IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 22, Issue 4 Ser.5 (April. 2023), PP 19-27
www.iosrjournals.org

Low Level Laser Therapy in Periodontics

Rasha Usman M[1], S Santhosh Kumar[2], Roshni Ramesh[3], Archana M K[4], Sonia P J[5]

[1]*(Department of Periodontics, Government dental college Trivandrum ,Kerala, India)*
[2]*(Department of Periodontics, Government dental college Trivandrum ,Kerala, India)*
[3]*(Department of Periodontics, Government dental college Trivandrum ,Kerala, India)*
[4]*(Department of Periodontics, Government dental college Trivandrum ,Kerala, India)*
[5]*(Department of Periodontics, Government dental college Trivandrum ,Kerala, India)*

Abstract:
The use of low level lasers have been increasingly advancing in the recent years. Low level laser therapy seems to have promising results in areas like wound healing, pain management, tissue stimulation, cell proliferation, differentiation and control of inflammation. Anti-microbial photodynamic therapy also helps in reducing the bacterial contamination. The future of LLLT depends on the correlation of technological innovations with clinical application.

Key word: *Low level laser, Periodontics, Photobiomodulation, Photodynamic therapy*

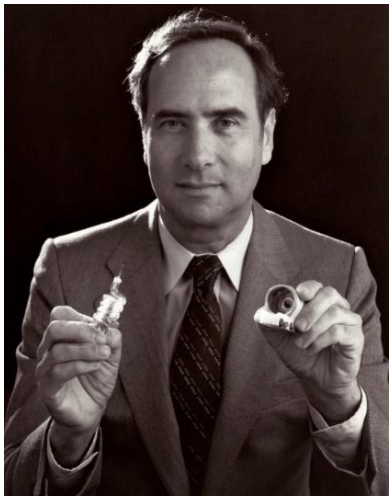
Date of Submission: 03-04-2023 Date of Acceptance: 14-04-2023

I. Introduction

Laser stands for light amplification by stimulated emission of radiation. So, the laser device emits light through the process of optical amplification based on the stimulated emission of electromagnetic radiation. Lasers has been used in dentistry for a number of procedures, most conventional being removal of hard tissues and caries. Later on, in 1990s due to further researches and investigations the spectrum of usage of lasers expanded incorporating antimicrobial photodynamic therapy, low level laser therapy and so on. So, in periodontics it has been employed for both surgical and non-surgical periodontal therapy.

II. History and background

The very initial landmark invention was made when Sir Albert Einstein in 1917 explained the basic quantum mechanics of radiation. Later in 1953 John von Neumann described the concept of first semiconductor laser. Schawlow and Townes[1] invented MASER in 1958. Theodore H Maiman[2] made the landmark invention of first working laser in 1960 in Hughes research laboratory in California. Later on the first gas laser was invented by Ali Javan[3] and William Bennett in 1960. In 1967 professor Endre Mester[4] began using low power lasers in medicine. Initially it was used in the field of ophthalmology. The first medical treatment with laser was performed on a human patient in 1961 by doctor Charles J Campbell[5] at the Columbia-Presbyterian hospital in Manhattan for the treatment of retinal tumour. The first report of laser application in musculoskeletal field was by Mester et al. In 1963 carbon dioxide laser was developed by Chandra Kumar N Patel, later Goldman[6] in 1963-1964 introduced laser into medical field. He also reported the impact of laser beam on dental caries. Bell laboratories in 1964 developed Nd:YAG and carbon dioxide laser that made the use of laser in soft tissue possible. In 1980 Yamamoto[7] and Sato used Nd:YAG laser for dental caries prevention. It was in 1989 when Myers[8] and Myers developed pulsed Nd:YAG laser that made its used in general industry possible.

