Effect of low level lasers in orthodontic tooth movement

Type of Manuscript – Review article
Running title – Low level lasers in tooth movement

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Abstract:

Aim:
To review about the effect of low level lasers in orthodontic tooth movement
Background:
Orthodontic treatment uses the movement of teeth to achieve its goals that are mainly esthetic and functional. These movements result in functional forces and periodontal tissue remolding, particularly alveolar bone. Long duration of fixed orthodontic treatment, which usually lasts for 2-3 years, is accompanied by side effects such as root resorption, gingival inflammation and dental caries. Various methods were used to increase orthodontic tooth movement, but recent studies have shown that low level laser therapy can be used for acceleration of tooth movement and alveolar bone remodeling. Low level laser therapy acts by causing increase in RANKL in periodontal ligament and thereby causing increase in the rate of tooth movement during orthodontic treatment.
Materials and methods:
Articles from Pubmed and Google Scholar , google with search title “ low level lasers and tooth movement ” was used. Studies related to the topics were selected and parameters of laser including wave length and average power or laser of energy and its effect on tooth movement were included.
Reason for this study:
To study and correlate about the different mechanisms and wavelengths by which the low level lasers cause a positive orthodontic tooth movement.

***Keywords*: Tooth movement, lasers, bone remodelling, periodontal ligament, wavelength**

Introduction:
Orthodontic treatment uses the movement of teeth to achieve its goals that are mainly esthetic and functional to the patient (1). It mainly deals with alignment of teeth and correction of proclined teeth by bringing about movement of teeth by application of mild continuous forces. Though orthodontic treatment is initially taken up by patients in the adolescent and teen age groups, there is no limitation of this treatment to elder age group when the periodontal status of the individual is good (2).Orthodontic tooth movement occurs due to the presence of a mechanical stimuli sequenced by remodeling of the alveolar bone and periodontal ligament (PDL). Bone remodeling is a process by which there is both bone resorption and bone formation which occurs by bone resorption on the pressure site and bone formation on the tension site (3). Orthodontic tooth movement can be controlled by the size of the applied force and the biological responses which we receive from the periodontal ligament. The changes in the microenvironment around the PDL can be due to the orthodontic forces applied on the tooth which may cause alterations of blood flow, leading to the secretion. Cellular responses in the periodontal ligament brings about the bone resorption and formation in the pressure site and tension site respectively (4). Different factors cause alterations to the bone remodeling pattern altering the rate of tooth movements in the alveolar bone. Such factors include Parathyroid hormone (PTH), estrogen, the applied force values, different drug injections, electrical stimulation or ultrasound. There is always an inverse proportional action between PTH and estrogen were PTH causes

bone formation and estrogen induces found to decrease the bone formation. Furthermore studies reveal that, loads lower than 1000 μ strain are associated with the increased bone formation while loads more than 2000 μ strain leads to decreased bone formations and subsequently lowering the tooth movements. These factors also have side effects like uncontrolled tooth movements, root resorption, pain and patients' discomfort together with increased tooth movements (5-7). Longer duration of fixed orthodontic treatment usually lasts for about 2-3 years, it is also accompanied by side effects such as root resorption, gingival inflammation and dental caries (8). Clinicians are constantly striving towards developing new strategies to increase the rate of orthodontic tooth movement, certain methods such as Surgical Methods, Physical/ Mechanical stimulation method, Molecular Methods and injecting Drugs have been followed to bring about the tooth movement. These methods include surgical cortical incisions around the teeth according to regional acceleratory phenomenon to accelerate tooth movement (9), injecting local prostaglandins, vitamin D3, interleukins, parathyroid hormone, misoprostol ,osteocalcin around the sockets that can lead to acceleration of tooth movement by altering bone remodelling pattern causing increased tooth movement (10,11). Although these methods are successful in the treatment, they also possess complications such as root resorption and overdosage of drug injections causes uncontrolled tooth movement. The newly accepted and one among the most promising approaches in providing accelerated tooth movement is Photobiomodulation or lowlevel laser therapy (LLLT). Low level lasers are non invasive, easy to use, cheap and does not require any special expensive machinery. The laser light stimulates the proliferation of osteoclast, osteoblast, and fibroblasts, and thereby remodeling the bone and accelerating the tooth movement. The mechanism involved in the acceleration of tooth movement is by producing ATP and activation of cytochrome C, that low-energy laser irradiation enhanced the velocity of tooth movement through the RANK/RANKL pathway and the macrophage colony-stimulating factor and its receptor expression.Studies on animals show that lasers has a biostimulatory effect on bone regeneration, which has been demonstrated in the midpalatal suture during rapid palatal expansion, also stimulates bone regeneration after bone fractures and in the site of extractions and also collagen synthesis (12-14).

