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Low Level Laser Therapy

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ABSTRACT

Low level laser therapy (LLLT) is a non-invasive accessory in contemporary orthodontics. Derived out of the idea of biostimulation, LLLT also uses photobiomodulation as its principle by which cells may be stimulated to repair tissues, i.e. by increasing the production of ATP in mitochondria and the expression of various genes. The therapy has demonstrated encouraging clinical benefits like faster orthodontic tooth movement (OTM) via improvement of alveolar bone remodeling by activation of osteoclast and osteoblast.

Moreover, LLLT is a safe, non-invasive, and nonsteroidal alternative to the nonsteroidal anti-inflammatory drugs (NSAIDs) in the treatment of treatment-related pain through enhancement of microcirculation and decreasing inflammatory mediators. Other advantages discussed in the review are that it may prevent orthodontically induced inflammatory root resorption (OIIRR), faster healing of soft tissue and periodontal wounds, also the pain treatment of temporomandibular disorders (TMD). Although these power benefits exist, the review points out that absence of standardized clinical protocols which is a product of extensive disparities in the parameters and application techniques of laser is currently a setback to routine practice. Therefore, more clinical trials are necessary to develop the best and standardized guidelines that will make LLLT an indispensable part of patient centered care in orthodontics

KEYWORDS: Low Level Laser Therapy (LLLT), Photobiomodulation, Orthodontic Tooth Movement (OTM), Pain Management, Root Resorption, Tissue Healing, Bone Remodeling.

INTRODUCTION

The integration of laser technology into the dental world in 1960s has greatly enhanced precision, planning and comfort of the patients. Soft tissue procedures involving lasers are much easier in orthodontics and have been examined as a way of improving the result of a given treatment.[1] Low-level laser therapy (LLLT) is a non-invasive method, which enhances cell activity by photobiomodulation and leads to greater ATP synthesis, as well as bone remodeling. This may also hasten tooth movement during orthodontics and minimize the orthodontic pain. Among these benefits, effective clinical use also needs proper knowledge of the interaction between lasers on the tissues, the right selection of the parameters, and proper training. In general, LLLT is a potentially exciting addition to the current state of orthodontics reforming minimally invasive and patient centered care.[2,3]

HISTORY[4] AND CLASSIFICATION

Low-level laser therapy (LLLT) is based on Einstein's principle of stimulated emission (1917), with its clinical application beginning after the development of the first laser by Theodore Maiman in 1960.

Studies by Endre Mester demonstrated that low-power lasers enhance wound healing and tissue regeneration without carcinogenic effects, establishing the concept of biostimulation.

The Arndt–Schulz law defines an optimal therapeutic dose range, where appropriate laser energy promotes healing, while very low or high doses may be ineffective or inhibitory.[4]

Table 1 Timetable

1900	Strahlungsgesetz (Law of radiation)	By Max Planck
1917	Theory of spontaneous emission	By Albert Einstein
1951	Amplified electromagnetic radiation	By V.A. Fabrikant
1954	Optical bomb	By Dicke
	Maser	By Gorden, Zieglel, and Townes
1957	Creation of acronym ''laser''	By Gould
1960	First commercially available laser	By Maiman
1961	First gas laser	By Javan, Bennett, and Herriott
1964	Nobel price	To Townes, Prokhorov, and Basov

CLASSIFICATION[5]

Classification based on physical construction

Sl. No.	Physical Construction	Laser
1.	Gas	Carbon dioxide, Argon, Helium/neon
2.	Liquid	Not so far in clinical use
3.	Solid/ Semiconductor	Nd: YAG, Er: YAG, Er,Cr: YSGG, Ho :YAG, Diode

Classification based on power

High-Power Lasers (Hard/Hot)	Intermediate-Power Lasers	Low-Power Lasers (Soft/Cold)
a. Lasers have an output power of more than 500 mW b. Lasers increase tissue kinetic energy and produce heat, resulting in a therapeutic effect through thermal interactions c. Effects include necrosis, carbonization, vaporization, coagulation and denaturation	a. Lasers have an output power of more than 250-500 mW b. Lasers leave their therapeutic effects without producing significant heat c. Intermediate lasers are used to shorten the length of treatment period and to accelerate the therapeutic effect	a. Lasers have an output power is less than 250 mW b. Lasers have no thermal effect on tissues and produce a reaction in cells through light, called photo-bio-stimulation or biochemical reaction

