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Photo-Biomodulation in Endodontics

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Abstract: This scientific review explores the emerging field of photobiomodulation (PBM) in endodontics, investigating its potential applications and efficacy in root canal therapy. Through a comprehensive analysis of current literature, this review highlights the impact of PBM on biological processes, including its influence on inflammation, tissue repair, and pain management within the endodontic context. The synergistic relationship between PBM and conventional endodontic procedures is examined, shedding light on the potential enhancement of treatment outcomes. Furthermore, the review addresses challenges, gaps in research, and future directions for harnessing the full therapeutic potential of PBM in endodontic practice. Overall, this synthesis of evidence aims to provide valuable insights for clinicians, researchers, and practitioners seeking to integrate PBM into contemporary endodontic protocols. Through this comprehensive analysis, we aim to foster a better understanding of photobiomodulation's potential in endodontics and encourage further research to establish evidence-based guidelines for its implementation in clinical practice. By harnessing the power of light as a therapeutic tool, photobiomodulation may revolutionize endodontic care and improve the quality of life for patients undergoing endodontic treatments.

I. INTRODUCTION

The growing significance of employing low-power lasers and photobiomodulation (PBM) in dentistry stems from their painless and non-intrusive capabilities. As defined by the North American Association of Laser, LLLT involves the nonthermal application of laser light using photons from the visible and infrared spectrum to promote tissue healing and alleviate pain.[1]

Moreover, as laser science progressed, it was discovered that non-coherent radiations like Light-Emitting Diodes (LEDs) also exhibit bio-stimulatory properties beyond coherent radiation from lasers. This broadened the scope, leading to the term “low-dose light therapies.”[2,3] Presently, the term “Photobiomodulation” (PBM) encompasses a spectrum of electromagnetic wavelengths, including broadband lights, LEDs, and laser/LED applications with low-energy densities. [2,3] PBM operates on photochemical mechanisms, where the absorbed photo energy by mitochondrial chromophores is transmitted to respiratory-chain components.[4]

Photobiomodulation (PBM) has two main effects on target tissues: photostimulation and photoinhibitory effects. Therapeutic contexts can benefit from these effects. The way laser treatment works is that it uses energy transmission to start a biological reaction. According to Arndt-Schultz's Biomodulation Law, high energy levels suppress biological reactions whereas low energy levels promote biological processes.[5]

Photobiomodulation therapy (PBMT) employs electromagnetic radiation within the visible wavelengths (380–700 nm) or the near-infrared range (700–1,070 nm). This radiation penetrates tissues at depths ranging from 3 to 15 mm in both hard and soft tissues.[6-9]

Previous studies have demonstrated that Photobiomodulation Therapy (PBMT) is widely acknowledged for its positive effects in endodontics. These include analgesia, sterilization/disinfection, diminished dentin sensitivity to tactile and thermal stimuli, enhanced dentin formation in dental pulp, reduced inflammation of oral mucosa, accelerated bone formation, and improved wound healing processes. These represent just a few of the benefits associated with the use of PBMT in dentistry.[10,11]

Certainly, this review intends to explore the various types of lasers, their mechanisms of action, and the Photobiomodulation (PBM) dental treatment protocols within the realms of Endodontic and Restorative dentistry. The discussion is grounded in validated clinical studies published to date.

II. MECHANISM OF ACTION

Karu et al. were the first researchers to describe the mechanism of action of Photobiomodulation Therapy (PBMT).[12] PBM's primary technique is the direct application of light radiation to increase biological activity within bodily cells. This light is absorbed by cellular photoreceptors, such as pigments and cytochromophores, and is then transferred to the mitochondria. This influences the Krebs cycle and cytochrome oxidase activity, ultimately increasing the synthesis of adenosine triphosphate (ATP). A portion of the energy produced by the increased ATP is converted to heat, which causes a photothermal impact that permeates the tissues and increases cellular activity. [1, 5, 8, 13–15] Light-sensitive ion channels in cells are activated by exposure to near-infrared light, which raises the concentration of calcium ions. Then, these ions interact with cAMP and reactive oxygen species (ROS).[16] Wang and associates

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suggested that green and blue light with shorter wavelengths activate light-gated ion channels, fostering cellular proliferation, differentiation, and migration.[17]

