Photobiomodulation: An Invaluable Tool for All Dental Specialties

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J Laser Dent 2009;17(3):117-124

INTRODUCTION

Although low-level lasers are being used successfully in many dental clinics, the wide range of applications is still largely unknown to many practitioners, especially dental specialists. In these fields, there is the potential to see the most definitive results of what laser therapy can do to improve clinical outcomes and patient satisfaction.

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. 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.\(^1\)\(^2\) It has been proposed that when light photons are absorbed by these receptors, three events occur: stimulation of adenosine triphosphate (ATP) synthesis by activation of the electron transport chain; transient stimulation of reactive oxygen species, which increases the conversion of adenosine diphosphate (ADP) to ATP; and a temporary release of nitric oxide from its binding site on cytochrome-c oxidase. These factors contribute to the clinical effects seen with PBM, including tissue repair, relief of inflammation and pain, and repair of nerve damage.\(^3\)

Figure 1 depicts a flowchart showing these interactions.

Studies have documented beneficial effects of PBM, such as stimulation of fibroblasts and osteoblasts, as well a reduction of the depolarization of nerve fibers.\(^4\)\(^5\) From a clinical perspective, PBM offers dental practitioners a noninvasive and nonthermal treatment modality that can be used as an adjunct to traditional therapies or as a therapeutic tool on its own.\(^6\)

Examples of these clinical applications, which will be discussed below, include dental analgesia, treatment of dentin 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.

Determining the Appropriate Dose

Treatment dose is probably the most important variable in laser treatment. 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. Clinical effects of the 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.\(^7\) Thus, for wound healing, the clinician should ideally use a dose lower than 5 J/cm\(^2\).

The biostimulatory 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. A therapeutic window, which includes both biostimulatory and bioinhibitory effects, is evident and is the intended target for PBM treatments. A depiction of the law, based on Baxter,\(^8\) is shown in Figure 2.

Figure 1: Summary of the primary mechanisms of photobiomodulation
The importance of dose should always be kept in mind when using PBM; if the clinician is not achieving the anticipated response to laser treatment, the dose should be re-evaluated to ensure it is within the optimal range. Additionally, treatments may need to be modified over time to ensure the practitioner is achieving the ideal effect from the laser dose (pain relief vs. wound healing).

**Acute vs. Chronic Pain**

Treatment dose and duration will largely be governed by the status of the injury. PBM can effectively speed the resolution of acute inflammation and pain, conditions that should be treated frequently (daily). The reverse applies to chronic pain; treatments should be done using lower doses over a longer period of time (e.g., treat 2 to 3 times per week for 3 to 4 weeks).

**CLINICAL APPLICATIONS OF PHOTOBIO MODULATION IN DENTAL SPECIALTIES**

**Oral Surgery**

Dental surgeons can utilize PBM in almost every facet of their practice. Many procedures a dental surgeon performs, especially extraction of molars, create an acute inflammatory response that can result in edema, bruising, and pain. Currently, the primary method of dealing with the pain and discomfort of the surgical procedures is prescription of pain analgesics, many of which carry side effects or decreased mental alertness. Studies have demonstrated that PBM in acute pain reduction compares well to standard nonsteroidal anti-inflammatory drug (NSAID) treatment, with a better risk-benefit profile. Healing is also accelerated by stimulation of fibroblasts and osteoblasts, which produce soft tissue and bone, respectively, as noted in an animal study conducted by Gerbi et al.11

**Dry Socket**

Tunér and Hode describe the benefits of PBM in helping to prevent alveolitis after a tooth extraction.14 The following case study illustrates PBM treatment for a painful ‘dry socket.’

**Oral Mucositis**

Oral mucositis, presenting as an open sore over the oral soft tissue, is a life-altering condition that is a side effect of chemotherapy and radiation therapy. Laser therapy has been investigated as a preventative application to mucositis and as a treatment modality for healing erupted sores, with positive results.15 A 2006 study by Corti et al., using a light-emitting diode device with an emission of 645 ± 15 nm, demonstrated that PBM accelerated the healing rate of oral mucositis by 117% to 164%.16

Often, oral mucositis can be so debilitating for patients that they cannot continue their cancer treatments, so a tool that can treat or

**Figure 2: Arndt-Schultz curve.** The horizontal axis depicts an increasingly higher dose from left to right, and indicates that biostimulation occurs with relatively smaller doses when compared to the higher doses that cause bioinhibition.