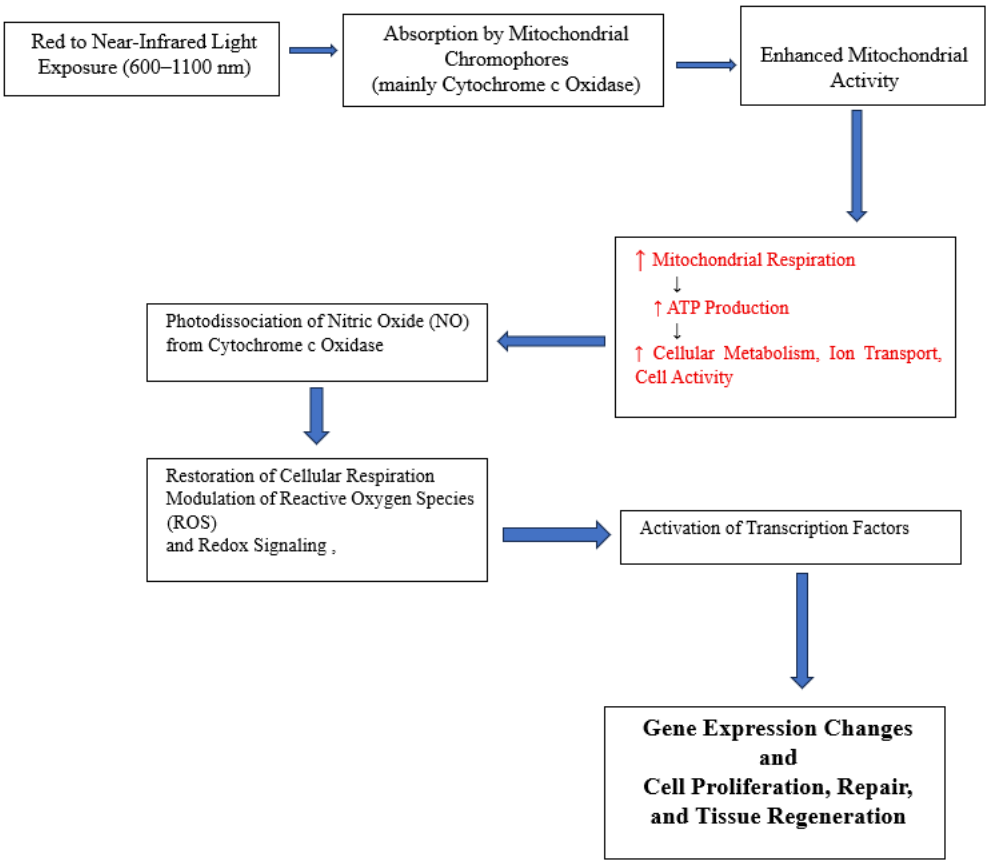
Classification based on light spectrum

Sl. No.	Spectrum of Light	Wavelength	Laser
1.	UV Light	100 nm - 400 nm	Not used in dentistry
2.	Visible light	400 nm to 750 nm	Most commonly used in dentistry (Argon & Diagnodent Lasers)
3.	Infrared light	750 nm to 10000 nm	Most dental lasers are in this spectrum

Classification based on hardness

Sl. No	Soft lasers	Hard lasers (surgical)
1.	Cold (athermic) energy emitted as wavelengths and Stimulate cellular activity	Shows good absorption by hydroxyapatite crystals and water making it more efficient on enamel and dentine
2.	Smaller and less expensive	Expensive
3.	Utilize diodes	Transmit their energy via a flexible fibre optic cable
4.	Aid healing of tissue, reduces inflammation, edema, and pain	Cut both soft and hard tissues
5.	Clinical application - Healing of localized osteitis, healing of aphthous ulcers, reduction of pain, and treatment of gingivitis	
	a. Argon lasers (Ar) b. Carbon-dioxide lasers (CO2) at 10.6 micro-meter c. Neodymium-doped yttrium aluminum garnet (Nd: YAG) d. Helium-neon (He-N) at 632.8 nm (red, visible) e. Gallium- arsenide (Ga-As) at 830 nm (infra-red, invisible)	a. Erbium, chromiummyttrium-slenium-gallium-garnet (Er,Cr: YSGG) b. Neodymiummyttrium-aluminum-perovskite (Nd:YAP) c. Holmiumyttrium-aluminum-garnet (Ho: YAG) at 2.1 micro-meter