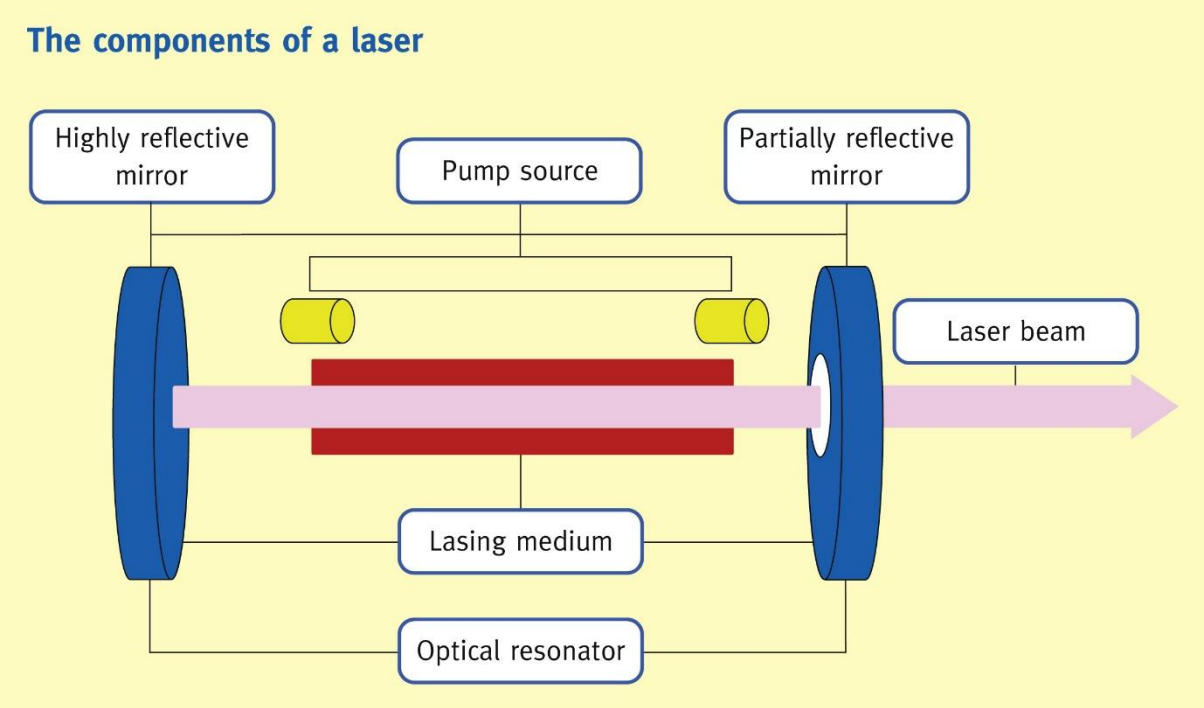


III.Production

Main components of laser device consist of:

- Medium
- Optical chamber or laser tube
- Externally applied energy source
- Optical mirror
- Optical resonator
- Lens to converge light to a focal point

When the energy from external source is applied to the medium the electrons get excited to the higher orbital level. When they return to the normal orbit, they release photons. As all the photons are of the same wavelength it makes a laser beam coherent. Maiman made the first working laser by pumping high amount of energy from a flash tube into a solid-state Ruby medium that produced deep red laser wavelength 694.3 nm.



IV. Properties

- Reflection- the laser beam gets bounced off from the surface of the tissues so there are no interactions with that tissues hence it is totally undesirable
- Absorption- laser beam explodes into the target cells and extracellular matrix it is called **ablation**[9]

- Scattering- when the laser beam is not completely absorbed it get scattered which results in some adjacent thermal reactions like carbonisation, charring etc.
- Transmission- some lasers can get transmitted all the way from the superficial tissues to that of the deepest issues and it can interact with the tissues at the deepest level. Eg-Nd:YAG lasers

Each laser has its own particular wavelength and absorption and interaction characteristics for that specific wavelength. The interaction with the soft tissues and hard tissues will be different for different lasers and care must be taken not to transmit excessive amount of energy to that tissue as it can adversely affect the outcome. Most of the lasers used in periodontics fall in the wavelength of red or infrared category.

Absorption coefficient is the affinity of the laser to the tissues. So, depending on its certain lasers are suitable for hard tissues and soft tissues and some others can be used for either soft tissues or hard tissues. Even the same laser with the same wavelength, the variation in the amount of energy radiated can affect the outcome of the therapy. Energy transmitted by laser is given as photothermal energy, it can be measured either in Watt or Hertz. Energy can be delivered either in a continuous or pulsed mode.