III. APPLICATIONS

The application of Photobiomodulation Therapy (PBMT) through a low-level laser (LLLT) offers endodontists a non-invasive and non-thermal approach. This method serves as an adjunct to traditional Root Canal Treatment (RCT) and various clinical applications, including but not limited to direct pulp capping (DPC), treatment of dentin hypersensitivity, dental analgesia, and mitigating postoperative pain following endodontic procedures. Additionally, PBMT proves to be a therapeutic tool in Regenerative Endodontic Procedures (REPs), providing anti-inflammatory effects, promoting apical cicatrization, and expediting the healing process.[18-22]

Table 1:- Current Applications of PBMT in Endodontics

1	PBMT-Induced Anesthesia
2	Laser-based Prevention and Preparation of Enamel Caries
3	PBMT-assisted Direct Pulp Capping
4	Decontamination of Root Canal System
5	Postoperative sensitivity in restorations
6	Postoperative Pain After Endodontic Treatment
7	PBMT used in Endodontic Surgery
8	Tooth/Dentinal Hypersensitivity
9	Tooth Bleaching
10	Regenerative Endodontic Procedures

A. PBMT-Induced Anesthesia

Given the crucial need for effective anesthesia in many endodontic procedures, Photobiomodulation Therapy (PBMT) emerges as a non-drug and non-invasive method capable of achieving anesthesia with an estimated significance ranging from 60% to 95%.[23] For instance, using an 810 nm diode laser (power of 250 mW, 53.3 J/cm per side, 120 s, and continuous mode) in PBMT has been recommended for achieving high-quality anesthesia during conventional tooth excavation.[24] However, existing systematic reviews indicate inadequacies in current clinical parameters, emphasizing the need for further studies before proposing a definitive treatment protocol based on current findings.

B. Laser-Based Prevention and Preparation of Enamel Caries

Diode lasers with wavelengths of 810 nm, 830 nm, and 890 nm have been employed for caries prevention.[25] Photobiomodulation Therapy (PBMT) at 810 nm, with parameters of 30 mM and 90 s, demonstrated an increase in calcium and phosphate levels.[26,27] At a wavelength of 830 nm, PBMT suppressed demineralization around orthodontic brackets on bovine teeth and enhanced enamel surface hardness.[28,29] The erbium laser has emerged as an option for cavity preparation, causing minimal invasive damage.[30]

C. PBMT-Assisted Direct Pulp Capping

Photobiomodulation Therapy (PBMT) has been proposed to significantly enhance the outcomes of Direct Pulp Capping (DPC) procedures for permanent teeth.[31,32] Its notable effects in reducing inflammation, discomfort, and pain, as well as promoting wound healing and robust dentin tissue formation, contribute to the improved prognosis of DPC.[33,34] The photo energy penetrating pulp tissue coagulates the exposed pulp, forming the biological basis for reparative dentin.[35] Dental pulp cells, when exposed to laser irradiation, have demonstrated the ability to generate hard tissue. The hypothesis suggests that laser treatment can stimulate odontoblasts, leading to the formation of tertiary dentin and a dentin bridge at the exposed site. PBMT's biostimulatory properties decrease the risk of inflammation or pulp injury, enhancing patient comfort and post-therapy discomfort control.[36]

It's crucial to remember, though, that the majority of earlier research in this area was carried out in vitro and in animal experiments. The results show how important DPC technique and materials are compared to PBMT. The lack of general application of laboratory study results to clinical trials to date highlights the need for additional in vitro and in vivo research to produce more precise and useful results.[37–39]

D. Decontamination of a Root Canal System

Effective root canal decontamination, also known as disinfection or sterilization, is essential due to the presence of several aerobic and anaerobic microorganisms that cause diseases. When paired with chemical-mechanical preparations, laser treatment is an invaluable addition to regular canal disinfection.[40] Photobiomodulation Therapy (PBMT) is a viable option for root canal disinfection due to its antibacterial properties on the pulp of human teeth with necrotic and periapical diseases.[41,42] By combining methylene blue with a diode laser operating at 60 J/cm and 50 mW, for example, PBMT was able to significantly reduce E. faecalis colonies by 77% and 99%.[43, 44] An other method that combined methylene blue with diode red light at 30 J/cm energy led to an 80% decrease in Actinomyces israelii, Fusobacterium nucleatum, Porphyromonas gingivalis, and Prevotella intermedia colonies.[45]

