



PHOTOBIMODULATION IN DENTISTRY - A REVIEW

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ABSTRACT

The scientific field of dentistry is ever welcoming of newer and more advanced tools for problem solving. And when the tool is non-invasive in nature and causes little to no side effects, it only proves to be a bigger asset than it already is. Photobiomodulation is one such tool. Also known as low-level laser (or light) therapy (LLLT), has been known for almost 50 years but still has not gained widespread acceptance, largely due to uncertainty about the molecular, cellular, and tissular mechanisms of action. However, in recent years, much knowledge has been gained in this area. It is the application of red and near infra-red light over the tissues to reduce inflammation, give relief for both acute and chronic pain and is also known to improve soft tissue healing among its many other applications.

KEYWORDS : Photobiomodulation ; LLLT ; Laser ; Non-invasive

INTRODUCTION AND HISTORY

LLLT was discovered in 1967 by Endre Mester at the Semmelweis Medical University in Hungary. Mester was trying to repeat an experiment first conducted by Paul McGuff in Boston USA, who had successfully used the newly discovered ruby laser to cure malignant tumors in rats.

However, Mester's custom-made ruby laser possessed only a very small fraction of the power possessed by McGuff's laser. Despite not curing any tumors with his low-power laser beam, he did observe a heightened rate of hair growth and better wound healing in the rats in which he had surgically implanted tumors. This was the first indication that low-level laser light (rather than high power thermal lasers) could have its own beneficial applications in medicine^[14]

Subsequently, thousands of clinical and laboratory studies have been conducted to describe physiological function as well as clinical effects of Low-Level Laser Therapy (LLLT)^[11]



**Professor Endre Mester, MD, DSc
(1903-1984)**

Figure 1: Father of photobiomodulation^[11]

Definition And Terminology

In accordance with the definition of the North American Association of Laser, LLLT is "Nonthermal laser light application using photons (light energy) from visible and infrared spectrum for tissue healing and pain reduction."^[4]

It was found that in addition to lasers as coherent radiation, non-coherent radiations such as Light-Emitting Diodes (LEDs) also have biostimulatory properties, and hence the term "low-dose light therapies" was used for this group of treatments.

Today, the term "Photobiomodulation" (PBM), provides a more

accurate interpretation of low-power treatments, because it includes a wide range of electromagnetic wavelengths such as broadband lights, LEDs, and lasers^[2,3]

Older Terminology

PBM lasers have also been called Low Level Lasers (LLL); Cold Lasers; Therapeutic Lasers, and Soft Lasers^[7]

Mechanism Of Action

Among the remarkably broad biological responses noted with PBM therapy, its effects on mitigating pain, inflammation, and aberrant immune responses as well as promoting tissue healing and regeneration have been well documented. These responses appear to be mediated through discrete photobiological targets located intracellular (mitochondria), on the cell membrane and in the extracellular milieu^[5]

Primary Process:

The first law of photochemistry (and photophysics) states that light must be absorbed for photochemistry (or photophysics) to occur. This is a simple concept, but it is the basis for performing photobiological experiments correctly^[6]

The biosystem is very complicated, but it can be studied at cellular level. The primary process of cellular PBM of LI is the interaction of LI with cellular molecules^[6]

The wavelength range between 700 and 780 nm has been found to be rather ineffective as it coincides with a trough in the absorption spectrum of cytochrome c oxidase (Cox). Moreover red/NIR light is chosen because its penetration through tissue is maximal in this wavelength range, due to lower scattering and absorption by tissue chromophores^[15]

It is known that if the incorrect parameters are applied, the treatment is likely to be ineffective. There is a biphasic dose response curve (or the phenomenon known as hormesis) in which when too low or too high doses (fluence (J/cm²), irradiance (mW/cm²), delivery time, or number of repetitions) can lead to no significant effect or, sometimes, excessive light delivery can lead to unwanted inhibitory effects.

