

Laser Photobiomodulation in Dentistry

Mohammed Salim Esmail Alhabil*

Dental Manager, Oral Surgeon Specialist, Salamaty Ployclinic, Saudi Arabia

***Corresponding Author:** Mohammed Salim Esmail Alhabil, Dental Manager, Oral Surgeon Specialist, Salamaty Ployclinic, Saudi Arabia.

Received: December 26, 2016; **Published:** January 23, 2017

Introduction

The word "Laser" is abbreviated for "Light Amplification by Stimulated Emission of Radiation". It was described by Maiman (1960) for first time. Generally, lasers consist of large number of individual laser materials and oscillator setups that work in a continuous wave or pulse mode.

The development and application of lasers has led to innovations in therapeutic science. Its vast application in research science has renovated many procedures in medical sciences specially dentistry. One of such examples is use of laser biomodulation in dentistry.

Laser biomodulation is an important tool in therapeutic science and is well used in all surgical procedures. Despite of variable level of use of laser biomodulation in various fields, this technique is well accepted to date. Use of lasers and its applications are dominant especially in treatment of cancers, invasive and non-invasive surgical procedures and dentistry. Laser biomodulations offer amazing and indefinite applications in modern dentistry comprising periodontology, wound healing, pain relief, endodontics and soft tissue treatment.

Generally, laser biomodulation is outstanding application of red and infra red light for treatment of injuries, wounds and lesions to enhance wound and soft tissue healing with reduction of inflammation along with relief of chronic and acute pain. It has been reported that photobiomodulation has a strong impact in terms of healing, increase quality and quick tensile strength of tissue repair with resolution of inflammation and pain.

In dentistry, role of laser biomodulation has strong impact in wound healing and pain relief. In correct intensity and treatment, red and infra red rays reduce oxidative stress and inflammation by improving cell metabolism, thus, strongly influence in wound healing. The safe use of photobiomodulation does not provide any damage or heating effect to any tissue. It is therefore photobiomodulation (LLLT) is being extensively used in dentistry.

However, some dentists say that use of laser in dentistry is much complicated as they don't realize all the terms and parameters of its functions and operations. In order to make clear understanding of laser biomodulation we have presented associated information in a systematic way so that readers will be aware of easy use in procedures.

The current study deals with investigation of some of basic parameters of lasers working in various aspects of dentistry. Use of lasers in dentistry has facilitated patients as well as doctors in managing many intricate situations. In this review, we will analyze some basis of use of lasers, its mechanism of action, advantages and disadvantages and eventually will spot light some of key benefits of lasers in dentistry.

Basics of Laser Biophysics

In order to understand functional dynamics of lasers, let us first study basic components of lasers.

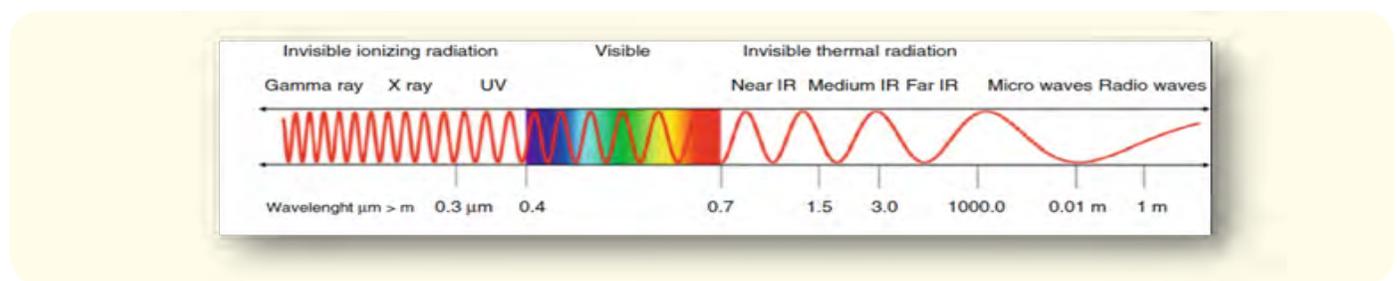
Basic Components of Lasers

There are following important components of lasers:

1. Optical resonator (or optical cavity)
2. Active medium
3. Source of energy (or pumping source)
4. Controller (or microprocessor)
5. Cooling system
6. Delivery system
7. Hand piece and tips

Electromagnetic Spectrum of Light

Laser can be observed in various spectrums e.g. ultraviolet spectrum, visible spectrum, near-infrared spectrum, mid-wavelength infra-red spectrum and in far-infrared spectrum (Figure 1).