V.Low level laser therapy

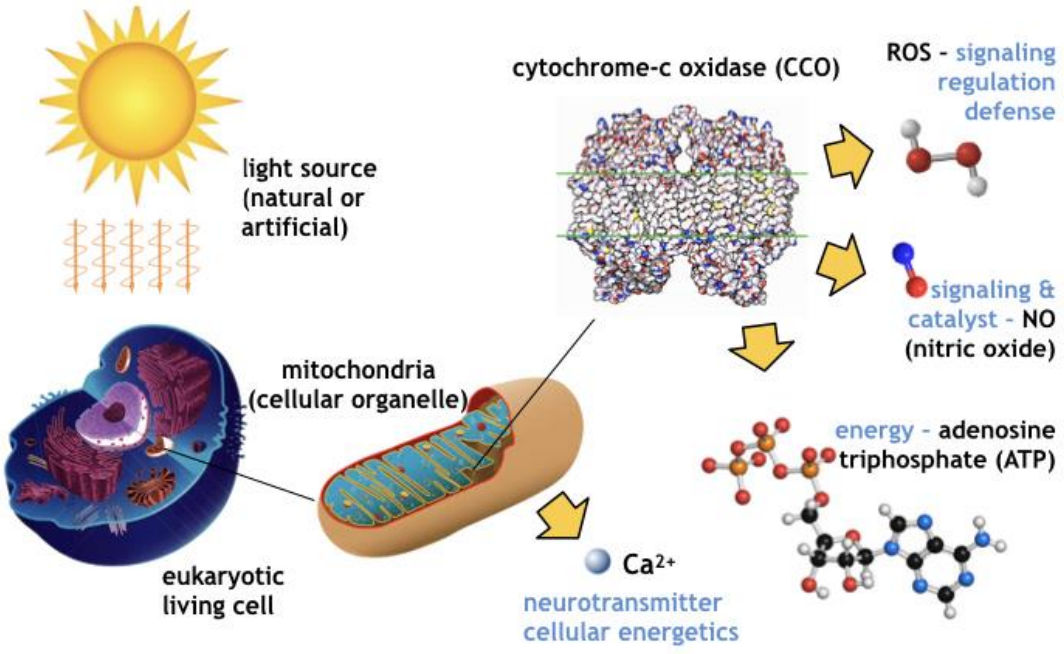
It was recognised later in 1960s that laser had the potential to reduce pain, inflammation, swelling and to improve wound healing[10]. So, it deals with a therapeutic application of laser towards improving wound healing and reduce pain.

- Wavelength used are in the range of 600- 1070 nanometer. Energy density is low as compared to other lasers so it is called as "**low level"**.
- Power ranges from 1 to 1000 milliwatt[10].
- Penetration depth from 3 to 15 mm.
- It has a very low absorption in water

VI.Photobiomodulation

The basic mechanism of low-level laser therapy lies in biostimulation, more precisely **photobiomodulation.** Photobiomodulation is the process in which light is used to control the biological activities of the cell that helps in promoting analgesia and Anti-inflammatory properties and aid in wound healing.

- It is used in a power of $1mW/cm^2$ to $1000mW/cm^2$.
- Time : 2 minute 30 seconds to 3 - 4 minutes
- Wavelength 632-904 nanometers.



VII.Molecular mechanisms of photobiomodulation

- **Chromophores**

✓ Cytochrome oxidase
✓ Retrograde mitochondrial signalling
✓ Light sensitive ion channels
✓ Direct cell free light mediated effect on molecules

- **Signalling molecules**

✓ ATP
✓ c-AMP
✓ Reactive oxygen species
✓ Calcium
✓ NO

- **Activation of transcription factors**

✓ NF-kB
✓ RANKL
✓ Hypoxia inducible factor 1 alpha
✓ Beta catenin pathway
✓ Cyclin D 1 pathway
✓ Extra cellular signal regulated kinase
✓ PPAR
✓ RUNX-2

- **Effector molecules**

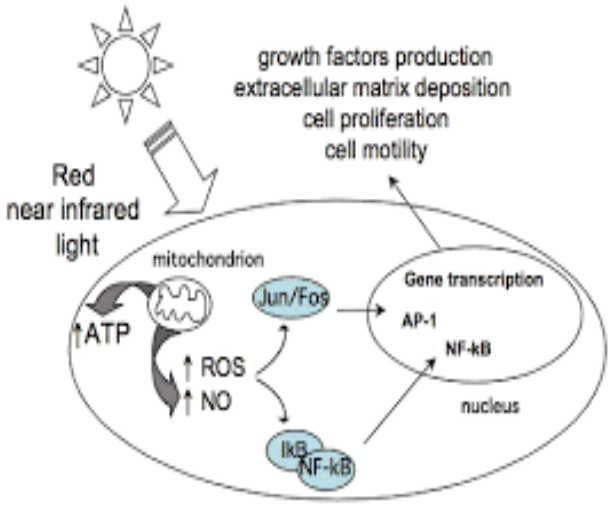
✓ TGF- beta
✓ Oxidative stress
✓ Pro and anti-inflammatory cytokines
✓ Brain derived neurotropic factor(BDNF)
✓ VEGF
✓ Hepatocyte growth factor
✓ Basic FGF
✓ Heat shock protein