MECHANSIM OF ACTION OF LOW LEVEL LASERS[6,7,8,9]



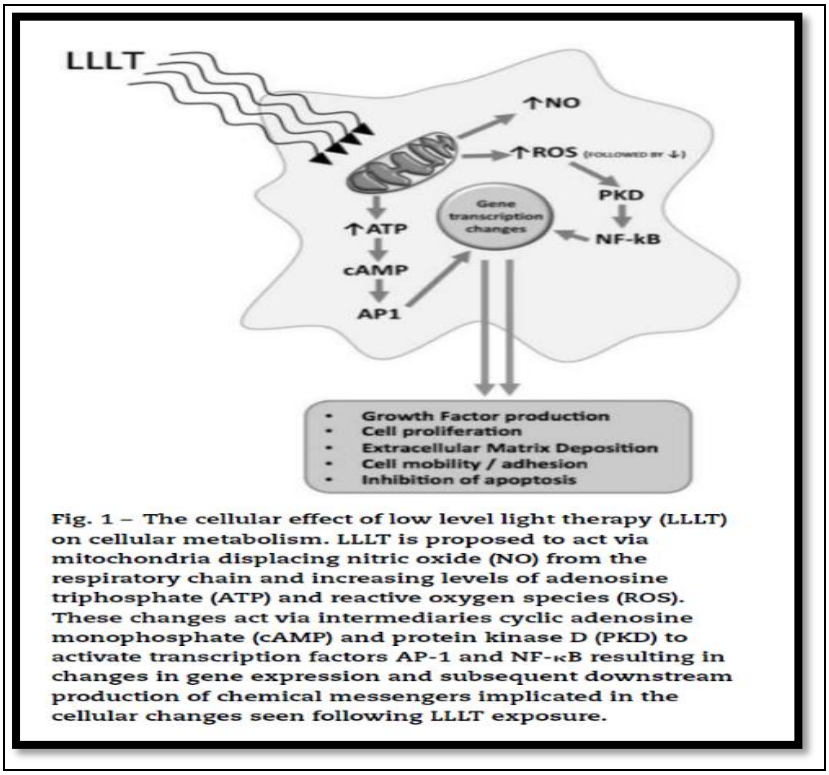


Fig. 1 – The cellular effect of low level light therapy (LLLT) on cellular metabolism. LLLT is proposed to act via mitochondria displacing nitric oxide (NO) from the respiratory chain and increasing levels of adenosine triphosphate (ATP) and reactive oxygen species (ROS). These changes act via intermediaries cyclic adenosine monophosphate (cAMP) and protein kinase D (PKD) to activate transcription factors AP-1 and NF-κB resulting in changes in gene expression and subsequent downstream production of chemical messengers implicated in the cellular changes seen following LLLT exposure.

ORTHODONTIC TOOTH MOVEMENT WITH LLLT

Orthodontic tooth movement (OTM) is a biologic mechanism that involves mechanically controlled forces that induce remodeling of periodontal ligament (PDL) and alveolar bone to achieve functional and esthetic results. Nevertheless, the period of the treatment(2-3 yrs) is linked with the adverse effects such as root resorption, gingivitis, and dental caries. Numerous strategies have been suggested to hasten OTM, though many are invasive, or with side effects that are unacceptable. Low level laser therapy (LLLT) has become a non-invasive, safe, and affordable procedure that improves bone remodelling and has the potential of speeding up the tooth movement. Based on the pressure-tension theory, applied forces form compression and tension in PDL zones, which provoke cellular and vascular reactions to deploy osteoclasts and osteoblasts to conduct bone resorption and growth.[10,11]

MECHANISM OF ACTION OF OTM[12]