Laser Classification with respect to wavelength position on the electromagnetic spectrum of light

On the basis of wavelength position on the electromagnetic spectrum of light, it can be divided into Ultraviolet, visible, near infra red, medium infra red and Far-infra red (Table 1).

Ultraviolet	Visible	Near Infra red	Medium Infra Red	Far Infra red
Excimer 308 nm	Blue Diode 445 nm Argon Blu 470-488nm Green 514 nm	Diode 810 nm Diode 940 nm	Er, CR YSGG 2780 nm	CO ₂ 9300 nm CO ₂ 9600 nm CO ₂ 10,600 nm
	Green KTP 532 nm Red Diode 635-675 nm	Diode 970 nm Diode 1064 nm Nd: YAG 1064 nm ND: YAP 1340 nm	ER: YAG 2940 nm	

Table 1: Categorization of lasers with respect to wavelength position on the electromagnetic spectrum of light.

Laser Classification with respect to clinical application

On the basis of clinical application of lasers, it can be divided into following categories:

1. Hard and Soft Tissue laser
2. LLLT
3. Soft Tissue Laser

Further specifications can be seen in Table 2.

Soft Tissue lasers	Hard /Soft Tissue lasers	LLLT	Diagnosis
Diode 445 > 1064 nm	Er, CR-YSGG Er. YAG	Diode 445 > 1064 nm	405 nm 655 nm
Nd: YAG, ND: YAP CO ₂ 10,600 nm	CO ₂ 9300 nm		

Table 2: Categorization of dental lasers according to clinical applications.

Active medium of lasers (used in dentistry)

Different types of lasers use different type of active medium in it. There are three most common active mediums that are being used in dentistry i.e. Gas, Semi-conductor and Solids.

Further specifications regarding type of lasers, wavelengths, hosting medium and doping atom used in different type of lasers are given in Table 3.

Lasers	Medium		Doping Atom	Wavelength (nm)
	Active	Hosting		
Argon	Gas	-	-	488, 514
Carbon dioxide	Gas	-	-	9300, 9600 and 10,600 nm
Diode	Semi conductor	-	-	445, 635 - 810 940 - 980 - 1064
Potassium titanyl phosphate	Solid	YAG Crystal	Neodymium	532
Neodymium - doped yttrium aluminum garnet	Solid	YAP Crystal	Neodymium	1064
Neodymium - doped yttrium aluminum perovskite	Solid	YAP Crystal	Neodymium	1340
Erbium-doped yttrium aluminum garnet	Solid	YAG crystal	Erbium	2940
Erbium -doped yttrium scandium gallium garnet	Solid	YSGG crystal	Erbium and chromium	2780

Table 3: Active medium of lasers most used in dentistry.

Basic Parameters of laser in light emission

It has been documented that following parameters have been recommended in laser light emission.

1. Average power (P) is expressed in Watt = $E (J) \times F (Hz/pps)$
2. Energy (E) is expressed as J
3. Frequency of pulsation (F) is expressed in Hz /pps
4. Power density (Pd) is expressed in W/cm^2
5. Fluence (Fl) is expressed in J/cm^2
6. Peak power (PP) formula is expressed as under
 $W = E (J) \div \text{duration of the single impulse (s)}$

Laser Emission Mode

It has been reported that there are different modes of emission of lasers depending upon free- running or continuous running energy mode.

Continuous Wave (CW) and Gated Mode

In this type of laser emission mode, a laser can give off energy in a continuous mode (cw), with no disruption. Then again, the emission can be instinctively disrupted (i.e. “chopped” or “gated “mode) to gain a better organization of thermal emission.

Free-Running Pulsed Mode

In this type of laser emission mode, a laser can give off energy in free-running pulsed mode (Also called as pulsed mode, for example; an Nd: YAG lasers and erbium family lasers). In this type of lasers each pulse has a start, a peak, and an end, with a progressive rise and ending in the units of time.

