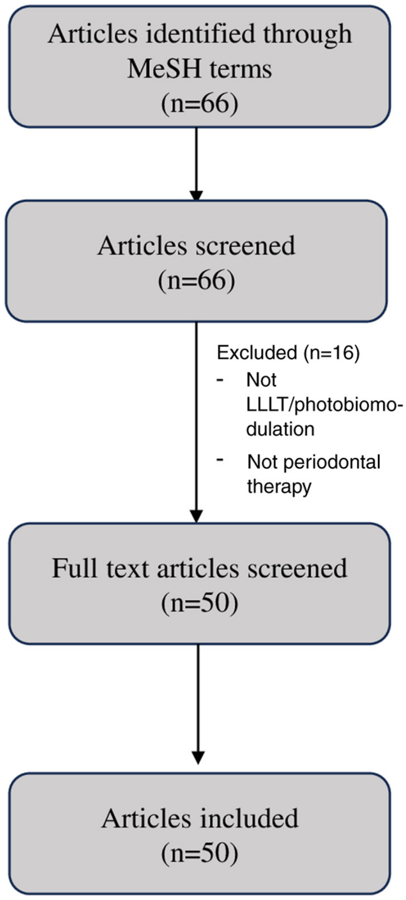

Figure 2. Article screening process for the narrative review. MeSH, medical subject headings; LLLT, low-level laser therapy.

Osteoblasts are crucial for bone formation and repair in periodontal regeneration. Diode lasers have demonstrated promising effects on osteoblasts, stimulating cell proliferation, viability and migration, and enhancing mineralization. These cells also upregulate key osteogenic markers such as alkaline phosphatase, osteocalcin and bone morphogenic proteins, while also influencing osteoclast-related markers and signaling pathways. Nd:YAG lasers can also enhance cell proliferation, mineralization and the gene expression of osteogenic markers. Er:YAG lasers, under specific conditions, can increase cell proliferation and mineralization and modulate gene expression. CO_2 lasers have been shown to enhance bone sialoprotein expression through specific signaling pathways (38). Although laser irradiation, specifically with diode lasers, has shown potential for promoting bone formation, further research is required to optimize parameters and elucidate the underlying mechanisms for different types of lasers (38).

Fibroblasts play a crucial role in connective tissue, migrating to the lesion site from the late inflammatory phase until the epithelium is formed completely. These cells support various cellular processes involved in wound healing and tissue regeneration. They contribute by breaking down blood clots, secreting growth factors and cytokines, and forming new extracellular matrix and collagen structures. Furthermore, they play a pivotal role in promoting wound contraction. Over the years, the biological and molecular mechanisms underlying these effects have been actively investigated, with a particular focus on the impact of lasers on fibroblasts. PBM stimulates fibroblast proliferation, increasing collagen synthesis, reducing inflammation and improving blood circulation, which further accelerates the healing process (39). Different laser types, such as diode, Nd:YAG, Er:YAG, Er,Cr:YSGG and CO_2 lasers can be employed for PBM. Diode lasers have been shown to stimulate fibroblast proliferation, increase collagen synthesis and reduce inflammation. Nd:YAG lasers can modulate collagen synthesis and reduce inflammation, promoting tissue repair. Er:YAG and Er,Cr:YSGG is usually used for tissue ablation and resurfacing. However, PBM with these lasers can stimulate fibroblast proliferation and collagen synthesis. CO_2 lasers can modulate growth factor expression and reduce inflammation. The exact mechanisms of the underlying effects of PBM are not yet fully understood, but are considered to involve various cellular signaling pathways (38).

The periodontal ligament (PDL) which supports and attaches the tooth to the alveolar bone also responds positively to PBM therapy, particularly diode and Er:YAG lasers. These have shown promising effects on PDL cell proliferation, migration and differentiation, and also enhance their calcification potential. By targeting specific cellular signaling pathways, lasers can promote tissue repair and improve periodontal health (33).

Endothelial cells, which form the inner lining of blood vessels, play a critical role in blood clotting, inflammation and vascular permeability. They are essential for angiogenesis, which is crucial for delivering oxygen and nutrients to the wound site. PBM therapy has been shown to stimulate endothelial cell proliferation, migration and reduce inflammation. However, the effects of PBM on endothelial cells can vary depending on factors, such as laser parameters, cell type and experimental conditions (38). Similarly, epithelial cells found on tissue, organs protect deeper tissues and support homeostasis. They are crucial for wound healing. The effects of PBM on various epithelial cells are limited. However, it has been proposed that pulsed diode laser irradiation can significantly increase the proliferation of gingival epithelial cells by activating the MAPK/ERK pathway (38).

CO_2 and Er:YAG laser irradiation have been shown to decrease the expression of sclerostin (*Sost*), a gene encoding sclerostin, a protein that inhibits bone formation. By reducing *Sost* expression, laser irradiation may reduce the inhibition of bone formation and thus promote it. Diode laser irradiation can stimulate the differentiation and activation of osteoclast precursor cells by upregulating RANK expression (38).