**Figure 3: Application of low-level laser energy into the socket immediately following extraction.**
prevent the sores will have considerable clinical importance. Consultation with the oncologist should always be done prior to commencing laser treatments.

Fractures and Orthognathic Surgery
PBM accelerates healing of bone after fractures or orthognathic surgery through the stimulation of osteoblasts. A 2005 study in rats 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, who received no radiation.\(^{11}\)

Soft Tissue Lesions
Soft tissue lesions, such as herpes simplex, denture sores, and angular cheilitis respond positively to low-level laser irradiation. Schindl and Neumann investigated the effect of LLLT on recurrent herpes simplex and demonstrated that 10 daily irradiations significantly lowered the incidence of local recurrence and is a beneficial treatment alternative to commonly used drugs such as acyclovir and famciclovir.\(^{17}\) Further, the author has clinically observed that laser irradiation of herpes simplex decreases the incidence of lesion recurrence. Marei et al. examined the effect of laser irradiation on denture sores and noted that LLLT eased the pain caused by denture lesions, while at 4 weeks post-treatment the laser-irradiated areas showed clinically superior healing, and histological epithelialization and vascularization of the lesion.\(^{16}\) Tunér and Hode report successful treatment of angular cheilitis with PBM, but warn of its recurrence if the fundamental cause is not dealt with.\(^{19}\) It is advantageous to treat any soft tissue lesion in its most acute stage. For example, herpetic lesions are most susceptible to LLLT during their prodromal stage. Figure 4 demonstrates the treatment of a lesion on the lip using an 830-nm PBM device.

Dental Infections
For infections and edema, PBM has been reported to dilate lymphatic vessels and reduce the permeability of blood vessels.\(^{20}\) Figure 5 demonstrates the application to the lymph nodes using a PBM device.

Primary Tooth Restorations
A variety of factors contribute to the analgesic effect produced by PBM which allows dental practitioners to perform many primary tooth restorations without anesthesia. Small animal studies show that laser irradiation promotes a release of endorphins and serotonin; inhibits the conduction of C fibers, the fibers that carry pulpal pain; and increases oxygenation and lymphatic drainage, which are responsible for pain relief after the first minutes of tissue irradiation.\(^{6, 21-22}\)

CASE STUDY: ORAL MUCOSITIS
Treating Dentist: Dr. Gerald Ross
A 61-year-old female patient undergoing chemotherapy for terminal cancer presented with numerous sores over the inside of her mouth. The patient could not eat, drink, or swallow without extreme pain. Treatments (mouth rinses) assigned by the oncologist had no effect on healing of the sores. A visible red laser (660 nm) was applied intraorally overlapping throughout the mouth for 2 days in a row. When the patient came in on the second day, the pain was markedly decreased and she was able to eat soup. By the fourth day, she was able to eat normally. The patient passed away in the following month but no sores returned during that time.

NOTE: Prior to laser treatment, the dentist contacted the oncologist who was willing to try any treatment that could work on the mucositis.

CASE STUDY: DRY SOCKET
Treating Dentist: Dr. Gerald Ross
A 45-year-old male patient had a lower first molar extracted. During the postoperative instructions, the patient (a smoker) was advised to avoid smoking cigarettes for a minimum of 2 days. The patient presented the following day with dry socket and admitted to smoking the previous evening. An 830-nm PBM device was used. The intraoral light guide was placed in the socket and the socket was irradiated until pain relief was felt by patient (in this case 48 J/cm\(^2\) of energy was applied before the patient started to experience a reduction in discomfort). A dressing was placed into the socket and the patient was sent home without any pain medications. The patient returned the next day for a dressing change and the laser was applied into the socket using 4 J/cm\(^2\) before application of the new dressing for stimulation of the epithelium in the socket. The patient did not require any additional treatments and the area healed in 7 days.
Laser irradiation is applied to the apex of each root for analgesia and again after the tooth has been prepared for reduction of pain and inflammation, as shown in Figure 6. Distraction techniques are recommended to help the patient deal with the mental fears or anxiety surrounding the dental appointment. Dental analgesia does not seem to be as effective in permanent teeth because of the increased size and sensitivity of the dental pulp; however, it has been shown clinically to be effective for pain relief during crown cementations and decreased sensitivity during scaling appointments.