Pulse Duration and Pulse Repetition Rate

In order to calculate “Pick power” (PP), and “Pulse repetition rate” and “Peak Power” there are some rules, for instance:

How to find Pick power (PP) of the laser emission

$(W = \text{energy} \div \text{duration of the single impulse})$

How to find Pulse repetition rate

It is the number of pulses emitted in the unit of time (1s)

How to find Peak power (PP)

Peak power (PP) = $W = E (J) \div \text{duration of the single impulse (s)}$

Note:

- i. Power (W) = Energy (J) × Frequency of repetition (pps / Hz).
- ii. Power density (W/cm^2).

Mechanism of Action

General Mechanism of photobiomodulation

The working mechanism of photobiomodulation is just like process of photosynthesis in plants. At right intensity and treatment, red and near infrared light work lessen oxidative stress and boost ATP. This enhances cell metabolism and decrease inflammation. Photobiomodulation effects are biochemical, not thermal and therefore do not cause heating or any damage to living tissue.

Lasers work by adsorption, activation of the respiratory chain and stimulation that eventually results into physiological changes at cellular level. There are following steps that define working mechanism of lasers.

Absorption: In adsorption, visible red and near-infrared wavelengths in photoreceptors within cellular components stimulate the electron transport chain inside the membranes of mitochondria (a respiratory components) that results in stimulation and activation of respiratory chain.

Activation of the respiratory chain: As a result of adsorption and visible red and near-infrared wavelengths in photoreceptors, activation of respiratory chain and oxidation of the NADH pool takes place.

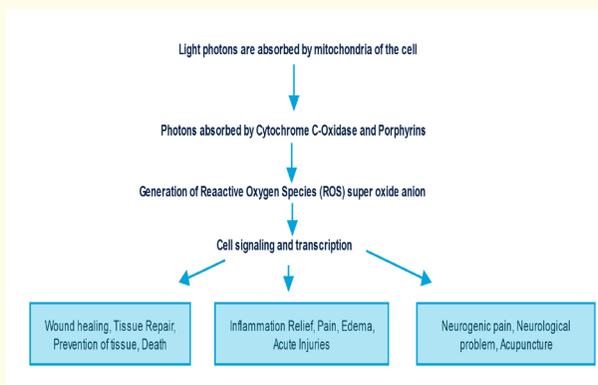
Cellular changes: At cellular level, oxidative phosphorylation give rise to alteration in the redox status of mitochondria and cytoplasm of the cell.

Physiological changes at cellular level

Following physiological changes at cellular level takes place.

- a) Enhanced level of promotive force to cell
- b) Enhanced supply of ATP
- c) Enhanced level of electrical potential of mitochondria, alkalization of the cytoplasm and activation of nucleic acid synthesis
- d) Activation and stimulation of nucleic acid synthesis
- e) Increased respiratory process at cellular level enhances electrophysiological properties of the cell.

Flow Chart of Cellular effects of Photobiomodulation during wound healing



Cellular effects during wound healing

Vasodilative effect of Photobiomodulation

Photobiomodulation cause vasodilatation and enhances local blood flow and it is used for treatment of cases of joint inflammation.

Smooth Muscles Relaxation

Photobiomodulation causes relaxation of smooth muscles associated with cellular endothelium. Therefore, vasodilatation enhances oxygen supply intake and allows better passage of highly immune cells in the tissue.

Mechanism of Wound Healing

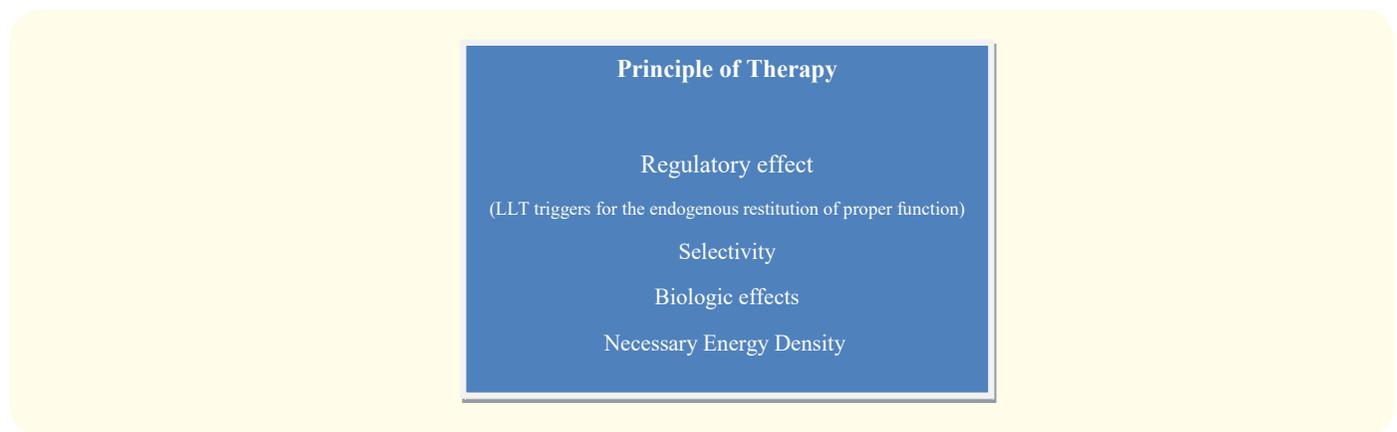
Mechanism of wound healing is best explained by involvement of macrophages, lymphocytes, epithelial cells, endothelium and neural tissues. The possible mechanism involved in the whole process is given as under (Table 4).