Materials and methods:

Electronic databases such as Pubmed, Google scholar were all searched using search tool of
(((Lasers) OR Low level lasers)) AND ((Tooth movement) OR Orthodontic tooth movement)
The total no of articles obtained from the Pubmed according to the search was 67 and relevant 17 articles were picked up for the review. The aim of this review article is to find out the effect of low level lasers in the orthodontic tooth movement. The articles was screened based on the title, Abstract and results. Articles which fulfilled the inclusion criteria was taken into consideration.

Inclusion criteria:
Clinical trials, Animal studies, in-vitro studies.
Exclusion criteria:
Non – randomized experimental studies, irrelevant literature reviews, case series were are excluded.

S.No	Topic	Authors	Journal
1.	Clinical application of prostaglandin E 1 (PGE1) upon orthodontic tooth movement	Yamasaki K, Shibata Y, Imai S, Tani Y, Shibasaki Y, Fukuhara T.	Am J Orthod. 1984 Jun;85(6):508-18.
2.	Stimulatory effects of low-power laser irradiation on bone regenera-tion in midpalatal suture during expansion in the rat	Saito S, Shimizu N	AmJOrthodDentofacial Orthop.1997 May;111(5):525-32.
3.	Administration of osteocalcin accelerates orthodontic toothmovement induced by a closed coil spring in rats	Hashimoto F, Kobayashi Y, Mataki S, Kobayashi K, Kato Y, Sakai	Eur Orthod. 2001 Oct;23(5):535-45.
4.	The effects of diode laser (660 nm) on the rate of tooth movements: an animal study.	Shirazi M[1], Ahmad Akhoundi MS, Javadi E, Kamali A, Motahhari P, Rashidpour M, Chiniforush N.	Lasers Med Sci. 2015 Feb;30(2):713-8.
5.	Efficacy of low-intensity laser therapy in reducing treatment time and orthodontic pain: a clinical investigation.	Doshi-Mehta G[1], Bhad-Patil WA.	Am J Orthod Dentofacial Orthop. 2012 Mar;141(3):289-97
6.	Effect of low-level laser therapy (LLLT) on orthodontic tooth movement.	Genc G[1], Kocadereli I, Tasar F, Kilinc K, El S, Sarkarati B.	Lasers Med Sci. 2013 Jan;28(1):41-7.

