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Photobiomodulation current concept and its application in dentistry

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Abstract

Light therapies are widely used in various clinical therapeutics which includes photodynamic therapy to kill cancer cells; UVA therapies used to treat a variety of skin diseases and Photobiomodulation used for promoting cell growth and recovery from injury using light emitting diodes or low energy lasers, From a clinical perspective, PBM offers dental practitioners a non-invasive and non-thermal treatment modality that can be used as an adjunct to traditional therapies or as a therapeutic tool on its own as patient's acceptance of PBM is incredibly high, in this review we present to you the mechanism of action and clinical applications of Photobiomodulation in various fields of dentistry.

1 Introduction

The use of sunlight in heliotherapy dates as far back as 1400 BC and has been practiced for several centuries in many different countries including ancient Rome, Greece and Egypt. It has been recognized for long that light can affect the growth and metabolism of organisms ranging from simple unicellular microorganism to multicellular plants and mammals and can have a variety of beneficial therapeutic effects.

Photobiomodulation (PBM), also commonly referred to as low level laser therapy (LLLT) or cold laser therapy uses light energy to elicit biological responses from the cell and normalize cell function.

Photobiomodulation uses light to affect the activity of one or more endogenous enzyme photoreceptors, which likely initiate cell-signaling pathways and alter cell and tissue metabolism as well as cell proliferation.

The effective wavelengths for Photobiomodulation are in the far red to near infrared range i.e. b/w 590 – 850 nm. Light in this region of the spectrum can penetrate tissue and at the same time lacks the carcinogenic and mutagenic properties.

Most of the studies report a therapeutic effect in the infrared and the near infrared regions of the electromagnetic spectrum. Even though the tissue is irradiated superficially it is effective in deeper tissue structures making this treatment noninvasive.

2 Mechanism of action

An important first step in understanding this phenomenon has come from the finding that Cytochrome C oxidase, the terminal member of the mitochondrial electron transport chain is a photoreceptor that mediates many, if not all of the beneficial effects of the Photobiomodulation [Karu 1999; Wong Riley et al 2001, karu et al 2004, 2005].

Numerous studies have shown that PBM affects the mitochondria of the cell, primarily Cytochrome c oxidase in the electron transfer chain and porphyrins on the cell membrane. When light photons are absorbed by these receptors, it has been proposed that three things occur:

1) Stimulation of ATP synthesis by activation of the electron transport chain.
2) Transient stimulation of reactive oxygen species, which increases the conversion of ADP to ATP; and a
3) Temporary release of nitric oxide from its binding site on Cytochrome c oxidase, which results in an increase in cell respiration.

The clinical effects of PBM come not only from the direct irradiation of the tissue, but from the secondary and tertiary effects as well. Factors such as an increase in lymphatic flow and circulation; stimulation of fibroblasts, osteoblasts,

odontoblasts and endorphins; reduction of the depolarization of nerve fibres; and modulation of inflammatory chemicals all contribute to the clinical effects seen with PBM.

3 Photobiomodulation and dentistry

Photobiomodulation offers dental practitioners a non-invasive and non-thermal treatment modality that can be used as an adjunct to traditional therapies or as a therapeutic tool on its own.

The use of Low Level Laser Therapy (LLLT) for Photobiomodulation (PBM) in daily general dental practice is a paradigm shift. Applications such as dental analgesia, treatment of dentine hypersensitivity, healing of soft tissue lesions, reduction of pain and swelling after surgical procedures, better integration of implants into bone and faster movement of teeth during orthodontic procedures are commonly performed and thoroughly researched procedures. Patient's acceptance of laser therapy is incredibly high; the beneficial effects of laser therapy can be enhanced by the placebo effect and result in improved clinical outcomes.

Treatment dose is probably the most important variable in PBM. Dose is measured in joules per square centimeter (J/cm^2) and is a measure of the amount of energy that is conducted into the tissue. Clinicians should be aware of the optimal dose for each application to maximize the beneficial effects of laser therapy.

Clinical effects of laser, such as wound healing, pain relief or muscle relaxation, are all sensitive to different irradiances or doses. An example of this is the stimulation of fibroblasts; a dose of 5 J/cm^2 will stimulate the cellular activity of fibroblasts whereas higher doses inhibit cell viability and proliferation. Thus, for wound healing, you want to ideally use lower doses [1].

The bio stimulatory and inhibitory effects of lasers are governed by the Arndt-Schultz Law, which indicates that weak stimuli will increase physiological processes and strong stimuli will inhibit physiological activity. [2]

The importance of this parameter should always be kept in mind when using PBM; if you aren't getting the anticipated response to laser treatment, a clinician should re-evaluate the dose being used to ensure it within the optimal range.

Additionally, treatments may need to be modified over time to ensure you are achieving the ideal effect from the laser dose (pain relief vs. wound healing).

