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ILLUMINATING PEDIATRIC DENTISTRY: A REVIEW OF PHOTOBIOMODULATION

Dentistry

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ABSTRACT

Recent advances in the use of biophotonics in engineering and biology led researchers to investigate evidence suggesting the use of photobiomodulation (PBM) therapy, a low-dose biophotonics treatment, in pediatric dentistry. Low-level laser treatment (LLLT), frequently referred to as photobiomodulation (PBM), has been around for about 60 years, although it is still not commonly used, largely because of the lack of understanding surrounding the molecular, cellular, and tissue-level benefits of it. Photobiomodulation (PBM) is a minimally invasive medical approach that uses low-level lasers or light-emitting diodes (LEDs) to promote tissue repair, reduce inflammation, and relieve pain. Dentistry is one of the medical specialties where PBM has gained popularity. In pediatric dentistry, photobiomodulation (PMB) therapy has been for the treatment of pulpotomies, post-surgical oral pain, and the treatment of oral lesions such as recurrent aphthous stomatitis, herpes infections, mucositis, and prevention of gag reflex in pediatric patients.

KEYWORDS

Photobiomodulation, low-level laser therapy, minimally invasive.

INTRODUCTION

Our circadian rhythms, sleep-wake cycles, and vitamin absorption together provide strong evidence of the role light plays in biological systems and processes. Researchers now have access to and can make use of powerful light (at particular wavelengths) in biology, bringing out new possibilities for its use in tissue engineering and healing because of the development of lasers as sources of radiation that are stimulated and amplified. [1]

Photobiomodulation (PBM) was first discovered by the Hungarian physician Endre Mester around 60 years ago. He performed the very first animal studies of PBM therapy in the 1960s. He was examining the possible carcinogenic effects of coherent light (ruby laser, wavelength of 694.3 nm) in animal models. PBM, which has been around since 1967, employs the use of a nonionizing, coherent (using a light source that emits light by the stimulated emission of radiation [LASER]), and incoherent (using a light-emitting diode [LED]) light source that operates in the red and near-infrared spectrum (600–1000 nm).[2] The term "PBM" was formally adopted by the field that was considered most suitable to replace a plethora of older terms such as "Low-Level Light/Laser Therapy" (LLLT), "Biostimulation," "Photostimulation," "soft laser," and "cold laser" among many others that have been used since the 1970s.[3] Since ruby lasers (694 nm) and HeNe lasers (633 nm) were the first devices employed, PBM was referred to as "low-level laser therapy" for most of this period. It was recently suggested to use the term "PBM" because the word "low-level" was too arbitrary. It is also now recognized that non-coherent light-emitting diodes (LEDs) can function just as well as actual lasers. [4]

Laser therapy in pediatric dentistry is a good choice for its known advantages especially for the safety of its application and its gentle approach to patients. Studies have demonstrated that low-level laser therapy (LLLT) functions effectively for a few particular clinical dental applications because of its anti-inflammatory and regenerative effects as well as the conditioning effect on tooth enamel. [5] Anxiety over needles, loudness, and vibration associated with dental treatment cause discomfort in children. Both dentists and patients are extremely interested in any new technology that reduces dental pain and anxiety. Positive reports of the benefit of low-level laser therapy (LLLT) used in dental surgery to treat disorders including TMJ pain, trigeminal neuralgia, and muscular pain have been presented. An additional area of interest in this field is the use of low-level laser therapy (LLLT) to achieve an analgesic effect in the dental pulp before the restorative procedure.[6] Photobiomodulation has the potential to improve healing by reducing pulpal inflammation and maintaining dental pulp vitality, according to recent studies. [7] PBM has an advantage in pediatric dentistry due to the intrinsic properties of lasers being safe, effective, and minimally intrusive for procedural analgesia. [8] Lasers are recommended for a wide range of procedures in dentistry treatment because of their ease of use, cost-effectiveness, specificity, comfort, and ease of use compared to conventional modalities.[9]

Mechanism Of Photobiomodulation

Considering its mechanism of action on cells and tissues is still insufficiently comprehended, the use of laser therapy through the technology of photobiomodulation (PBM) is yet to be included in standardized surgical procedures for tissue repair and regeneration.[10] The specific mechanism of action of PBM remained unknown for a long time, but chromophores and signaling routes have been better understood in recent years.[11]

Two of the main chromophores have been identified as calcium ion channels (which may be mediated via opsin-mediated light absorption) and Cytochrome C Oxidase (CCO) in mitochondria. One of the primary mechanisms of PBM is the process by which CCO, is a key enzyme involved in cellular respiration and energy production. Studies have shown that exposure to specific wavelengths of light, usually in the red to near-infrared spectrum, enhances the activity of CCO. This activation leads to an increase in ATP production, promoting cellular metabolism and facilitating tissue repair.[11] The widespread choice for red/NIR wavelengths, which have more effective tissue penetration than wavelengths of blue or green light, which have greater absorption by hemoglobin, has been explained by an assumption that CCO is the primary target of PBM. Due to the non-covalent bond between nitric oxide (NO) and the heme and Cu centers, which results in a 1:10 competitive blockage of oxygen, a relatively low-energy photon can kick out the NO and allow a lot of respiration to take place. [12] The most widely accepted explanation for how photo-dissociation of inhibitory nitric oxide (NO) could cause an increase in enzyme activity, oxygen consumption, and production of ATP in response to photon absorption by Cytochrome C Oxidase (CCO) (Figure1).[13]

