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Review Article

Photobiomodulation in restorative dentistry and endodontics

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ABSTRACT

Photobiomodulation (PBM), often also known as low-level laser therapy, is a non-invasive method of treatment. It employs a specific wavelength of red and infrared light and induces several physiological responses in cells and tissues that form the foundation of PBM. This light treatment photochemically stimulates the cells to produce chemicals, such as adenosine triphosphate, reactive oxygen species, calcium ions, etc. This contributes further to cellular proliferation, differentiation, and migration. On specific tissues, PBM aids in pain relief, stimulates tissue repair, and has an anti-inflammatory impact. PBM research began in the 1960s, and several earlier studies have demonstrated that this therapy has many uses in various dental specialities. At present, more research is being undertaken to identify other positive features of this medicine in the field of endodontics.

1. Introduction

Light amplification by the stimulated emission of radiation (LASER) is an acronym for the "LASER," which was initially developed by Maiman on July 7, 1960, at Hughes Research Laboratories in Malibu, California, utilising a combination of helium and neon. As time passed, multiple scholars investigated this topic and shed light on the diverse laser uses in various fields of study. It was determined that the introduction of lasers to dentistry was helpful to dental practise. The hard lasers CO_2, Nd: YAG, and Er: YAG may be utilised on both soft and hard tissues. Hard lasers have a number of disadvantages, including heat injury to the pulp of the tooth and a high price. Additionally, soft lasers or cool lasers are based on low-cost semiconductor diode diodes. They are also commonly referred to as low-level laser treatment (LLLT) or biostimulation.[1] Lasers may be utilised in a variety of ways in the field of dentistry, and their expanding use is altering both the approach to oral health care and the patient's quality of life. It is an efficient method for completing a variety of dental operations.[2]

Charles Townes and his colleagues established the laser era by introducing microwave amplification by stimulated emission of radiation (MASER) in 1954 and 1955 in physics review articles. Despite the fact that multiple experts informed Townes that his device would not function, others began creating variants of his technology, and in 1960, the first light-emitting MASER was produced, which later became known as the LASER. In 1961, the 1%–3% neodymium-treated crystal of yttrium-aluminum-garnet was the first to produce Nd: YAG. In 1962, an argon laser was produced. In 1967, Endre Mester, the father of photobiomodulation, conducted an experiment at Semmelweis University in Budapest, Hungary on the effects of laser biostimulation following an animal study examining the function of "Ray of Light" in the development of cancer. For his experiment, he employed mice with their back hairs removed and separated into two groups. One batch was treated with a low-level laser whereas the other was not. In contrary to his assumptions, he saw that the

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mice treated with low-level laser were clear of cancer and that hair regrew on their backs. The rapid development of laser-exposed mice relative to non-exposed mice led to the discovery of "laser bio stimulation."

Consequently, dozens of clinical and laboratory investigations have been undertaken to investigate LLLT physiologic function and therapeutic consequences. The North American Association of Laser defines LLLT as "non-thermal laser light application utilising photons (light energy) from the visible and infrared spectra for tissue healing and pain control." In addition to lasers as coherent radiation, it was discovered that non-coherent radiations such as light-emitting diodes (LEDs) also had biostimulatory qualities; hence, the name "low-dose light therapies" was used for this class of treatments. The term "Photobiomodulation" (PBM) gives a more realistic description of low-power treatments, as it encompasses a broad spectrum of electromagnetic wavelengths which is capable of both photostimulatory and photoinhibitory actions on target tissues, both of which has therapeutic implications. Laser treatment is accomplished by transferring energy to induce a biological reaction. According to Arndt-Biomodulation Schultz's Law, low-dose energy promotes biological processes whereas high-dose energy inhibits biological responses.

The PBM approach employs electromagnetic radiations of visible wavelengths (380–700 nm), or near-infrared wavelengths (700–1010 nm), which have minimal absorption in water and a depth of penetration of 3–15 mm in soft and hard tissue, respectively. PBM activates photoreceptors and increase the production of adenosine triphosphate (ATP). ATP production stimulation enhances cellular activity via Kerbs cycle. This review aims to discuss the types of lasers, mechanism of action and PBM dental treatment protocol in Endodontic and Restorative dentistry.

2. Discussion

2.1. Types of lasers

There are two types of lasers: (i) High intensity and (ii) Low intensity.