Collectively, these findings suggest that PBMT serves as an antibacterial adjunctive device for Root Canal Treatment (RCT) in endodontics.[46]

E. Postoperative Sensitivity in Restorations

Dental sensitivity, often stemming from polymerization shrinkage following composite restorative therapy, remains a common issue. Despite several suggested remedies, ongoing research aims to identify the most effective method for alleviating this sensitivity. Recent studies exploring the impact of low-power lasers on postoperative sensitivity reduction have shown promise, particularly for deep restorations. Moosavi et al. recommended the use of Photobiomodulation Therapy (PBMT) in deep cavities, proposing a protocol of 630 nm, 28 mW, continuous wave, 60 sec, and 1.68 J.[47] According to their findings, this

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approach significantly reduces postoperative sensitivity in class V composite restorations.

F. Postoperative Pain After Endodontic Treatment

A common side effect of endodontic therapy is pain, which can have a major negative influence on a person's quality of life. Damage to pulp tissue can be caused by a number of things, such as chemical, thermal, or microbiological effects. Research indicates that pain is more common after root canal retreatment. Low-power laser therapy has becoming more popular as a pain management method because it is non-invasive, affordable, and has few side effects.[48–50] The impact of Photobiomodulation Therapy (PBM) on postoperative pain in patients with symptomatic apical periodontitis was investigated by Yildiz et al., a noteworthy study that demonstrated PBM's utility in lowering pain following endodontic treatment.[51]

Asnaashari et al.'s study, on the other hand, indicated that using an 808-nm low-power laser had only a minimal impact on lowering discomfort related to root canal retreatment in molars. The 48-hour pain reduction shown in the laser and control groups suggested that PBMT had only mediocre results in this situation.[48] By suppressing the synthesis of inflammatory factors and pain-related neurotransmitters, PBMT works by increasing the synthesis of anti-inflammatory prostaglandins, immunoglobulins, beta-endorphins, and lymphokines.[52–54] While PBMT has been suggested as a useful treatment for pain following root canal retreatment, the lack of clinical data makes it difficult to establish a precise protocol, highlighting the need for more study in this field.[36]

G. PBMT used in Endodontic Surgery

Three clinical studies have investigated the importance of using Photobiomodulation Therapy (PBMT) in endodontic surgery. Specifically, the research have focused on PBMT's ability to reduce pain and swelling as well as promote the healing of both soft and hard tissues. Diode lasers operating at 680 or 810 nm, power outputs between 50 and 75 or 129 mW, energy density of 3-7.5 J/cm2, irradiation times between 3 and 600 seconds (300 seconds for each buccal and palatal surface), noncontact scanning movement, irradiation area between 9 and 10 cm2, and application during and one to seven days following surgery are some of the radiation characteristics of the lasers used. The results of these investigations show that laser irradiation has a positive effect on pain relief as well as soft and hard tissue healing.[18,55]

However, to draw more conclusive results, additional clinical studies are deemed necessary. In conclusion, while laser irradiation shows promise for enhancing soft and hard tissue healing and reducing pain, further clinical research is warranted for clearer and more definitive results.

H. Tooth/Dentinal Hypersensitivity (DH)

Tooth or Dentinal Hypersensitivity (DH) is a common chronic pain condition in dentistry, often challenging to predictably treat. Stimulation of A-d nerve fibers in exposed dentin by chemical, osmotic, thermal, or tactile factors can lead to sharp, short pain without apparent dental defects or pathologies.[56,57] Laser technology, was first applied by Matsumoto et al. In the mid-1980s, has evolved, with Photobiomodulation Therapy (PBMT) emerging as a crucial non-drug, non-invasive treatment for DH.[58]

Various lasers have been explored for DH treatment, working through the obliteration of dentin tubules, alteration of nerve endings affecting pain thresholds, and stimulation of reactive dentine production.[59,60] Clinical investigations suggest that GaAlAs (795 or 830 nm) or InGaAlP (660 nm) lasers, with specific radiation protocols, significantly reduce dentin sensitivity. Despite proven efficacy in several studies, the subjective nature of DH has led to ongoing disagreements over treatment success.