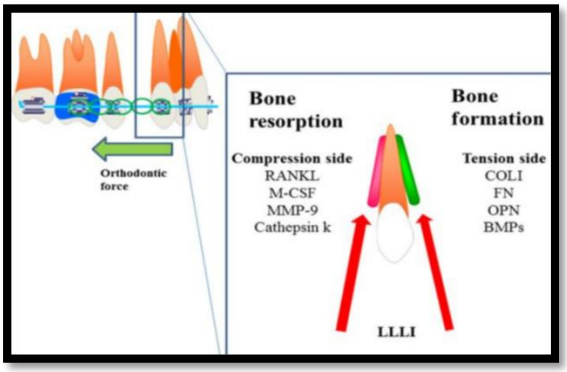
LLLT exerts its effect on a photobiomodulation change in which it induces an increase in the amount of ATP production by mitochondria and the activation of intracellular signalling. It stimulates osteoclastogenesis through the upregulation of RANK/RANKL and an increase of M-CSF production on the compression side, and stimulates osteoblast proliferation, collagen type I production, and fibronectin production on the tension side. Moreover, LLLT enhances vascularization, which facilitates the effective process of tissue turnover and permanent tooth movement.

RESEARCH HIGHLIGHTS:

Experimental studies (in vitro and animal models) demonstrate upregulation of RANK and RANKL expression following LLLT, confirming its role in enhancing osteoclast differentiation and activity, which accelerates bone resorption on the side.

Studies using GaAlAs lasers (~808 nm, ~96 mW) show increased fibronectin and type I collagen expression from early stages, indicating enhanced periodontal ligament turnover and connective tissue remodeling throughout OTM.

Evidence from histological and animal studies indicates increased osteoblastic activity, bone nodule formation (especially with early irradiation), and enhanced vascularization, all of which contribute to faster and more efficient bone remodeling and tooth movement.



PAIN MANAGEMENT WITH LLLT

According to the definition of the International Association to the Study of the Pain, pain describes an unpleasant feeling of emotion caused by something that causes or has caused a harm or a probability of a harm to the tissue. It is a normal and major feature in the treatment of orthodontics, which usually influences patient compliance. Even though nonsteroidal anti-inflammatory drugs (NSAIDs) have been utilized extensively as analgesics, the effects of their prevention of the formation of prostaglandins can disrupt the movement of teeth. Low-level laser treatment (LLLT) is a noninvasive option that possesses analgesic, anti-inflammatory, and biostimulatory effects. It acts through photobiomodulation, which improves the activities of the mitochondria, ATP production, microcirculation, lowering of inflammatory mediators, elevation of the release of endorphins and lowering of nerve excitability.[13]

Research highlights[14]:

An estimated 80 percent of the literature (32/40) indicate a beneficial effect of LLLT in the complex of decreasing orthodontic pain, especially during the separator placement, initial alignment and canine retraction , and pain tends to be evaluated using VAS scales.

Most commonly, they are GaAlAs diode lasers, with wavelengths of 630 -1064 nm (810- 830 nm in particular) although power output can vary widely (0.7-800 mW) and energy densities can be 1-35.4J/cm^2.

LLLT is usually delivered right after application of a force, and also further sessions within the first week (days 0, 3, 7); irradiation regimes are heterogeneous, ranging between 2-16 points per tooth, 20-480 seconds exposure and thus standardized

clinical guidelines are necessary.

ROOT RESORPTION AND LLLT.

Orthodontic tooth movement (OTM) is a biologic phenomenon whereby, the periodontal ligament (PDL), alveolar bone, and other tissues undergo controlled mechanical force that induces remodeling[15]. A major side effect is orthodontically induced inflammatory root resorption (OIIRR) which is due to undue compression of PDL which causes ischemia, hyalinization and consequent inflammatory and resorptive cell activation[16]. OIIRR is considered mild and sometimes may lead to considerable root damages. It has the multifactorial etiology with the considerations of patient (genetics, age, root morphology) and treatment (force magnitude, duration, and distance of teeth movement) factors.

Low-level laser therapy (LLLT) has become one of the non-invasive modalities that have a promising prospect of benefit in OTM:[17,18,19,20]

Biostimulation effects: Increases the activity of mitochondria, ATP, and metabolic activity of cells.

Bone remodeling: Stimulates osteoblast growth and differentiation with a balance on osteoclast activity through RANK/RANKL and OPG pathways.