**Nausea and Gagging**

Application of the laser to the P6 (Pericard 6) acupuncture point on the wrist can decrease or eliminate the nausea and gagging some patients feel during impression-taking or X-ray procedures. As shown in Figure 7, the P6 is located on the underside of the wrist, approximately 1 inch from the distal palmar crease (approximately the width of the distal thumb phalanx). For patients who are extremely nauseous or anxious, application to three acupuncture points in the wrist can be effective; H7, LU9, and P6 are the parasympathetic calming points and stimulation of these points can be very effective in reducing anxiety.

A 1998 report in the *British Journal of Anaesthesia* investigated the effectiveness of laser irradiation to the P6 acupuncture point on post-operative vomiting. In the laser stimulation group, the incidence of vomiting was significantly lower (25%) than in the placebo group (85%), and the patients were quite receptive to the painless procedure.

**Uptake and Elimination of Anesthesia**

Based on the mechanisms of PBM therapy’s ability to increase blood circulation, the author has found that there is an increase in uptake and elimination of anesthesia. PBM is applied to the submandibular lymph nodes and the site of injection after the injection and upon completion of the dental appointment, for uptake and elimination, respectively.

**Implant Placement**

Three papers indicate that PBM can reduce inflammation following implant placement, help speed the integration of the implant into the bone, and improve the quality of the bone around the implant. A study using rabbits utilized Raman spectroscopy and electronic microscopy to investigate the effect of infrared light on the loading time of dental implants, and 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 that received no laser irradiation.

Another study used rats to examine the effect of laser therapy on bone and demonstrated that the laser group had an abbreviated initial inflammatory response and a rapid stimulation of bone matrix formation at 15 and 45 days. An earlier rabbit study showed that bone healing is improved and those authors concluded that it is possible to reduce the loading time of implants in the mandible of humans from 4 months to approximately 2 months and 24 days, and in the maxilla, from 6 months to 4 months and 6 days.

**Orthodontics**

Orthodontic treatments are lengthy and often painful for many patients. As mentioned previously, Gerbi *et al.* have shown that PBM irradiation on bone increases osteoblastic proliferation, collagen deposition
and bone neoformation when compared to non-irradiated bone.11

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 teeth compared to teeth that received no irradiation. In addition, the pain intensity was also at a lower level in the lased group throughout the entire retraction period.28 Histological observations made during another study on rabbits showed that both osteoblasts and osteoclasts remained more active on the lased side which could account for the accelerated movement.29 Finally, Turnhani et al. showed that a single application of LLLT reduced the pain at 6 and 30 hours after banding treatment.30

**Periodontics**
The use of PBM as a treatment modality in periodontics is effective, either as a treatment method on its own or as an adjunct to the increasingly popular surgical lasers. A recent study investigated the gingival inflammatory response and dental plaque reduction following scaling and root planing combined with PBM in 60 patients. The authors found a significant decrease in the clinical indices (plaque, gingival, and sulcular bleeding), which they thought could be beneficial in the treatment of chronic advanced periodontitis.31

**Periodontal Surgery**
Healing after periodontal surgery 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 non-laser treated area, which served as a control.32

**Endodontics**
PBM is effective for reducing pain and inflammation after endodontic treatments, for dentin hypersensitivity, and as a diagnostic tool for pulp hyperemia.34

**Laser Therapy as a Diagnostic Tool**
Occasionally, a patient will present to a dental practitioner with excessive tooth pain, the source of which cannot be accurately identified. Traditional diagnostic methods such as thermal or electrical stimuli often do not show any indication of the problem, making the diagnosis and treatment stressful for both the patient and the doctor. As stated previously, PBM irradiation increases circulation, thus a patient with a hyperemic pulp will feel a sharp pain when the laser is applied to a tooth.35 Figure 9 shows a diagnostic outline that could be used in endodontics.