Fibroblasts:	Proliferation Maturation, Locomotion, Transformation into Myofibroblasts, Reduced secretion of PG E2 and IL-1, Enhanced secretions of bFGF
Macrophages:	Secretion of fibroblasts growth factors, Fibrin resorption
Lymphocytes	Activation and Enhanced Proliferation
Epithelial Cells:	Mortality
Endothelium:	Increased granulation tissue, Relaxation of vascular smooth muscles
Neural Tissue	Reduced synthesis of inflammatory mediators

Table 4: Acceleration of wound healing by LLLT (Possible Mechanism).

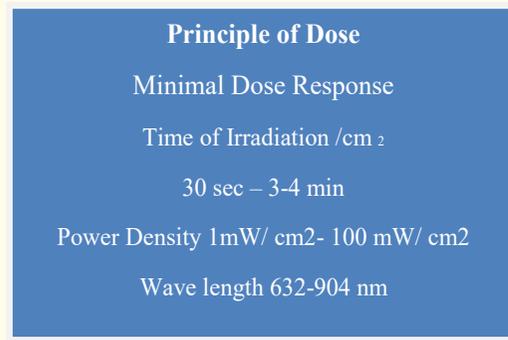
Principle of Therapy

Principle of therapy by photo modulation involves regulatory effect, selectivity, biological effects and necessary energy density.



Dosage Principles

The dosage principle with respect to photobiomodulation involves following specification.



Factors affecting Efficacy of Photo modulation

There are different factors that contribute to the efficiency of photo modulation. For example, patient selection factor like use of anesthesia, follow-up length, inclusion (controls), standard clinical presentation, timing of treatment. Some other factors also contribute to the efficiency of photo modulation. This include optical factors like spot size, laser/ LED light source, power and energy density, form of operation, treatment timing and wavelength etc.

Advantages and disadvantages of Photo modulation

It has been reported that there are advantages and disadvantages of photobiomodulation therapy

Advantages include mainly:

- a) Laser power and mode sight can be controlled effectively.
- b) In photobiomodulation, period of application can be elected
- c) It is aseptic and a traumatic as there is no touch system
- d) Photobiomodulation is rapid, painless as well as possesses accurate application
- e) Its treatment period is short and rapid.
- f) In photobiomodulation, analgesic, antiphlogistic in addition to wound healing outcomes occur concurrently
- g) Photobiomodulation has broad spectrum of indications

Whereas disadvantages include mainly:

- In photobiomodulation, sometimes, split devices are essential to get beam on the specified area under treatment.
- In addition, the therapeutic outcomes are hard to manage by objective parameters some times.

Indications and Contraindications

Photobiomodulation is indicated and contraindicated in many cases. Indications are as under;

Indications

Photobiomodulation is indicated in:

Traumatological and postoperative conditions:

- a) In case of wound healing difficulty
- b) In case of Contusion Post implantation
- c) Cases of Hematoma
- d) Cases of Superficial anesthesia
- e) Cases of Post extraction

Diseases of the jaw joint

- a) In case of Trismus
- b) Cases of Arthrosis temperomandibularis
- c) In case of Hemarthros
- d) Arthrogeous pain cases
- e) In cases of Hyarthros
- f) In cases of Myogenous pain