PBM is emerging as an effective tool in non-surgical periodontal therapy (NSPT), particularly in moderate to deep periodontal pockets. It promotes periodontal healing by reducing inflammation, enhancing fibroblast and osteoblast activity, and improving tissue repair. NSPT has shown additional clinical benefits in moderate to deep pockets when combined with laser therapy or laser therapy alone compared to traditional mechanical debridement. The studies by Crespi *et al* (40), and Eltas and Orbak (41) have demonstrated the superior properties of Er:YAG and Nd:YAG lasers, respectively, over traditional scaling and root planning. Notably, these positive outcomes were particularly evident in deeper periodontal pockets. However, the European Federation of Periodontology does not currently recommend the routine use of PBM as an adjunct to NSPT due to insufficient evidence supporting its efficacy (42). This is supported by Salvi *et al* (43), who found no significant benefit in probing depth reduction with adjunctive laser use and highlighted heterogeneity of study designs and outcomes. While PBM shows promise, its role in NSPT has yet to be elucidated (43). Future research is thus required to perform well-designed trials with standardized protocols. Additionally, exploring PBM in combination with other adjunctive therapies, such as ozone, probiotics and paraprobiotics may provide synergistic benefits and enhance periodontal healing outcomes (44-46).

PBM has also been applied in dental implantology, wherein implant success hinges on both the health of the soft tissue surrounding the implant and the secure integration of the connective tissue to the implant surface (47). Khadra *et al* (47) conducted a study examining the impact of laser therapy on enhancing fibroblast attachment to implant surfaces. Their findings revealed that laser therapy stimulated fibroblast activity and promoted better attachment to the implant surface (47). That study provided the foundation for utilizing PBM to enhance the soft tissue interface around implants. Experimental research also indicates that PBM can stimulate osteoblast proliferation and differentiation, which can improve osseointegration (48). The early use of post-operative PBM strengthens the connection between bone and implant, while boosting bone matrix production. Dörtbudak *et al* (49) investigated the effects of PBM on osteoblast activity *in vitro* using bone marrow-derived mesenchymal stem cells. Their study concluded that laser treatment enhanced osteoblastic activity, which could aid in improving implant osseointegration (49). Additionally, PBM has been shown to accelerate the healing around the surgical site by the aforementioned mechanism that includes the production of ROS and growth factors. Saini *et al* (50) conducted a systematic review to evaluate the impact of PBM of dental implants. Their findings suggest that PBM may enhance implant stability and increase density by facilitating cellular activity, such as osteoblast stimulation and collagen synthesis (50). PBM has demonstrated potential in the management of peri-implantitis and peri-implant mucositis. In their study, Al-Askar *et al* (51) employed the use of PBM and photodynamic therapy (PDT) as an adjunct to mechanical debridement for the treatment of peri-implantitis. It was concluded that PBM and PDT had a positive impact in reducing inflammation (51).

Recent studies have demonstrated that combining PBM with biological adjuncts, such as PRP, platelet-rich fibrin (PRF) and bone grafts enhances periodontal regeneration (52,53). Systematic reviews and meta-analyses have found that PBM with PRP/PRF stimulates tissue regeneration and improves clinical attachment gains and bone fill compared to grafts alone (52,54). A previous systematic review reported that PRP as an adjunct led to greater improvements in clinical attachment level and bone level in periodontal defects than conventional treatments (55). Additionally, as demonstrated in a previous systematic review of *in vitro* studies, PBM promotes the proliferation and osteogenic differentiation of periodontal ligament stem cells, supporting its regenerative benefits when paired with biomaterials (56).

Animal studies combining PBM with melatonin have reported improved healing and reduced inflammation in periodontitis models (57). Microbiome-modulating agents, such as probiotics, when used adjunctively with non-surgical therapy, help restore microbial balance and reduce inflammation, with PBM potentially augmenting these effects (45,58). Ozone therapy used as an adjunct to PBM and SRP has demonstrated significant improvements in probing depth and gingival health, with outcomes comparable to those achieved with chlorhexidine and without added adverse effects (59). The integration of PBM with advanced biomaterials and microbiome modulation is gaining interest. A nano-hydroxyapatite/chitosan (nHAp/CS) bioaerogel has shown superior osteogenic potential in preclinical models, indicating promise for periodontal bone regeneration. Bioactive glasses also support osteogenesis in periodontal defects, though PBM-specific combinations require further study (60). While these findings are promising, the majority of available evidence stems from preclinical or small clinical trials, highlighting the need for larger, well-designed studies to establish definitive clinical protocols.

The present narrative review is limited by the absence of a systematic methodology, which may introduce selection bias. The variability in PBM protocols across studies further limits generalizability. Additionally, the lack of quantitative synthesis restricts the strength of conclusions drawn.

6. Conclusion and future perspectives

PBM has emerged as a promising adjunct in periodontal therapy, demonstrating significant potential in enhancing wound healing following periodontal procedures. By modulating inflammatory responses, stimulating cellular processes and promoting tissue regeneration, PBM accelerates healing while reducing patient discomfort. The ability of PBM to enhance fibroblast proliferation, osteoblast activity and periodontal ligament regeneration highlights its role in improving periodontal outcomes.

Despite the growing body of evidence supporting the efficacy of PBM, further research is required to optimize laser parameters, establish standardized protocols and better understand the underlying molecular mechanisms. With advancements being made in laser technology and acquiring a more in-depth understanding of the biological effects of PBM, its integration into mainstream periodontal therapy is expected to expand. Ultimately, PBM stands as a valuable, non-invasive and patient-friendly modality, reinforcing its role as a promising tool for improved periodontal wound healing and regeneration.

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AS and NS were involved in designing the concept of the review followed by conducting the literature search and drafting the initial manuscript. AT and KSC were involved in revising and editing the manuscript. Data authentication is not applicable. All the authors reviewed, and have read and approved the final manuscript.

Ethics approval and consent for publication

Not applicable.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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