This biphasic response follows the "Arndt-Schulz Law" (which states that weak stimuli slightly accelerate vital activity, stronger stimuli raise it further until a peak is reached, whereas even stronger stimuli suppress it until a negative response is achieved), and has been demonstrated several times in low level light works^[15]

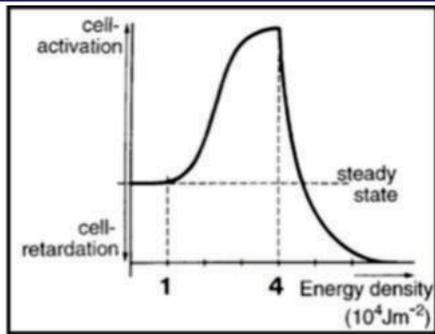


Figure 2: Arndt-Schultz Curve^[16]

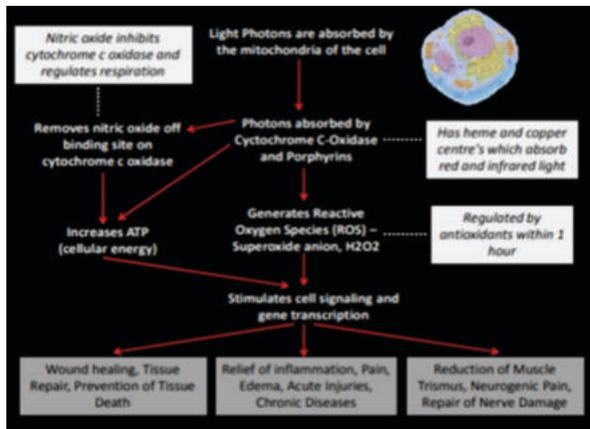


Figure 3: Summary of the primary mechanism of photobiomodulation^[16]

It has been postulated that photostimulation induces athermal photochemical reactions that alter the pain threshold of nociceptors. Evidence abounds that phototherapy modulates inflammation by reducing prostaglandin E2 concentrations, inhibiting cyclooxygenase 2 and reducing tumor necrosis factor alpha. It has also been shown that phototherapy enhances the release of endorphins. it enhances local hemodynamics, thus aiding the removal of pain-causing substances from the site of lesion. Yet, another mechanism relates to its capacity to increase cellular oxygenation and mitochondrial adenosine triphosphate but how this mediates pain remains unclear. The exact mechanisms by which phototherapy relieves pain continue to evolve^[18]

The mechanism by which PBM achieves this effect for pain relief and in anaesthesia has been somewhat unraveled by experiments on individual neurons as shown by Chow et al. In these studies, cultures of dissociated DRG neurons were exposed to PBM and examined by real-time confocal microscopy and demonstrated morphological changes including significantly decreased MMPs, indicating decreased ATP level, disruption of axonal microtubule b-tubulin polymerization. The confocal studies also showed significant decrease of movement and clustering of the mitochondrial along the axonal microtubules^[17]

PBMT parameters

The light parameters and the doses applied are fundamental in PBM. The most important parameters regarding the light source and the light doses are described on the following tables

Table 1: Irradiation parameters [15]

IRRADIATION PARAMETERS		
Irradiation Parameter	Measurement unit	Description
Wavelength	nm	Light is an electromagnetic form of energy with a wave-like behavior. Its wavelength is measured in nanometers (nm), and it is visible within the 400-700 nm range.
Intensity	W cm ⁻²	It can also be called Power Density or Intensity, and corresponds to the power (in W) divided by the area (in cm ²).
Pulse Structure	Pulse Power (W) Pulse frequency (Hz) Pulse width (s) Duty cycle (%)	If the beam is pulsed, the Power should be called Average Power, which is calculated as follows: Average Power (W) = Peak Power (W) x pulse width (s) x pulse frequency (Hz)
Coherence	Coherence length depends on spectral bandwidth.	Coherent light produces laser speckle, which is believed to play an important role on photobiomodulation interaction with cells and organelles.
Polarization	Linear polarized or circular polarized	Polarized light is known to have its polarity in highly scattering media such as biological tissues, therefore this property is not considered very often on the effects of PBM.