Diseases of the nerval structures

- a) In cases of dentalgia
- b) In cases of trigeminal neuralgia
- c) In cases of Iatrogenic neuralgia
- d) In cases of tumor neuralgia

Soft tissue lesions

Inflammatory conditions such as:

- a) Abscess,
- b) Gingivitis,
- c) Periodontitis,
- d) Pericoronitis,
- e) Alveolitis,
- f) Pulpitis,
- g) Granuloma,
- h) Aphthous

Infectious conditions such as:

- a) Herpes labialis,
- b) Candidacies,
- c) Stomatitis
- d) Aphthosa

Other dental indications

- a) In cases of patients with bone regeneration
- b) Photo modulation is recommended in orthodontic treatment to speed up alveolar bone remodeling
- c) Photo modulation promotes wound healing: In such cases postoperative regeneration occurs in 3 stages: Inflammatory stage, proliferative stage and tissue reconstruction stage
- d) Photo modulation is advised in case of tooth hypersensitivity: Change of neuronal transmission
- e) In cases of patients with peri-implantitis
- f) In cases of patients with periodontitis

Contraindications

- a) The most horrible outcome with Photobiomodulation is that not anything happens.
- b) Photobiomodulation is prohibited in case of existence of identified malignancies, as it promotes cell growth.
- c) Photobiomodulation is prohibited in case of pregnancy
- d) Photobiomodulation is prohibited in case of Irradiation over the thyroid gland.

Clinical Use of Photobiomodulation In Dentistry

Clinical use of photobiomodulation (PBM) in dentistry is a recognized fact. Its role is critical in future as well. It is needless to say here that dentistry of current era cannot be discussed without use of PBM. We have shortlisted some significant clinical uses of PBM in dentistry with practical information.

Clinical Uses in treatment of Edema

Photobiomodulation (PBM) has an acknowledged effect on lymph nodes in treatment of edema in many cases. Treatment protocol involves specific irradiation process that must begin with most distal nodes and then move toward the swollen part (By making use of 4 J per node). Repeated irradiations with specific parameters will reduce permeability of the lymph vessels and associated healthy growth will be proliferated.

Photobiomodulation (PBM) and Endodontics

In photobiomodulation (PBM), infrared light can arrive at all apices, and evident red light can achieve further shallow apices throughout the mucosa, to turn out an anti-inflammatory and analgesic outcome. Laser application is a good model of an indication of PBM in endodontics.

As photobiomodulation (PBM) can stimulate bone formation as apical bone most likely can repair earlier following a completed endodontic treatment. In photobiomodulation (PBM) energy required is connected to the profundity of the apex, with a range from 4 - 8 J per apex.

Herpes Simplex Virus

Photobiomodulation (PBM) is an effective treatment method in case of patients infected with a herpes simplex virus type 1. Such patients are typically hesitant to go to dentist. Though, Photobiomodulation (PBM) is a proficient technique of treating such type of infection. Especially when patients are at prodromal stage, heal will occur quickly, or even fade away within no time. However, in acute stage of

HSV-1 infection, recurring treatment is required. At this stage irradiation may only be a single session (2- 6 J) on each blister and almost 4 J to the submandibular lymph nodes on the affected area, according to size and period.

It has been further documented that laser light in contrast to traditional therapeutic measures facilitates more cellular resistance against viral attack, thus provide immune system to respond quickly.

Photobiomodulation (PBM) in cases of Extractions

Photobiomodulation (PBM) has tremendous role in reducing inflammation and pain reduction by stimulating fibroblasts in the wound side-line and osteoblasts in socket. However, in cases of post-extraction failure i.e. dry socket, conventional techniques are used in arrangement with very high doses of PBM to decrease patient distress.

From various researches and reports, it has been confirmed that PBM has valuable role in pain and inflammation reduction after extractions by stimulating the development of fibroblasts and osteoblast.

PBM after Implants

It has been witnessed that single high dose of PBM after implant placement can diminish postoperative pain, swelling, and also conditions of edema may subside. Later on frequent sessions at a lesser dose can arouse stimulation of growth of osteoblasts. It has been documented in various surgical notes that use of PBM at the range 1.5 to 3 J/cm² can enhance activity of cells interactions with an implant, thus enhancing tissue curing and eventual implant achievement (Table 5).