- **Cellular mechanisms**

✓ Inflammation
✓ Cytoprotection
✓ Proliferation
✓ Migration
✓ Protein synthesis
✓ Stem cells

- **Tissue mechanisms**

✓ Muscles – increases creatine kinase
✓ Brain – cognitive benefits and memory enhancement
✓ Nerves -repair and pain reduction
✓ Healing – bones, tendons and wounds
✓ Hair – proliferation and differentiation of new follicles



VIII.Mechanism of action

When light falls on cells, it basically stimulates mitochondrion and within mitochondrion it affects cytochrome oxidase and porphyrins. When stimulated, any of the following can happen:

- ✓ It increases electron transport chain, which in turn increases ATP production
- ✓ Increases the production of ROS, which leads to the increased conversion of ADP to ATP.
- ✓ Increased release of NO from cytochrome oxidase, which increases the cellular respiration

Primary events include increase in ATP production, electron transport chain and alteration in mitochondrial membrane potential.

Secondary events include increased circulation and lymphatic flow, modulation of inflammation and stimulation of formative cells.

In turn both these primary and secondary events lead to increased nucleic acid production, cell's promotive force, ATP production and mitochondrial membrane potential. So, it improves the electro-physiological properties of cells

Effects of photobiomodulation

- ✓ Stimulation of mitochondrial activity
- ✓ Effect on angiogenesis
- ✓ Modulation of inflammation
- ✓ Increase in oxygen availability
- ✓ Effect on vasodilatation
- ✓ Improves wound healing
- ✓ Bone regeneration

Mitochondrion

Cytochrome oxidase is the key enzyme of mitochondria and it is the terminal enzyme responsible for the transfer of electrons from cytochrome to oxygen. It has 2 centres:

- ✓ 2 iron centres- heme a and heme a_3
- ✓ 2 copper centres-Cu A and Cu B

Cytochrome oxidase can act as a photoreceptor molecule and can aid in photobiomodulation.

Angiogenesis

It increases vasodilation, vascular endothelial development and angiogenesis[11]. It is contraindicated in heavily vascularised tissues like neoplasms. Studies on angiogenesis was conducted by Dourado et al[11] 2011 and Cury et al 2013[12]. Dourado et al concluded that lower wavelength was more effective than higher wavelength on angiogenesis while Cury et al concluded that lower wavelength was effective only at lower doses while higher wavelength was effective at both higher as well as lower doses.

Modulation of inflammation

It reduces pro-inflammatory mediators and increases anti-inflammatory mediators.

Downregulates :

- ✓ MMP 8

- ✓ PGE2
- ✓ IFN – gamma
- ✓ IL- 1 beta

Upregulates:
- ✓ TGF- beta
- ✓ PDGF
- ✓ FGF

It also reduces the latent collagenase activation and influences both plasminogen and COX-2 pathways[13,14,15].

Oxygen availability and vasodilation

It increases the release of oxygen from oxyhaemoglobin to the tissues[16]. It also increases smooth muscle relaxation, was a dilation and increases blood supply to the tissues due to the peri-vascular release of nitric oxide. Carrera et al [17] in 2010 demonstrated that low level laser therapy increases vasodilatation in acute surgical wounds and study conducted by Mi et al[18] 2006 proved that it aids in the RBC flow, deformability as well as the haemoglobin concentration.

Bone regeneration

It stimulates osteocytes and osteoblasts[19]. But at least 2 to 3 sessions per week for at least 2 weeks is required to have any significant outcome.

Wound healing

It accelerates wound healing because of the 2 factors:
- ✓ It increases blood supply, and
- ✓ Increased immune cell migration to the site

It increases proliferation of fibroblast which in turn increases collagen production[20]. It accelerates mast cell degranulation and so increases TNF -alpha production which increases the migration of leukocytes[21].It also increases proliferation of lymphocytes add it can it increases the conversion of fibroblast to myofibroblast it decreases production of prostaglandin and increases production of fibroblast growth factor[22].

In macrophages, it increases:
- ✓ Phagocytosis
- ✓ Fibroblast production
- ✓ FGF production
- ✓ Speedy epithelialisation

IX.Applications of LLLT

The soft laser therapy has been a news for almost 3 decades. So, they are basically implemented for pain control anti-inflammatory actions, promote repair and wound healing antimicrobial photodynamic therapy, recurrent aphthous ulcer and halitosis. Antimicrobial photodynamic therapy uses a photo sensitizer that get activated in presence of light and oxygen and there are 2 types of reactions that can happen in photodynamic therapy.