(i) Warm lasers are high-intensity versions with wavelengths between 450–532 nm and 800–2940 nm, which correspond to the visible and infrared portions of the electromagnetic spectrum, respectively. These lasers are designed for surgery on hard or soft tissues.[3]

(ii) Low-intensity cold lasers (LLLT), also known as PBM treatment, utilise low-power radiation. These lasers have non-thermal effects on tissues and aid in tissue repair, inflammation reduction, and pain relief. Mester et al. was the first to document the results of LLLT in the medical literature.[4]

PBM treatment is based on the discovery that irradiation with certain wavelengths of red or near-infrared light generates several physiological changes in cells and tissues. This laser therapy is a non-invasive treatment that alleviates pain, reduces inflammation, and promotes tissue repair and regeneration.

2.2. Mechanism of action

Photobiomodulation therapy (PBMT) is a sort of light treatment that use non-ionizing light sources (LED, LASERS, broad-spectrum light) that emit visible and near-infrared light. In recent years, research has attempted to shed light on the effect of PBM on cells. The fundamental mechanism of PBM treatment is that it combines photochemically with cells and stimulates the cell's mitochondria, which contain chromophores that absorb photons from PBM. The Cytochrome c oxidase (Cco) enzyme influences the function of several substances, including Adenosine triphosphate (ATP), nitric oxide (NO), reactive oxygen species (ROS), and calcium ions.[5]

According to reports, the PBM can affect cellular activity in four distinct ways[6]: (1) Following the absorption of light by Cco, the rate of electron transfer in the respiratory chain rises, which in turn raises the rate of ATP production. (2) Cco transforms NO_2 to NO enzymatically and lowers O_2 to H_2O. NO has an antagonistic action since its binding to Cco limits respiration, hence lowering ATP generation. PBM may separate NO and Cco, resulting in a rise in free NO and an increase in subsequent consequences such as hypoxia and immunological signalling. (3) PBM inhibits the generation of reactive oxygen species. In stressed and injured cells, the anti-oxidation impact is advantageous. ROS is essential for cell signalling in addition to maintaining homeostasis. (4) A portion of the energy is converted into heat, which generates photothermal effect and distributes it throughout the tissues. When cells are exposed to near-infrared light, the light-sensitive ion channels are activated, leading to an increase in calcium ions, which then interact with ROS and cAMP. Wang et al. suggested that blue and green light with shorter wavelengths activates light-gated ion channels that can activate various chromophores, such as the rhodopsin channels. All of these processes enhance cellular proliferation, differentiation, and migration.[7]

2.3. Uses of photobiomodulation in restorative dentistry and endodontics

2.3.1. Direct pulp capping

Direct pulp capping (DPC) is treated with PBMT procedure due to its considerable benefits in lowering inflammation and discomfort, expediting the wound-healing process, and encouraging the creation of robust dentin tissue. However, the majority of studies in animal and in vitro studies suggest that technique and the materials used in DPC is important over PBMT; however, results were insignificant in the clinical studies. Further clinical studies are required to arrive

at conclusive results.[8–10]

Dental pulp cells have been demonstrated to generate hard tissue when exposed to laser irradiation. It has been hypothesised treatment of laser can lead to the formation of tertiary dentin by stimulating odontoblasts and forms a dentin bridge at the site of exposure. Because of its biostimulatory properties, there is decreased risk of inflammation or injury to the pulp on treatment with PBMT, thereby increasing patient comfort and also controlling discomfort in patients after therapy.

2.3.2. *Dentinal hypersensitivity*

Dentinal hypersensitivity (DH) causes persistent pain with a poor rate of prediction in dentistry. A-delta nerve fibres in the dentinal tubules are activated due to external stimuli like thermal or chemical stimulation, resulting in acute pain in teeth.[11,12] Various therapy strategies for DH have been investigated. Matsumoto et al. were the first to apply laser technology to treat dentin hypersensitivity in the mid-1980s. PBMT is currently regarded as an essential non-drug, non-invasive treatment.[13]

Numerous lasers for the treatment of DH have been investigated and studied so far. These lasers can work in two ways: obliteration of dentin tubules with high-power laser treatment, alteration of the nerve endings influencing the pain threshold, and reactive dentine production.[14,15] Clinical investigations shown that the use of GaAlAs (795 or 830 nm) or InGaAlP (660 nm) with the following radiation protocol: power of 15–120 mW, energy density of 1.8–10 J/cm^2, 24–160 sec, 3–6 sessions, continuous mode, and scanning motion can significantly reduce dentin sensitivity.