Table 2 : Light dose parameters^[15]

LIGHT DOSE PARAMETERS		
Irradiation Parameter	Measurement unit	Description
Energy	Joules (J)	It cannot be measured, as dose, as it assumes reciprocity (the inverse relationship between power and time). It is calculated as:
Energy Density	Energy (J) = Power (W) x Time (s) J cm ⁻²	This is a important descriptor of dose, but it could be unreliable when we consider that it assumes a reciprocity relationship between irradiance and time.
Irradiation Time	s	Possibly the best way to prescribe and to record PBM would be to define the four parameters of Table 1 and then define the irradiation time as the real "dose".
Treatment Interval	Hours, days or weeks	Different time intervals may result in different outcomes, but more data need to be gathered in order to define the extent of the differences between them.

Scope Of Photobiomodulation In Dentistry

Endodontic Therapy:

Endodontic procedures LLLT can assist with endodontic procedures by reducing postoperative pain and swelling, eliminating the need for analgesics, and reducing pulp hyperemia. Following root canal treatment, a high dose (8–16 J/cm²) is applied at the apex of each root to reduce postoperative pain and modulate the inflammatory response^[8]

Dental Surgery :

Following extractions as well as bone surgery, LLLT can be used to effectively eliminate postoperative pain, stimulate lymphatic flow, which effectively reduces edema, modulate inflammation, and stimulate osteoblasts^[9,10] Pain is the primary concern immediately following dental surgery; therefore, a high dose (8–16 J/cm²) is used immediately and preferably directly into the socket. In cases in which a soft tissue flap is involved in the procedure, a low dose (2–4 J/cm²) is applied after suturing to stimulate the fibroblasts and obtain faster wound healing.^[11]

Soft Tissue Lesion:

Soft tissue lesions Using laser therapy for soft tissue lesions (herpes simplex, aphthous ulcers, and, most dramatically, oral mucositis) can reduce pain and speed tissue healing. The lymphatic system is treated first, followed by the direct application to the lesion in a noncontact mode. Pain relief is almost instantaneous, and healing is dramatically improved. A study by Munoz Sanchez et al. recently showed the laser irradiation can, in some cases, prevent lesion eruption when applied at the prodromal (tingling) stage as well as causing a decrease the recurrence of lesion outbreaks.^[12]

Kalhari et al. found that PBM therapy had a therapeutic benefit in treatment of various oral diseases such as oral lichen planus, recurrent aphthous stomatitis, hyposalivation, pemphigus vulgaris, recurrent herpes simplex, burning mouth syndrome, medication-related osteonecrosis of the jaw, trigeminal neuralgia, facial nerve paralysis, geographic tongue, and chronic sinusitis among others.^[5]

Restorative Procedures:

Laser therapy has been shown to reduce the conduction of nerve fibers. C fibers, which carry pain sensations from the dental pulp, have a very thin myelin sheath and respond to light very dramatically^[13]

Clinically, laser irradiation applied at a higher dose (8–16 J/cm²) can provide significant pulpal analgesia, which allows for a number of dental procedures to be performed without the need for "freezing."

CONCLUSION

Photobiomodulation continues to prove to be an incredible asset to a dental practice.

It strives to utilize a more sophisticated mechanism to eliminate the patients' fear to a visit to the dentist, and subsequently gone will be the days when patients would leave the office wincing in pain. With laser therapy as a prominent tool in practice, clinicians will be able to provide a higher level of care, with reduced stress for both the patient and the doctor^[8]

And it is an understanding over many studies that the primary process of cellular PBM might be the key process of cellular PBM.^[6]

Harnessing its potential with a sound understanding of its molecular interactions has and will further give way to a whole new perspective to non-invasive practice

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