**Dentin Hypersensitivity**
A study by Marsilio et al. demonstrated that LLLT treatment of dentin hypersensitivity in two different groups of patients was effective for 86% to 88% of all the participants.36 Another study compared LLLT to topical fluoride varnish application for treatment of dentinal hypersensitivity and found that 86% of the laser irradiation group achieved absence of pain compared to 27% of the fluoride group.37

Figure 8: LLLT irradiation after flap surgery

Figure 9: Flowchart for endodontic diagnosis
**TMJ and Facial Pain**

When treating temporomandibular joint (TMJ) or facial pain, PBM is a useful tool to add to the therapeutic arsenal. From simple 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 a systematic review of postoperative pain relief in patients after undergoing third molar extraction, a PBM irradiation was shown to be beneficial in reducing acute inflammatory pain. In a clinical study of 74 patients complaining of TMJ pain, 64% were pain-free or had improvement in comfort after 12 PBM sessions over a six-week period. Pinheiro and colleagues analyzed the effect of PBM on maxillofacial disorders by irradiating 141 female and 24 male patients twice a week for 6 weeks. At the end of the treatment 72% of patients were asymptomatic and 15% had improved considerably.

**Neuropathic Pain**

Neuropathic facial pain is a debilitating condition for a patient that results in their living with excruciating pain or with a continuous dose of prescription analgesics. As stated above in the study by Bjordal et al., PBM permits many patients to live a life free from discomfort or with less pain.

**CONCLUSION**

Although PBM has been available to health care professionals since the 1960s, low-level laser therapy did not really begin to gain popularity until the 1980s when controlled and randomized studies began to be published.

In 2007, Karu reported that the effects of PBM are dependent on the initial redox status of a cell. If a cell is damaged, or in a reduced redox state, the cellular response to PBM will be stronger. Conversely, a cell which is at an optimal redox potential will have a weak or absent cellular response to PBM. Thus, cells that are damaged will respond to PBM better than cells that are healthy and functioning normally.

However, there are precautions all laser users should take and areas to avoid treating when using PBM. Specifically, those include avoiding exposure to the thyroid gland, to pregnant women, and to radiation therapy patients. Also important to note is that the laser will be ineffective if the patient has had a steroid injection in the last six months. All laser users should consult their laser manufacturer for any questions regarding contraindications and appropriate treatment doses, as well as for instructions about safety eyewear for everyone within the nominal hazard zone of the beam.

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. Photobiomodulation can be used effectively in dental specialties to better manage treatments that are often deemed painful by patients, without prescribing pharmaceuticals that often have a number of side effects. All healthcare professionals, including dentists and dental specialists, should further investigate photobiomodulation to enhance their clinical treatments and outcomes.

### CASE STUDY: TMJ PAIN

**Treating Dentist: Dr. Gerald Ross**

A 55-year-old patient presented with pain in the left temporomandibular joint and a limited ability to open the mouth. The computed tomography (CT) tomogram (R = right, SMV = submental vertex, L = left) showed degenerative joint disease (osteoarthritis) of the left TMJ with no disc present.

Six applications of the laser were performed over a three-week period, with treatment applications to the joint, joint capsule, and the lateral pterygoid muscle. This treatment resulted in the patient being pain-free for the last two years and with the ability to open the mouth wider.
CLINICAL REVIEW AND CASE REPORTS

CASE STUDY: NEUROPATHIC PAIN

Treating Dentist: Dr. Gerald Ross

A 61-year-old male patient presented with pain and felt it was coming from the lower left molar. The tooth was extracted and the socket healed uneventfully but the pain got worse. At that point, there were no other problems with teeth in that quadrant, however the pain was worsening and the patient was taking Tylenol® No. 3 (30 mg) approximately 4 times per day, every day. Laser irradiation was applied to the trigeminal nerve, the molar site, and the trigeminal ganglion. After 1 application, the patient said he was no longer taking Tylenol No. 3 and took only 2 Advil® at bedtime. Three days later a second application was done to the same site, and the patient reported as pain-free and no longer needing medication. The pain-free status has lasted for three months.

REFERENCES