Due to the subjective character of DH, there are still many disagreements over the efficacy and success of this type of treatment, despite the fact that several studies have proven its efficacy and success. Despite the variety of PBMT protocols and comparison approaches used in clinical research, non-invasive PBMT must be investigated. Lasers can function in two ways, either by obliterating dentin tubules with high-power laser treatment or altering the neural system stimulating tertiary dentine production.

Optimal desensitisation of hypersensitive dentin is achieved by first administering analgesia with a laser and then applying a chemical agent to the dentin. Research by Marsilo et al. revealed that the treatment of dentine hypersensitivity had a statistically significant success rate of 88.8% when compared to the control group. In addition, by 60 days, the statistically significant distinction between the experimental and control groups was still present.[16]

2.3.3. *Teeth bleaching*

The main drawback of teeth whitening, particularly the in-office method is dental hypersensitivity.[17–19] After bleaching, 55 to 100% of patients on average report dental sensitivity. PBMT is a non-drug, non-invasive technique for lowering postoperative sensitivity. The majority of the research in this area has been conducted in laboratories and has mainly examined how PBMT affects odontoblastic cell response or neutralises gel bleaching by-products.[20] The application of PBMT, however, with the following diode laser radiation properties: (780, 810 nm), 70–200 mW, 10–15 sec, 12 J/ cm^2, has been shown to be efficient in lowering tooth sensitivity following in-office bleaching, according to the findings of clinical investigations. Even while PBMT reduces clinical sensitivity and neutralises cytotoxicity brought on by bleaching gel by-products, results of current in vivo and in vitro investigations do not adequately explain PBM performance, necessitating future clinical research.

2.3.4. *Postoperative sensitivity in restorations*

One of the frequent problems following composite restorative therapy is dental sensitivity, which is mostly brought on by polymerization shrinkage. The best method is currently being researched, despite the fact that several remedies have been suggested to avoid these kinds of dental sensitivity. Recent papers with the goal of analysing its impact on postoperative sensitivity reduction have suggested the use of low-power lasers for deep restorations. Moosavi et al. advised the use of PBMT in deep cavities because they claimed that their proposed protocol of 630 nm, 28 mW, continuous wave, 60 sec, and 1.68 J considerably lowers postoperative sensitivity in class V composite restorations.[21–23]

2.3.5. *Postoperative pain after endodontic treatment*

Pain is usually among the most prevalent side effects of endodontic treatment, which can have a substantial impact on an individual's quality of life. Discomfort due to thermal, chemical, or microbiological may cause damage to the pulp tissue. Several studies show incidence of pain higher following root canal retreatment. Low-power laser is one of the pain-relieving techniques that has been given considerable consideration, based on existing research that is of great value. This therapy method includes benefits such as being non-invasive, inexpensive, and having little adverse effects.[24–26]

Yildiz et al. study is one of the most significant investigations on the effect of PBM on postoperative pain in patients with symptomatic apical periodontitis. They utilised a 970–15 nm laser with a 200-lm optical fibre and a bleaching tip that was put 10 mm away from the tissue around the apex and triggered at 0.5 W and 10 Hz. After 30 seconds of PBMT pain reduction was significantly evident post endodontic treatment in a separate investigation, Asnaashari et al. utilised a low-power 808-nm laser with 100 mW of power and a 600-lm fibre diameter to provide a dosage of 70 J/cm^2 for 80 seconds. Using a visual analogue scale, pain intensity was measured prior to therapy,

immediately after treatment, and 4, 8, 12, 24, and 48 hours after treatment. There was no difference in pain between the laser group and the control group at any time, and both groups had pain relief for up to 48 hours. The researchers found that PBMT had limited effectiveness in lowering the discomfort associated with root canal retreatment in the first and second molars.[24]

According to studies, PBMT delays the onset of pain and lessens its intensity and duration. Increased production of chemokines is its mode of action. It also suppresses the creation of inflammatory factors and neurotransmitters associated with pain. Therefore, it has been hypothesised that PBMT can effectively alleviate pain during root canal re-treatment. Due to the low number of clinical investigations, it is not possible to create a precise methodology, and more research should be considered.[27–29]