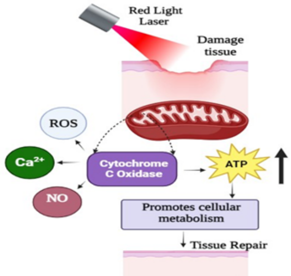

Figure 1. Mechanism of Photobiomodulation. Created with BioRender

Modulation levels of reactive oxygen species (ROS) by PBM is considered one of its major cellular reactions. Superoxide anions and hydrogen peroxide are examples of ROS that are produced naturally by biological metabolism. While minimal ROS are necessary for cellular signaling, too much ROS production can cause oxidative stress and cellular damage. It has been demonstrated that photobiomodulation upregulates antioxidant enzymes including superoxide dismutase and catalase, lowering ROS levels and re-establishing cellular equilibrium.[14]

Increases in ATP, a transient increase in reactive oxygen species, an increase in nitric oxide, and alterations to calcium levels are among the secondary effects associated with photon absorption. Tertiary effects include the activation of several transcription factors resulting in enhanced migration and proliferation of cells, as well as new protein synthesis .[8] Photobiomodulation, through its complex mechanism of action, demonstrates the potential to promote tissue repair, reduce inflammation, and alleviate pain. By targeting cellular chromophores and modulating various cellular and molecular processes, PBM harnesses the power of light to stimulate beneficial cellular responses .[10]

Furthermore, PBM has been found to stimulate the release of various growth factors and cytokines, which play crucial roles in tissue repair and inflammation modulation. It has been found to exert anti-inflammatory characteristics primarily modulating various signaling pathways. For instance, PBM can inhibit the nuclear factor-kappa B (NF-κB) pathway, a key regulator of inflammation. By suppressing NF-κB activation, PBM reduces the production of pro-inflammatory cytokines, such as interleukin-1β (IL-1β) and tumor necrosis factor-alpha (TNF-α), which contribute to tissue damage and prolong inflammation.[15] Moreover, PBM stimulates the release of anti-inflammatory cytokines, such as interleukin-10 (IL-10), promoting a shift towards a pro-healing environment. For instance, photobiomodulation promotes the release of modifying growth factor-beta (TGF-β), a potent stimulator of collagen synthesis and wound healing. Additionally, PBM can modulate the cytokine expressions with pro- and anti-inflammatory properties, contributing to the resolution of inflammation and pain relief.[16]

Photobiomodulation (pmb) In Pediatric Dentistry

The use of lasers and light-emitting diodes (LEDs) changed clinical dentistry, improving dental healthcare approaches and improving the treatment of patients. Dental applications for photobiomodulation are based on the usage of low doses of biophotonics therapy.[17] Photobiomodulation is a non-invasive and painless technique that has shown positive effects in managing pain associated with dental procedures in children. It offers several advantages over traditional methods, including minimal side effects, reduced need for pharmacological agents, and improved patient compliance. PMB has been found to alleviate pain during various dental procedures such as scaling and root planing, pulpotomies, and extractions.[18]

PBM for Pain Management in Pediatric Dentistry

Isolan et al. (2021) assessed the impact of laser therapy on postoperative pain following pediatric dental extractions. The study was a randomized controlled trial. Researchers discovered that as compared to youngsters in the control group, those who underwent photobiomodulation had considerably lower pain levels.[19] Cachorro et al. (2019) comprehensive review examined several research and concluded that photobiomodulation was useful for treating pain in young patients undergoing dental treatments.[20] Ezzat et al. (2016) showed a statistically significant variation in pain measured using a VAS at various evaluation scores, in the first three days following the secondary palate surgeries. The result showed that low-level laser therapy can help reduce the requirement for analgesic medication and reduce postoperative pain and edema after secondary palatal operations. [21]

PBM for Caries Management and Prevention

Caries, commonly known as tooth decay or cavities, are a prevalent oral health issue affecting people of all ages worldwide. Traditional treatment methods for caries, such as drilling and filling, have been effective but often cause discomfort and anxiety for patients. Several research studies have investigated the efficacy of PBM in managing and preventing caries. Khosravi et al. (2018) assessed the effects of PBM on primary molar caries prevention in a randomized controlled experiment. According to the study, PBM has the potential can be used as a preventive measure because it considerably decreased the occurrence of new carious lesions when compared to the control group.[23] Marotti et al. (2019) systematic review examined the findings of numerous trials and concluded that PBM showed promise for dentin remineralization and pain alleviation in the treatment of caries. [24]