Type I reaction: the activated photosensitiser interacts with a substrate which produces free radicals which in turn interacts with oxygen to produce reactive oxygen species

Type II reaction: where the activated photosensitiser directly reacts with oxygen to produce singlet oxygen species.

Photodynamic therapy can disrupt the biofilm[23]. It can be used for bacterial decontamination of periodontal pockets[24],[25] ,[26] . In vitro study conducted by Soukos et al[27] in 2003 reported that photodynamic therapy with methylene blue and diode laser was effective on killing 99 to 100% percentage of black pigmented bacteria.

Dyes used:
- Tricyclic dyes
- Chlorines
- Porphyrins
- Xanthenes
- Monoterpene

Costa da Mota and Lui et al reported that photodynamic therapy was effective in treating halitosis. Periodontitis treated with PDT achieved greatest bacterial reduction of 87.57% [28] . PDT treated biofilms are much

thinner than the control samples and had less dense biomass. It reduces dentinal hypersensitivity, reduces inflammation and alleviates faster repair[29].

Anderson 2007 reported that photodynamic therapy plus scaling and root planning has resulted in significant reduction in pocket depth after 6 to 12 weeks. Akram et al[30] 2016 in his systematic review concluded that 4 out of 17 studies reported that there was a significant reduction in pathogenic bacteria after photodynamic therapy. Chitzasi et al[31] 2004 conducted a study to find out the effect of photodynamic therapy in aggressive periodontitis patients and it did not have much significant difference as compared to scaling and root planning. Abdul Jabbar[32], Vohra, Javed in 2017 conclude that photodynamic therapy had no additional benefits so the results are mixed and non convincing[33] . Correa et al [33] 2007 used low level laser therapy(GaAs laser 904 nanometer) to treat lipopolysaccharide induced periodontitis in mice and reported that it diminished the inflammatory cell migration in a dose dependent manner. Pires et al[34] 2011 reported that low level laser therapy suppressed the expression of interleukin 6. Boschi et al 2008 reported that low level laser therapy significantly reduced interleukin 6 and TNF-alpha. Aykol et al [35] 2008 reported that low level laser therapy has tremendous role in modulation of inflammation and the and the dose was in the range of 8 to 12 joules per centimetre square. level laser therapy decreases the action of nuclear factor Kappa be in lipopolysaccharide stimulated human adipocyte derived stem cells[36] . In low level laser therapy inhibits the inflammation induced by lipopolysaccharide from E-coli and P.gingivalis through cyclic-AMP and NF-kB signalling pathway in hPDLCs. The response of periodontal ligament fibroblast to low level laser therapy was first described by Shimizu in 1995 by using 830 nanometers GaAlAs which inhibited the PGE2 and interleukin-1 beta.

Stein et al[37] 2005 reported that 632 nanometer was effective for osteoblasts but in contrary Barbosa et al[38] in 2013 concluded that 792 to 830 nanometer was best for osteoblast proliferation. Bauma et al[39] in 1996 reported that wavelength of 630 to 690 nanometer was effective in adhesion and proliferation of endothelial cells. Diese et al[40] 2008 and Kreisler et al[41] 2002 reported that LLLT scheduled 24 hours apart would have a cumulative effect. Yu et al[42] in 1997 used a He-Ne laser that promoted the release of FGF from fibroblasts and keratinocytes and nerve growth factor from keratinocytes. The recommendations to postpone the LLLT after the acute inflammatory phase was given by Akgul et al [43] 2014. Farouk et al[44] in 2007 reported that a He-Ne laser of wavelength 632.8 nm , power of 10.53 mW/cm2 resulted in optimal wound healing with fibroblast proliferation. In the treatment of RAS Aggarwal et al[45] in 2014 reported that LLLT induces conformational changes in the voltage gated Na-K channels and reduces nerve conduction leading to symptomatic relief in RAS patients. 75% of the population had better symptomatic relief after a single dose of LLLT[46]. Split mouth RCTs showed better wound healing in the gingivectomy sites irradiated by lasers as compared to the control sites[47,48] . Sobouti et al[49] 2014 reported that the laser gingivectomy sites had better healing and wound repair as compared to conventional scalpel gingivectomy sites. In periodontal flap surgery procedures, recession coverage and FGG , the laser treated sites had better results as compared to control sites. The tissue response and post operative pain after the surgical procedure also had significant differences[50–52]

X.Conclusion

Low level laser therapy is used as a therapeutic modality and it has several applications which are still under investigation and clinical trials .Photodynamic therapy is currently being applied in oncology and the concept of photodynamic laser therapy which selects its target tissue by marking it with a photo sensitizer and the therapy is active only on the marked cells and tissues. The knowledge about the success of low-level laser therapy has given the focus of using it in promoting regeneration of damaged periodontal tissues .It has bio stimulating activities too which makes its application in pain and palliative care feasible .More clinical trials and investigations are required to find out the optimal dosage and standardization of LLLT.