Sr. No	Clinical application of PBM	Dose Rate (J/cm ²)
1	Inflammation	8 to 12
2	PBM after Implants	1.5 to 3
3	Herpes Simplex Virus	2- 6
4	Endodontics	4 - 8
5	Treatment of Edema	4
6	Mucositis	4 to 6
7	Orthodontics	5
8	Paresthesias:	4 to 6
9	Pulpal Protection	2 to 4
10	Sinusitis	4

Table 5: Some Clinical Application of PBM and Recommended Dose Rate.

Treatment of Inflammation cases

Photobiomodulation (PBM) has tremendous role in reducing inflammation and course of the inflammatory process is shortened by using irradiation at appropriate recommended dose. This dose for inflammation reduction is recommended as 8 to 12 J/cm².

Mucositis

Photobiomodulation (PBM) has splendid function in treating mucositis patients (Mucositis is a severe problem after radiation and chemotherapy and patient is not capable to eat properly).

Medicines shown little therapeutic affect in such cases and presently, PBM has a positive outcome in its treatment. PBM can lessen pain and eating problems, therefore also minimizing hospitalization cases. In such cases, recommended dose of irradiation with a red laser is suggested as 4 to 6 J/cm².

Orthodontics

It has been reported that photobiomodulation (PBM) has impressive role in increasing orthodontic movement as well as its pain-reducing outcome. It is suggested that PBM can speed up orthodontic movement at 5.25 J/cm², while a more higher dosage i.e. up to 35 J/cm²) can obstruct movement. So effect at 5 J/cm² has been established clinically.

PBM role in managing Pain

Photobiomodulation (PBM) has promoted modern dentistry that cannot be treated as painful as conventional dentistry rather it has enhanced pain-free side of dentistry by using therapeutic Lasers.

Treatment of Paresthesias

Photobiomodulation (PBM) has been shown to offset the formation of paresthesias and even it has reduced symptoms in old aberration. Therefore, it is suggested that irradiation a particular area in which nerve damage is suspected can overcome the situation. The recommended dose is (infrared laser) 4 to 6 J per point.

Restorative Treatment

Photobiomodulation is used to excite analgesia in a number of situations by lessening the conveyance of nerve fibers and inspiring the fabrication and release of opioids.

Pulpal Protection

It has been reported that PBM is clinically applied after use of the drill. While using PBM, less harm to the odontoblasts and earlier formation of collagen and secondary dentin is observed. The dose rate recommended is 2 to 4 J in cases of indirect and direct pulp capping.

Periodontics

Generally, photobiomodulation (PBM) can be used after surgical intervention. Prolonged periodontal inflammatory course give rises to damage of the periodontal ligament and loss of alveolar bone. Photobiomodulation (PBM) minimizes gingival inflammation and MMP-8 expression whilst treated after scaling and SRP (root planning). At appropriate doage, at least four sessions are required for complete treatment.

Bone Regeneration

Scientific researches and studies have elaborated the stunning effect of PBM on osteocytes and bone marrow cells. Bone -regeneration is an important case that can be affected by PBM. PBM is used during the healing period at the surgical site after suturing is done. It has been reported that repeated irradiation (2-3 times/week for at least 2 weeks) is necessary for a marked outcome.

Dentinal Hypersensitivity

PBM is a valuable treatment in combination with conventional desensitizing agents

Sinusitis

Sinusitis presents a great deal of problem for the patient. PBM laser irradiation with a dose of 4 J (to lymphatics and base of the maxillary sinus) can decrease the edema and sinus pressure.

Wound Healing

Red laser light is taken as ideal for treating patients with wounds. PBM can reduce edema and enhance healing. In addition, infra red lasers can also work well in such cases.

Laser therapy frequently can be used for wounds produced by extended denture margins.

The dentists remove the overextended acrylic flanges to make a pain free condition, since the area is edematous. Laser irradiation reduces tenderness and edematous situation. Excessive grinding can reduce signs may rapidly.

Zoster and Postherpetic Neuralgia

In such cases, red laser is effective but infra red light can also play vital role for postherpetic neuralgia. Generally, this situation is rarely observed by dentists, but whenever they see, they cannot treat it well without PBM as eighth cranial nerve may be affected. Irradiation dose is 4 to 6 J per point on the affected area. PBM has no side effects in contrast to other therapeutic measures in cases of Postherpetic Neuralgia [1-16].