2.3.6. Endodontic surgery

Three clinical studies have explored the usefulness of employing PBMT in endodontic surgery in terms of lowering pain, edema, and soft and hard tissue recovery. Lasers have the following radiation characteristics: diode 680 or 810 nm, 50–75 or 129 mW power output, 3–7.5 J/cm^2 energy density, 360 to 600 sec irradiation time (300 sec), scanning movement, 9–10 cm^2 irradiation area, intraoperatively and 1–7 days after surgery. Laser irradiation has a favourable effect on soft and hard tissue healing and pain reduction; nevertheless, further clinical research are required for more clear results.[30,31]

2.3.7. Regenerative endodontic procedures

PBM treatment enhanced stem cell differentiation in vitro and pulp-like tissue regeneration in vivo, resulting in an increase in tertiary dentin volume and an improvement in pulp-like tissue development. Changes in dosage accompanied by modest variations in application time and frequency may result in an insignificant impact or even impede the desired effect. Both wavelengths (660 and 810 nm) were able to produce adequate findings for this subject. Nonetheless, the other PBMT characteristics varied considerably between trials. In in vivo experiments, the power of PBMT ranged from 20 to 300 mW, while the duration of exposure varied from 7 to 300 s. It is difficult to evaluate the results when there is such a wide range of parameters across the research in the scientific literature.

When assessing the rates of cell differentiation, all investigations demonstrated that PBMT was capable of producing beneficial outcomes. Nonetheless, these results did not hold true for proliferation/cell viability rates, since two investigations failed to show an increase in these values. It may be due to the fact that PBMT only yields substantial outcomes under situations of cellular stress. This stress can be promoted, for example, by dietary deficiencies, by decreasing foetal bovine serum concentrations in the cell culture medium supplementation. Under this context of cellular stress, Ferreira et al. discovered enhanced proliferation rates in cells bombarded with 5 J/cm^2 radiation. However, despite the fact that two studies promoted cell deficit, since they were paired with scaffolds or inflamed pulp, its stress state may not have been sufficient or the PBMT settings may not have been able to compensate for the cell deficit.

All in vivo investigations, however, have demonstrated the favourable effects of PBMT on the formation of dentin-pulp-like tissue, regardless of the animal species used. Studies that discovered an increase in the development of tertiary dentin yielded quantifiable data, demonstrating that PBMT was able to boost the rate of dentinogenesis. Both experiments utilised the 810 nm wavelength. Moreira et al. study on the other hand, analysed dental pulp regeneration and, while giving only qualitative data, provided crucial information on the properties of newly generated tissue.[32]

3. Conclusion

PBMT is a substitute for analgesics and anti-inflammatory drugs. PBMT can therefore play an important role in postoperative endodontic pain, endodontic surgery, regenerative endodontics, depth of anaesthetic, direct pulp capping, and tooth hypersensitivity. Based on the data presented by several studies, the application of PBM in dentistry is promising, and its use is on the rise since it has proved to be incredibly effective for a variety of operations. The improved efficacy of PBMT is attributable to its ability to alleviate pain and promote healing. It may be utilised in several facets of dentistry, as it is beneficial for the treatment of various oral diseases, promotes tissue repair, and lowers inflammation through a number of physiological effects. It increases cell migration, proliferation, and differentiation, hence improving the efficacy of the treatment. The therapeutic effectiveness of PBMT depends on several aspects, including site location, anatomic variance, subject uniqueness, and site clinical condition. To get the optimum outcomes of PBMT, one must have a comprehensive understanding of correct dosage administration. PBMT outcomes have improved as a consequence of dosage-related research. PBMT has not yet been associated with any adverse effects, which further supports its usage in clinical dentistry.

4. Abbreviations

ATP- Adenosine triphosphate, NO- Nitric oxide, ROS- Reactive oxygen species, DH- Dentinal hypersensitivity, DPC- Direct pulp capping, PBM- Photobiomodulation, PBMT- Photobiomodulation therapy, LLLT- Low-level laser therapy, LEB- Light-emitting diodes, MASER- Microwave amplification by stimulated emission of radiation, LASER- Light amplification by the stimulated emission of radiation.

5. Source of Funding

None.

6. Conflicts of interest

There are no conflicts of interest.

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