PMB pulpotomy in human primary teeth

According to the American Academy of Pediatric Dentistry (2016), pulpotomy is the process of ablation of the infected or affected pulp tissues, leaving the remaining vital pulp tissues intact. This preserves the radicular pulp's vitality and function, either completely or partially, and the capping agent is applied to the remaining pulp stump.[29] After the coronal pulp is amputated, the pulp stump could be treated with several agents. After pulpotomy, the most effective pulp dressing material should preserve the radicular pulp's vitality and health while enclosing it in an odontoblastic-lined dentin chamber. A pulpotomy medication that works efficiently needs to have clinical and radiographic success and the physiological compatibility of the pulp with the surrounding tissue.[25] Pescheck et al. (2002) observed that LPBM pulpotomy is shown to be an appropriate substitute for photobiomodulation pulpotomy performed in primary teeth, providing pulp stumps with more accurate and consistent hemostasis.[25] Ansari et al. (2018) evaluated the effectiveness of laser pulpotomy and observed that the laser group showed higher clinical, radiographical, and histological success rates than the control group.[26] De Coster et al. (2013) showed that laser pulpotomy has lower success rates than traditional pulpotomy techniques.[27] Fernandes et al. (2015) showed that for primary teeth in humans, low-level laser therapy may be used as an adjuvant alternative for vital pulp therapy. Before using calcium hydroxide, low-level laser therapy achieved satisfactory outcomes.[28] Yavagal, et al. (2021) evaluated formocresol pulpotomy at 9 months post-intervention in primary molars. In a study comparing formocresol pulpotomy, Laser Photobiomodulation (LPBM) pulpotomy showed a much higher radiographic success rate, suggesting that Laser Photobiomodulation (LPBM) is a potentially useful pulpotomy approach for pediatric patients. In human primary teeth, Laser Photobiomodulation (LPBM) may be an acceptable non-pharmaceutical alternative for formocresol pulpotomy.[29]

PBM for prevention and therapy in oral lesions

PBM can be used for the prevention of oral lesions such as recurrent aphthous stomatitis, herpes infections, mucositis, and burning mouth syndrome. [30-32] Recurrent aphthous stomatitis (RAS), also known as the recurrent oral ulcer, is a most common oral lesion that can be classified as a minor, major, or herpetiform ulcer. Jijin et al. (2016) reported that after three days, there was a statistically significant no change in the pain score between low-level diode laser therapy and another group of 5% Amlexanox oral paste; however, after seven days, there was a statistically significant reduction in pain. [30] Tezel et al. (2009) reported that the Nd:YAG laser at 100 mJ, 2W, 20 Hz for 2–3 min in contact mode has better patient acceptance, shorter treatment time, and lower rates of pain. [31] Han et al. (2016) found that when compared to a placebo group, there was a significant decrease in pain, particularly rapid pain alleviation. When PBM is used to treat herpes infections at dosages less than 10 J/cm^2, it has been shown that it has positive effects on pain management, healing acceleration, inhibition of the viral resistance mechanism, and recurrence reduction.[32] Primary burning mouth syndrome (pBMS) is a complex chronic pain disorder. According to the International Headache Society, it is defined as an intraoral burning or dysesthetic sensation that lasts for more than two hours every day for more than three months without having any clinically noticeable underlying lesions.[33] Bardellini et al. (2019) stated that during the conclusion of the study, participants in the PBM group experienced a significant reduction in their pain symptoms, with the treatment effects lasting for a month. [34] Zhang et al. (2020) reported that PBM demonstrated its effectiveness in pain management and enhanced quality of life in pBMS patients. [35]

PBM for controlling the gag reflex in children

PBM technique can be used to control gagging in children. [36, 37] The technique is non-invasive, low-cost, and vibration and heat-free.[38] Low-level laser energy is used in this technique to stimulate the acupuncture sites Pericardium 6 (PC 6), which is situated on the forearm about an inch above the wrist crease, and Conception Vessel

24 (CV 24), which is located in the labio-mental fold on the chin.[38, 41] Elbay et al. (2016) reported that photobiomodulation therapy of PC 6 acupuncture sites can be an effective method for reducing children's gag reactions during procedures using maxillary radiography.[39] Goel et al. (2017) reported that oxygen saturation levels increased and pulse rate decreased when low-level light laser therapy (LLLT) activated the PC 6 acupuncture point. Additionally, anxiety levels were also lowered and the gag reflex can be effectively suppressed. Hence, low-level laser therapy (LLLT) is an effective approach to controlling pediatric patients' gag reflex throughout the impression-taking procedure.[40] In a randomized placebo-controlled research, Schlager et al. (1998) observed that when children receiving strabismus surgery had laser photobiomodulation of point PC 6, the incidence of postoperative vomiting had been considerably reduced,[38] and Sari and Sari (2010) concluded that treating orthodontic patients with a high gag reflex with laser photobiomodulation targeting point CV 24 was effective in controlling the gag.[41]

CONCLUSION

In conclusion, photobiomodulation is a life-changing approach in the field of pediatric dentistry. Its non-invasive, pain-reducing effects and applications in pain management, wound healing, management of oral lesions, caries prevention, and management, prevention of gag reflex make it a versatile tool. As research in this field continues to expand, photobiomodulation is poised to redefine the standards of care and improve the overall dental experience for children. Future implications for photobiomodulation (PBM) for pediatric dentistry should be acknowledged by parents, pediatric dentists, and researchers.

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