Dental surgeons can utilize PBM in almost every facet of their practice. Any procedure a dental surgeon does, especially extraction of molars, creates an acute inflammatory response that can result in edema, bruising and pain

Studies have demonstrated that PBM in acute pain reduction compare well to standard NSAID treatment, with a better risk-benefit profile. [3]

In many cases, the use of PBM applied after surgery ensures that no post-op pain medications are required and patients can resume their normal day to day activities shortly after surgery. [4]

Laser therapy stimulates lymphatic flow and helps to modulate the immune response, which in turn causes significantly less swelling, bruising and pain. [5]

Healing is also accelerated dramatically by stimulation of fibroblasts and osteoblasts, which produces soft tissue and bone, respectively. [6]

Soft tissue lesions, such as herpes lesions, denture sores, and angular chelitis respond very well to laser irradiation.PBM decreases the pain associated with soft tissue lesions, while stimulating fibroblasts for accelerated healing. Further, it has been clinically observed that laser irradiation of herpes simplex decreases the incidence recurrence of the lesions.

Marei et al examined the effect of laser irradiation on denture sores and noted that PBM decreased the pain caused by denture lesions while accelerating epithelization and vascularization of the lesion. [7]

It is advantageous to treat any soft tissue lesions as acutely as possible, especially during the prodromal stage when treating herpes lesions.

Laser irradiation applied to the lymph nodes and ducts will increase lymphatic flow and stimulate the immune system, bringing neutrophils to the site of infection for faster healing.

It was demonstrated by Lopes et al that laser therapy was effective for treating acute infected processes (pericoronitis, endodontic abscess, and alveolitis). It was also shown that PBM enhanced the lymphatic drainage of the infected area. [8] In cases where an antibiotic is given to deal with an infection, laser therapy will potentiate the uptake of the antibiotic into the system through increased circulation and lymphatic flow.

Oral mucositis is a debilitating and life altering condition that is a side effect of chemotherapy and radiation therapy. Oral mucositis presents as open sores over the soft tissue of the inner mouth, which significantly affects a patient's quality of life and often their treatment regime. Laser therapy has been investigated as a preventative application to mucositis and as a treatment mechanism for healing erupted sores, with incredibly positive results. [9]

A 2006 study by Corti et al demonstrated that PBM accelerated the healing rate of oral mucositis by 117-164% and was able to control inflammation, maintain the mucosa integrity and improved the quality of life cancer patients. [10]

PBM accelerates healing of bone after fractures or orthognathic surgery through the stimulation of osteoblasts.

A 2005 study demonstrated that laser irradiation resulted in an increase in bone neoformation, with better quality bone on the irradiated groups when compared to the control group. [11] Stimulation of fibroblasts and analgesia also make PBM effective in this area.

3.1 TMJ and Facial Pain

When treating TMJ or facial pain, PBM is a great tool to add to your arsenal. From simple and acute cases like facial pain after long appointments to chronic TMJ cases, laser therapy will help reduce pain and inflammation, and significantly resolve muscle trismus. In many TMJ cases, a combination of lasers and clusters of light-emitting diodes (LEDs) are the most effective for treatment.
A 2007 study demonstrated that laser therapy softened overly tense and hard muscles by increasing circulation and removing noxious deposits associated with hypertension of the tissue. The authors postulated that an increase in microcirculatory flow and volume caused muscles to relax and thus normalized the intramuscular pressure on sensory nerve endings. [12]

3.2 Neuropathic Pain

Neurogenic facial pain is a debilitating condition for a patient that results in them living with excruitiating pain or with a continuous dose of prescription analgesics. PBM now permits many patients to live a life free from or with less pain.
A 1996 study investigating the use of PBM in the treatment of trigeminal neuralgia found that patients who received laser treatments had a considerable reduced consumption of analgesics and should be considered as an alternative and/or supplementary treatment to traditional treatment methods. [13]
Following any surgical extraction, the laser is applied into the socket immediately after the surgery for reduction of pain and inflammation and then after suturing for soft tissue healing
Aras and Gungormus studied the effect of PBM on trismus and facial swelling following surgical extraction of the third molar and found that both swelling and trismus were significantly less than in the placebo group on both day2and7.[14].
Further, in a meta-analysis of studies investigating pain within 24hr of surgery, Bjordal et al found that PBM with red and infrared is effective in reducing acute inflammatory pain after molar extraction. [15]
Although PBM will decrease the likelihood of a dry socket by stimulating the endothelial cells in the socket, PBM will significantly decrease the pain and stimulate healing when it does occur.
The effect of laser irradiation on c-fibres, endorphins levels, osteoblasts and odontoblasts make PBM an excellent tool in restorative dentistry.
Laser irradiation promotes a release of endorphins and serotonin; inhibits the conduction of c-fibres, the fibres that carry pulpal pain; and increases oxygenation and lymphatic drainage, which are responsible for pain relief after the first minutes of tissue irradiation. [16, 17, 18]
The laser is applied over the apex of each root for analgesia and again after the tooth has been prepared for reduction of pain and inflammation. Distraction techniques are recommended to help the patient deal with the mental fears or anxiety surrounding the dental appointment. Dental analgesia doesn't seem to be as effective in permanent teeth because of the increased size of the dental pulp; however, it may still be effective for pain relief during crown cementations and decreased sensitivity during scaling appointments.
PBM is effective for reducing pain and inflammation after endodontic treatments, but can also be used as a diagnostic tool for pulp hyperemia.