Conclusion

Since first discussion and first practical use of lasers in dentistry, lasers are becoming more attractive devices in general use in common dental treatment or as particular additions to the dental medical kit. Studies and researchers are continued to look into novel laser wavelengths and medical applications as they pertain to dentistry, extending the visualization of laser uses.

The increasing number of dental laser practitioners along with concept of safe, effective and appropriate use of lasers in dentistry will keep on to proceed the application of lasers to valuable use for patient and practitioner equally.

Since the introduction of laser in dentistry a continuous scientific research in the diverse applications of lasers in dental practice has led to many renovations. Diverse type of clinical applications has been observed by use of various lasers. Generally, laser applications are linked with both hard tissue and soft tissue applications, but have boundaries due to cost issues and a prospective for thermal damage to tooth pulp. These limitations are covered by relatively low-cost devices used principally for clinically applications i.e photobiomodulation or low-level laser therapy (LLLT) or 'biostimulation'. Because of comfortable use, high efficiency, particular specificity, and relatively low cost operations, these lasers are advised for a wide assortment of procedures in dental practice. It is therefore photobiomodulation is being used in wide range of non-invasive procedures in dentistry comprising wound healing, sinusitis, dentinal hypersensitivity, pulpal protection, orthodontics and pain management.

With the first dental laser in market in 1980 to now, innovations and renovations are continued along with laser uses in dentistry. It is because wavelength for this first device was selected because it was only known wavelength at that time, not due to the reason that it was the best wavelength. This inquisitiveness and urge pushed the researchers to find the best solution in all dynamics of laser utility. New advances in laser and its clinical applications are in progression as much has to be done in this area.

Photobimodulation has attained particular significance since its discovery and are believed to offer exceptional results in dentistry. While some of its applications remain impractical, a constant attention in this practice has remained to date.

The broad range of applications for the photobiomodulation means that it is now the most extensively used machine in laser dentistry. Further studies are required to explore its extensive novel clinical applications.

Bibliography

1. Abrahamse H. "Photobiomodulation: An Accepted Therapeutic Modality?" *Photomedicine and Laser Surgery* 34.9 (2016): 371-372.
2. Chow R and Armati P. "Photobiomodulation: Implications for Anesthesia and Pain Relief". *Photomedicine and Laser Surgery* 34.12 (2016): 599-609.
3. Convissar R. "Principles and practice of laser dentistry". *St. Louis, Mo.: Mosby Elsevier* (2011).
4. DR M Pandeshwar, *et al.* "Photobiomodulation- Current concept and its application in dentistry". *International Journal of Dental Research* 1.2 (2013).
5. Diakides M., *et al.* "Medical infrared imaging" (2007).
6. Johar K. "Fundamentals of laser dentistry". *New Delhi: Jaypee Brothers Medical Publishers* (2011).
7. Johnson W. "Fundamentals of Operative Dentistry: A Contemporary Approach". *Journal of Prosthodontics* 11.3 (2004): 224-225.
8. Kau C., *et al.* "The effect of photobiomodulation on root resorption during orthodontic treatment". *Clinical, Cosmetic and Investigational Dentistry* 6 (2014): 1-8.
9. Meffert R. "Implants in Clinical Dentistry". *Implant Dentistry* 11.2 (2002): 183.
10. Mester E., *et al.* "The biomedical effects of laser application". *Lasers in Surgery and Medicine* 5.1 (1985): 31-39.
11. Niemz M. "Laser-tissue interactions". *Berlin: Springer* (1996).
12. Pandeshwar P., *et al.* "Photobiomodulation in oral medicine: a review". *Journal of Investigative and Clinical Dentistry* 7.2 (2015): 114-126.
13. Ramalho K., *et al.* "Lasers in Esthetic Dentistry: Soft Tissue Photobiomodulation, Hard Tissue Decontamination, and Ceramics Conditioning". *Case Reports in Dentistry* (2014).
14. Ross G. "Photobiomodulation in Dentistry". *Photomedicine and Laser Surgery* 30.10 (2012): 565-567.
15. Tang E and Arany P. "Photobiomodulation and implants: implications for dentistry". *Journal of Periodontal and Implant Science* 43.6 (2013): 262-268.
16. Turrioni A., *et al.* "Transdentinal Cell Photobiomodulation Using Different Wavelengths". *Operative Dentistry* 40.1 (2015): 102-111.

Volume 7 Issue 3 January 2017

© All rights reserved by Mohammed Salim Esmail Alhabil.