References

[1]. Schawlow AL, Townes CH. Infrared and Optical Masers. Phys Rev. 1958 Dec 15;112(6):1940–9.
[2]. Maiman TH. Stimulated Optical Radiation in Ruby. Nature. 1960 Aug;187(4736):493–4.
[3]. Javan A. Possibility of Production of Negative Temperature in Gas Discharges. Phys Rev Lett. 1959 Jul 15;3(2):87–9.
[4]. Mester E, Mester AF, Mester A. The biomedical effects of laser application. Lasers Surg Med. 1985;5(1):31–9.
[5]. Campbell CJ. Charles J. Campbell, MD (1926-2007). :1.
[6]. Goldman L, Hornby P, Meyer R, Goldman B. Impact of the Laser on Dental Caries. Nature. 1964 Jul;203(4943):417–417.
[7]. Yamamoto H, Sato K. Prevention of Dental Caries by Acousto-optically Q-switched ND:YAG Laser Irradiation. J Dent Res. 1980 Feb;59(2):137–137.
[8]. Myers TD. Cover Story. The Journal of the American Dental Association. 1991 Jan;122(1):46–50.
[9]. Radvar M, MacFarlane TW, MacKenzie D, Whitters CJ, Payne AP, Kinane DF. An evaluation of the Nd:YAG laser in periodontal pocket therapy. Br Dent J. 1996 Jan;180(2):57–62.
[10]. Chung H, Dai T, Sharma SK, Huang YY, Carroll JD, Hamblin MR. The Nuts and Bolts of Low-level Laser (Light) Therapy. Ann Biomed Eng. 2012 Feb;40(2):516–33.
[11]. Dourado DM, Fávero S, Matias R, Carvalho P de TC, da Cruz-Höfling MA. Low-level Laser Therapy Promotes Vascular Endothelial Growth Factor Receptor-1 Expression in Endothelial and Nonendothelial Cells of Mice Gastrocnemius Exposed to Snake Venom. Photochemistry and Photobiology. 2011 Mar;87(2):418–26.
[12]. Cury et al. - 2013 - Low level laser therapy increases angiogenesis in .pdf.