Anti-inflammatory effect: Decreases the expression of cytokines and the activity of inflammatory cells.

Recovery of Tissues: Increases collagen synthesis, angiogenesis, and periodontal healing.

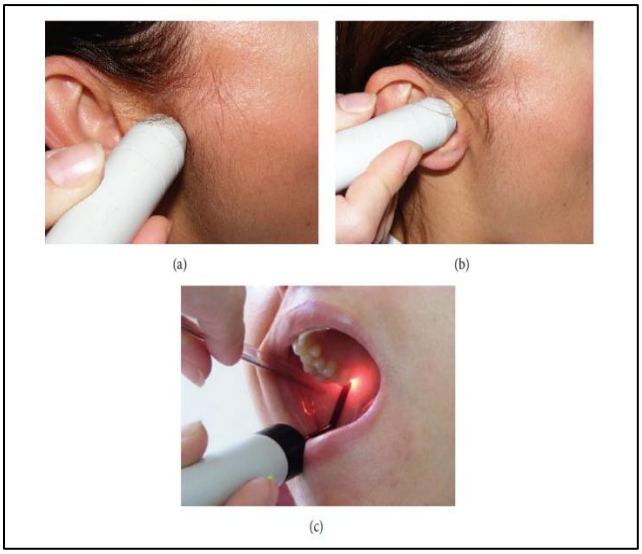
These characteristics allow concluding that LLLT can aid in decreasing, preventing, or correcting OIIRR and overall outcomes of treatment. Claims of their opposite, however, are present which is probably because of the specifics of laser parameters and usage procedures indicating the necessity of standardized clinical guidelines.

TISSUE HEALING WITH LLLT

Low-level laser therapy (LLLT) has demonstrated a great potential in improving periodontal and soft tissue wound healing by induced vasodilation, boosting the local blood flow, and augmenting oxygenation and immune cell migration. It provokes essential cellular activities, such as fibroblast growth (under optimum dose concentrations), macrophage scarring, and growth factor discharge, i.e.,PDGF, TGF-B, bFGF and VEGF, which together enhance tissue repair and angiogenesis. LLLT also increases collagen synthesis, epithelialization and granulation tissue formation, and alters inflammatory mediators such as the expression of cytokines such as IL-1B, COX-2, etc.[21.22] in a dose-dependent manner. These effects lead to accelerated inflammatory, proliferative, and remodeling of the process of healing. Nevertheless, the effect of therapeutic procedures requires proper parameters of irradiation since overdose of the treatment can suppress cellular activities, and inconsistency in study protocols outlines the importance of standard guidelines of treatment.

TMJ AND LOW LEVEL LASER THERAPY

Temporomandibular disorders (TMD) are another group of disorders that are associated with the temporomandibular joint, masticatory muscles, and related structures, usually manifesting in the form of pain, joint sounds, and limited movement of the jaw.[23] The most common is displacement of the discs with or without loss, which adds to the noise or restricted opening of the joints. It has a multifactorial etiology of predisposing, initiating, and perpetuating factors including parafunctional habits, trauma, stress, and occlusional problems. It is a multidisciplinary kind of management which involves physical therapies, occlusal splints, pharmacological agent and psychological support.[24] Low-level laser therapy (LLLT) is a technique that has attracted attention because of being non-invasive with biostimulatory action, improvements in cellular metabolism, tissue repair and analgesic/anti-inflammatory effects. There is some evidence indicating that LLLT can help in decreasing TMD pain, to provide a proper wavelength and dosage, however, the absence of standard protocols still has to be considered a weakness.[25]



CONCLUSION

The relevant, non-invasive adjunct treatment with low-level laser therapy (LLLT) can work miraculously in orthodontics by causing faster tooth movement, effective pain management, tissue healing, and possibly lessening the root resorption. Its photobiomodulation mechanism supports the better activity of cells and bone remodeling.

Although there is strong evidence, the fluctuation of laser parameters, use methods and studies results prevent the standardization of laser in clinical practice. Thus, additional clinical trials that are well designed are welcome to determine the best protocols. LLLT can become a part and parcel of the contemporary, patient-focused orthodontic treatment with appropriate knowledge and appropriate education

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