Using a high-power laser, PBMT can destroy dentin tubules, or it can modify the nervous system to increase the creation of tertiary dentine. Combining laser analgesia with a subsequent chemical agent application to the dentin is frequently necessary for optimal desensitization.[36] Notably, studies by Marsilo et al. showed that treating dentine hypersensitivity had a statistically significant success rate of 88.8% when compared to the control group, and the difference was still significant after 60 days.[61] The non-invasive aspect of PBMT is still being researched for the successful treatment of dentinal hypersensitivity, despite the range of PBMT protocols and comparative strategies utilized in clinical research.[21]

I. Tooth Bleaching

About 55–100% of patients experience increased tooth sensitivity during and after bleaching, which is a major disadvantage, especially when using in-office procedures.[62–65] Photobiomodulation Therapy (PBM) develops as a noninvasive, nondrug approach to alleviate postoperative sensitivity. While odontoblastic cell response and neutralizing gel bleaching byproducts have been the focus of laboratory studies, clinical trials show that PBMT is useful in lowering tooth sensitivity following in-office bleaching. Positive results have been seen when Diode lasers with radiation characteristics of 780 and 810 nm, 70–200 mW, 10–15 sec, and 12 J/cm2 are applied.

Despite these positive effects on reducing clinical sensitivity and neutralizing cytotoxicity from bleaching gel byproducts, existing in vivo and in vitro studies do not precisely elucidate the mechanisms of PBM. Therefore, further clinical studies are deemed necessary to gain a more comprehensive understanding of the performance of PBM in addressing tooth sensitivity associated with bleaching procedures.[21]

J. Regenerative endodontic procedures

The application of lasers in Regenerative Endodontic Procedures (REPs) implies that stem cells are biostimulated by Photobiomodulation Therapy (PBMT). This involves stimulating the proliferation of stem cells, raising metabolism, enhancing regeneration, quickening dentine regeneration following pulp exposure, and affecting the viability and differentiation of mesenchymal stem cells

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produced from dentoalveolar tissue.[66–68] Preclinical investigations have yielded positive results when applying PBMT for pulp regeneration during REPs, suggesting that it is a viable substitute for cell-homing therapies.[69,70]

Modest adjustments to the dosage combined with small adjustments to the application time and frequency could have little effect or possibly prevent the intended effects of photobiomodulation therapy (PBMT). For this topic, both wavelengths (660 and 810 nm) have shown satisfactory results. Other PBMT variables, including as power, which varied from 20 to 300 mW, and exposure time, which varied from 7 to 300 s in in vivo tests, differed significantly between trials. It is difficult to reliably assess the results due to the large range of parameters used in scientific literature study.

Every study that examined rates of cell differentiation showed that PBMT yielded positive results. Nevertheless, two experiments failed to demonstrate a rise in proliferation/cell viability rates, indicating that this was not consistently detected in these values. This disparity might be explained by the fact that PBMT frequently produces notable results in conditions of cellular stress, which can be brought on by things like nutritional deficits or adjustments to the replenishment of the cell culture media. The observed cell deficiency may not have been compensated for by PBMT settings, even in situations where cellular stress was present.

Regardless of the animal species employed, all in vivo studies showed the beneficial effects of PBMT on the development of dentin pulp-like tissue despite these differences. Quantifiable findings from studies demonstrating an increase in tertiary dentin formation suggested that PBMT may accelerate the rate of dentinogenesis. Notably, this impact was shown in both studies using the 810 nm wavelength. Despite only offering qualitative data, the study by Moreira et al. provided important details on the characteristics of newly produced tissue during dental pulp regeneration.[36,69]

IV. CONCLUSION

In many dental applications, including depth of anesthesia, direct pulp capping, regenerative endodontics, postoperative endodontic pain, endodontic surgery, and tooth hypersensitivity, photobiomodulation therapy (PBMT) is used as an alternative to analgesics and anti-inflammatory medications. Several studies demonstrate the potential benefits of PBMT in dentistry, including its increasing efficacy and utilization in a variety of dental treatments. The increased effectiveness of PBMT is attributed to its physiological effects on inflammation reduction, pain relief, wound healing, and tissue restoration. It improves overall therapy efficacy by its favorable effects on cell migration, proliferation, and differentiation. A number of variables, including subject uniqueness, anatomical variance, site location, and clinical state, affect the best results from PBMT.Accurate dosage administration, informed by comprehensive knowledge, is pivotal for achieving the best results. Notably, PBMT demonstrates a lack of associated adverse effects, further endorsing its safe and beneficial integration into clinical dentistry.

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