3.3 Dentin Hypersensitivity

Dentin Hypersensitivity is achieved by first applying the laser to get analgesia, followed by application to the dentin combined with a chemical agent for optimal desensitization. A study by Marsilo et al demonstrated that treatment of dentine hypersensitivity had a success rate of 88.8% when compared to the controls, a statistically significant value. Furthermore, the statistically significant difference between the experimental and control was still evident at 60 days. [19].PBM can effectively decrease pain sensations during the implant placement, help speed the integration of the implant into the bone and improve the quality of the bone around the implant. A study investigating the effect on infrared light on the loading time of dental implants found a significantly greater amount of mature bone, a better distribution of bone and more organization of bone after laser irradiation, when compared to the control group. [20]
Another study examining the effect of laser therapy on bone demonstrated that the laser group had an abbreviated initial inflammatory response and a rapid stimulation of bone matrix formation at 15 and 45 days. [21]
Orthodontic treatments are lengthy and often painful for many patients. PBM stimulates osteoblasts, which results in an increased velocity of tooth movement. It also decreases the inflammation and pain caused from the pressure on the teeth during orthodontic tooth movement.

A 2008 study investigating the effect of laser therapy on orthodontic movement showed that the velocity of canine movement was significantly higher in the laser irradiated group when compared the control group. In addition, the pain intensity was also at a lower level in the lased group throughout the entire retraction period. [22] Histological observations made during another orthodontic study showed that both osteoblasts and osteoclasts remained more active on the lased side which could account for the accelerated movement. [23]

Finally, Yossef et al demonstrated that a single application of PBM demonstrated a significant pain reduction at 6 and 30 hours after banding treatment. [24]

These findings show promise for orthodontic treatments by significantly decreasing the pain associated with the treatments and increasing the velocity of tooth movement.

The use of PBM as a treatment modality in Periodontics is a wonderful fit, both as a treatment method on its own or as an adjunct to the increasingly popular surgical lasers. Laser irradiation stimulates fibroblasts for soft tissue healing, decreases inflammation and results in an immediate and long lasting pain relief. PBM used in conjunction with surgical lasers for treatments such as gingivectomies, periodontitis and periodontal surgery have shown great promise in achieving improved clinical outcomes.

Healing after a gingivectomy is often a lengthy and painful process. PBM has been shown to stimulate fibroblasts for faster regeneration of soft tissue, while providing analgesia and a modulation of the inflammatory chemicals that cause pain and discomfort.

A 2006 study showed a statistically significant decrease in pocket depth at 21 and 28 days post-surgery. Moreover the laser treated wounds presented with factors suggestive of better healing, including color, contour and mucosa healing when compared with controls. [25]

To further exemplify these positive responses, a study by Ozcelik et al demonstrated that PBM enhanced epithelization and improved wound healing after gingivectomy and gingivoplasty operations. [26]

Periodontitis sets in when inflammation of the gingiva damages tissue, which reduces epithelial growth Periodontitis sets in when inflammation of the gingiva damages tissue, which reduces epithelial growth and causes bone resorption. Laser therapy stimulates healing within the pocket and decreases the pain associated with periodontitis.

Kreisler et al investigated the effect of a semiconductor laser on10 periodontal pockets as an adjunct to traditional root planing and scaling and demonstrated that laser-irradiated teeth had a significant decrease in tooth mobility, pocket depth and clinical attachment loss.12% of the laser irradiated group showed an attachment gain of 3mm or more and 24% demonstrated an attachment gain of 2-3mm. [27] Tooth mobility seems to be positively affected by the re-epithelization of the periodontal pockets leading to enhanced connective tissue attachment.

Kojovic et al investigated the therapeutic effects of PBM in periodontal surgery, and observed that the treated group healed in an average time of 5-10 days with an absence of pain, whereas the control group healed in 10-15 days with the presence of pain in duration to several days. [28]

4 Conclusion

Photobiomodulation is an evolving technology with every passing day, more is being discovered about the mechanisms of laser therapy, doses, treatment locations and diseases in which a laser will have an effect. At our hands is a tool that can reduce pain, stimulate wound healing, and modulate the inflammatory response and regenerate nerves. Photobiomodulation can be used effectively in dental specialties to better manage treatments that are often deemed painful by patients. In these fields, there is the potential to see the most definitive results of what Photobiomodulation can do to improve clinical outcomes and patient satisfaction.

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