[13]. Walsh LJ. Ultraviolet B irradiation of skin induces mast cell degranulation and release of tumour necrosis factor-a. :9.
[14]. Qadri T, Miranda L, Tuner J, Gustafsson A. The short-term effects of low-level lasers as adjunct therapy in the treatment of periodontal inflammation. J Clin Periodontol. 2005 Jul;32(7):714–9.
[15]. Qadri T, Poddani P, Javed F, Tunér J, Gustafsson A. A Short-Term Evaluation of Nd:YAG Laser as an Adjunct to Scaling and Root Planing in the Treatment of Periodontal Inflammation. Journal of Periodontology. 2010 Aug;81(8):1161–6.
[16]. Asimov MM, Asimov RM, Mirshahi M, Gisbrecht A. Effect of laser-induced photodissociation of oxyhemoglobin on biomedical processes. In: Atanasov PA, Cartaleva S, editors. Varna, Bulgaria; 2001 [cited 2022 Oct 18]. p. 390. Available from: http://proceedings.spiedigitallibrary.org/proceeding.aspx?doi=10.1117/12.425172
[17]. Pereira MCMC, Pinho CB de, Medrado ARP, Andrade Z de A, Reis SR de A. Influence of 670 nm low-level laser therapy on mast cells and vascular response of cutaneous injuries. Journal of Photochemistry and Photobiology B: Biology. 2010 Mar;98(3):188–92.
[18]. Mi XQ, Chen JY, Zhou LW. Effect of low power laser irradiation on disconnecting the membrane-attached hemoglobin from erythrocyte membrane. Journal of Photochemistry and Photobiology B: Biology. 2006 May;83(2):146–50.
[19]. Kau C, Shelly J, Nimeri G, Corona R. The effect of photobiomodulation on root resorption during orthodontic treatment. CCIDE. 2014 Jan;1.
[20]. Yasukawa A, Hrui H, Koyama Y, Nagai M, Takakuda K. The Effect of Low Reactive-Level Laser Therapy (LLLT) with Helium-Neon Laser on Operative Wound Healing in a Rat Model. The Journal of Veterinary Medical Science. 2007;69(8):799–806.
[21]. El Sayed SO, Dyson M. Comparison of the effect of multiwavelength light produced by a cluster of semiconductor diodes and of each individual diode on mast cell number and degranulation in intact and injured skin. Lasers Surg Med. 1990;10(6):559–68.
[22]. Yu W, Naim JO, Lanzafame RJ. THE EFFECT OF LASER IRRADIATION ON THE RELEASE OF bFGF FROM 3T3 FIBROBLASTS. Photochem Photobiol. 1994 Feb;59(2):167–70.
[23]. Robertson CA, Evans DH, Abrahamse H. Photodynamic therapy (PDT): A short review on cellular mechanisms and cancer research applications for PDT. Journal of Photochemistry and Photobiology B: Biology. 2009 Jul;96(1):1–8.
[24]. Chan Y, Lai CH. Bactericidal effects of different laser wavelengths on periodontopathic germs in photodynamic therapy. Lasers in Medical Science. 2003 Mar 1;18(1):51–5.
[25]. Qin YL, Luan XL, Bi LJ, Sheng YQ, Zhou CN, Zhang ZG. Comparison of toluidine blue-mediated photodynamic therapy and conventional scaling treatment for periodontitis in rats. J Periodontal Res. 2008 Apr;43(2):162–7.
[26]. O'Neill JF, Hope CK, Wilson M. Oral bacteria in multi-species biofilms can be killed by red light in the presence of toluidine blue. Lasers Surg Med. 2002 Aug;31(2):86–90.
[27]. Soukos NS, Mulholland SE, Socransky SS, Doukas AG. Photodestruction of human dental plaque bacteria: Enhancement of the photodynamic effect by photomechanical waves in an oral biofilm model. Lasers Surg Med. 2003 Sep;33(3):161–8.
[28]. Braun A, Dehn C, Krause F, Jepsen S. Short-term clinical effects of adjunctive antimicrobial photodynamic therapy in periodontal treatment: a randomized clinical trial. Journal of Clinical Periodontology. 2008 Oct;35(10):877–84.
[29]. Wood S, Nattress B, Kirkham J, Shore R, Brookes S, Griffiths J, et al. An in vitro study of the use of photodynamic therapy for the treatment of natural oral plaque biofilms formed in vivo. Journal of Photochemistry and Photobiology B: Biology. 1999 May;50(1):1–7.
[30]. Akram Z, Al-Shareef SAA, Daood U, Asiri FY, Shah AH, AlQahtani MA, et al. Bactericidal Efficacy of Photodynamic Therapy Against Periodontal Pathogens in Periodontal Disease: A Systematic Review. Photomedicine and Laser Surgery. 2016 Apr;34(4):137–49.
[31]. Chitsazi MT, Shirmohammadi A, Pourabbas R, Abolfazli N, Farhoudi I, Daghigh Azar B, et al. Clinical and Microbiological Effects of Photodynamic Therapy Associated with Non-surgical Treatment in Aggressive Periodontitis. Journal of Dental Research. 2014;Dental Clinics:Dental Prospects; eISSN 20082118.
[32]. Abduljbbar T, Vohra F, Javed F, Akram Z. Antimicrobial photodynamic therapy adjuvant to non-surgical periodontal therapy in patients with diabetes mellitus: A meta-analysis. Photodiagnosis and Photodynamic Therapy. 2017 Mar;17:138–46.
[33]. Correa F, Martins RABL, Correa JC, Iversen VV, Joenson J, Bjordal JM. Low-Level Laser Therapy (GaAs λ = 904 nm) Reduces Inflammatory Cell Migration in Mice with Lipopolysaccharide-Induced Peritonitis. Photomedicine and Laser Surgery. 2007 Aug;25(4):245–9.
[34]. Pires D, Xavier M, Araújo T, Silva JA, Aimbire F, Albertini R. Low-level laser therapy (LLLT; 780 nm) acts differently on mRNA expression of anti- and pro-inflammatory mediators in an experimental model of collagenase-induced tendinitis in rat. Lasers Med Sci. 2011 Jan;26(1):85–94.
[35]. Aykol G, Baser U, Maden I, Kazak Z, Onan U, Tanrikulu-Kucuk S, et al. The Effect of Low-Level Laser Therapy as an Adjunct to Non-Surgical Periodontal Treatment. Journal of Periodontology. 2011 Mar;82(3):481–8.
[36]. Wu JY, Chen CH, Wang CZ, Ho ML, Yeh ML, Wang YH. Low-Power Laser Irradiation Suppresses Inflammatory Response of Human Adipose-Derived Stem Cells by Modulating Intracellular Cyclic AMP Level and NF-κB Activity. Sutterwala FS, editor. PLoS ONE. 2013 Jan 16;8(1):e54067.
[37]. Stein A, Benayahu D, Maltz L, Oron U. Low-Level Laser Irradiation Promotes Proliferation and Differentiation of Human Osteoblasts in Vitro. Photomedicine and Laser Surgery. 2005 Apr;23(2):161–6.
[38]. Barbosa D, de Souza RA, Xavier M, da Silva FF, Arisawa EÂL, Villaverde AGJB. Effects of low-level laser therapy (LLLT) on bone repair in rats: optical densitometry analysis. Lasers Med Sci. 2013 Feb;28(2):651–6.
[39]. Bouma MG, Buurman WA, van den Wildenberg FAJM. Low energy laser irradiation fails to modulate the inflammatory function of human monocytes and endothelial cells. Lasers Surg Med. 1996;19(2):207–15.
[40]. Pires Oliveira DAA, de Oliveira RF, Zangaro RA, Soares CP. Evaluation of Low-Level Laser Therapy of Osteoblastic Cells. Photomedicine and Laser Surgery. 2008 Aug;26(4):401–4.
[41]. Kreisler M, Al Haj H, Daubländer M, Götz H, Duschner H, Willershausen B, et al. Effect of Diode Laser Irradiation on Root Surfaces in Vitro. Journal of Clinical Laser Medicine & Surgery. 2002 Apr;20(2):63–9.
[42]. Yu W, Naim JO, McGowan M, Ippolito K, Lanzafame RJ. Photomodulation of Oxidative Metabolism and Electron Chain Enzymes in Rat Liver Mitochondria. Photochem Photobiol. 1997 Dec;66(6):866–71.
[43]. Akgul T, Gulsoy M, Gulcur HO. Effects of early and delayed laser application on nerve regeneration. Lasers Med Sci. 2014 Jan;29(1):351–7.
[44]. Al-Watban FAH., Zhang XY, Andres BL. Low-Level Laser Therapy Enhances Wound Healing in Diabetic Rats: A Comparison of Different Lasers. Photomedicine and Laser Surgery. 2007 Apr;25(2):72–7.
[45]. Aggarwal - 2014 - Efficacy of Low-Level Laser Therapy in Treatment o.pdf.
[46]. De Souza TOF, Martins MAT, Bussadori SK, Fernandes KPS, Tanji EY, Mesquita-Ferrari RA, et al. Clinical Evaluation of Low-Level Laser Treatment for Recurring Aphthous Stomatitis. Photomedicine and Laser Surgery. 2010 Oct;28(S2):S-85-S-88.
[47]. Faria Amorim JC, Sousa GRD, Silveira LDB, Prates RA, Pinotti M, Ribeiro MS. Clinical Study of the Gingiva Healing after Gingivectomy and Low-Level Laser Therapy. Photomedicine and Laser Surgery. 2006 Oct;24(5):588–94.

[48]. Ozcelik O, Cenk Haytac M, Kunin A, Seydaoglu G. Improved wound healing by low-level laser irradiation after gingivectomy operations: a controlled clinical pilot study. J Clin Periodontol. 2008 Mar;35(3):250–4.
[49]. Sobouti F, Rakhshan V, Chiniforush N, Khatami M. Effects of laser-assisted cosmetic smile lift gingivectomy on postoperative bleeding and pain in fixed orthodontic patients: a controlled clinical trial. Prog Orthod. 2014 Dec;15(1):66.
[50]. Ozturan S, Durukan SA, Ozcelik O, Seydaoglu G, Cenk Haytac M. Coronally advanced flap adjunct with low intensity laser therapy: a randomized controlled clinical pilot study. Journal of Clinical Periodontology. 2011 Nov;38(11):1055–62.
[51]. Sanz-Moliner JD, Nart J, Cohen RE, Ciancio SG. The Effect of an 810-nm Diode Laser on Postoperative Pain and Tissue Response After Modified Widman Flap Surgery: A Pilot Study in Humans. Journal of Periodontology. 2013 Feb;84(2):152–8.
[52]. Moslemi N, Heidari M, Fekrazad R, Nokhbatolfoghahaie H, Yaghobee S, Shamshiri A, et al. Effect of 660nm low power laser on pain and healing in palatal donor sites a randomized controlled clinical trial. :7.

Rasha Usman M, et. al. "Low Level Laser Therapy in Periodontics." *IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)*, 22(4), 2023, pp. 19-27.