7.	Effects of two types of low-level laser wave lengths (850 and 630 nm) on the orthodontic tooth movements in rabbits.	Seifi M[1], Shafeei HA, Daneshdoost S, Mir M.	Lasers Med Sci. 2007 Nov;22(4):261-4
8	Effects of low-level laser therapy on the rate of orthodontic tooth movement	Limpanichkul W[1] Godfrey K, Srisuk N, Rattanayatikul C.	Orthod Craniofac Res. 2006 Feb;9(1):38-43.
9.	Accelerating orthodontic tooth movement using surgical and non-surgical approaches.	Fleming PS[1].	Evid Based Dent. 2014 Dec;15(4):114-5
10.	Influence of low-level laser on the speed of orthodontic movement.	Sousa MV[1], Scanavini MA, Sannomiya EK, Velasco LG, Angelieri F.	Photomed Laser Surg. 2011 Mar;29(3):191-6
11.	Biostimulation of wound healing by lasers; experimental approaches in animal models and in fibroblast culture	Abergel RP, Lyons RF, Castel JC, Dwyer RM, Uitto	J Dermatol Surg Oncol. 1987 Feb;13(2):127-33.
12.	Effects of low-intensity laser therapy on the orthodontic movement velocity of human teet	Cruz DR, Kohara EK, Ribeiro MS, Wetter N	Lasers Surg Med. 2004;35:117–20.
13.	A clinical investigation of the efficacy of low level laser therapy in reducing orthodontic post adjustment pain	Lim HM, Lew KK, Tay D	Am J Orthod Dentofacial Orthop. 1995 Dec;108(6):614-22.
14.	Photoradiation and orthodontic movement: Experimental study with canines.	Goulart CS, Nouer PR, Mouramartins L, Garbin IU, de Fátima Zanirato Lizarelli R	Photomed Laser Surg. 2006;24:192–6
15.	Effects of low-level laser therapy after Corticision on tooth movement and paradental remodeling. Lasers Surg Med. 2009 Sep;41(7):524–33	Kim SJ, Moon SU, Kang SG, Park YG	Lasers Surg Med. 2009 Sep;41(7):524–33
16.	Changes in the periodontal ligament after experimental tooth movement using high and low continuous forces in beagle dogs.	Von Bohl M, Maltha J, Von den Hoff H, Kuijpers AM.	Lasers Surgmed 2008 74(1):16-25.
17.	Effects of low-energy laser irradiation on bone remodeling during experimental tooth movement in rats.	Kawasaki K, Shimizu N.	Lasers Surg Med. 2000;26:282–91

Discussion:

The first ever low level laser which was commercially used was He-Ne lasers with wavelength of 632.8 nm (19). In a study by Shoji.et.al it reveals that RANKL and RANK were significantly increased and were detected in the initial stage of the irritation group which signifies that they are in involved in the tooth movement (21).

These lasers has the ability to stimulate epithelialization, vascularization and collagen synthesis (20). In a study it was stated that the wavelength of the laser and its energy wavelength determines its tissue response.(21) In order to reach the photo reactive parameters of low laser therapy, factors like light intensity, power output, density, total irradiation and energy density are important

It has been shown from different studies that, Different laser modalities have been used in different doses including helium-neon (632.8 nm wavelength), gallium-aluminum-arsenide (GaAlAs) (805 ± 25 nm wavelength) and gallium-arsenide (904 nm wavelength) . Out of all these it was found that gallium- aluminum-arsenide laser have higher tissue penetrating capability and also shows increased tooth movement (19-21). Certain studies report that power density is more important than the total dose in start of biomodulation (22, 23).

Several Animal studies have shown that low-level laser can accelerate the tooth movement (21-23). Furthermore, clinical trial attempts were made in which different intensities of laser were used and different results were obtained. Low-level laser therapy can be a very useful and safest technique for acceleration of tooth movement since it increases bone remodeling without side effects to the periodontium. Laser wavelength of 800 nm and output power of 0.25 mW have reported significant stimulation of bone metabolism, rapid bone formation, and also acceleration of tooth movement to 1.5-fold in rat experiments (24). In a clinical trial study, the laser wavelength they used continuous wave mode at an intensity of 800 nm, with an output of 0.25 mW, and with an exposure of 10 s was found to accelerate the tooth movement at 1.3-fold higher than the control (25). In study done by Kau it says that on 90 subjects there was an significant change of about 1.12-mm per week in the test subjects which was higher when compared with the control group which was 0.49 mm . Having said this, there are a lot of contradictory results related to the LLLT. Therefore, more several studies are needed to differentiate the optimum energy, wavelength, and the optimum duration for usage which provides a positive outcome of accelerated tooth movement. In a study by Seifi *et al*. suggested that the values of tooth movement after LLLT with both pulsed 850-nm laser (Optodan, 8.1 J/cm^2) and continuous 630-nm laser (potassium iodate, 27 J/cm^2) to be diminished, They suggested inhibitory effects of low level laser on the prostaglandins as an intermediate in the cell response to teeth movements as the involved mechanism for the findings (24).

Based on a study conducted by Kim et al. the application of low level laser therapy of GaAlAs with a wave length of 808 nm and with an output power of 96 mw there was increase of fibronectin and type I collagen levels from the first day and the increase remains significant to the end of the experiment in both the laser and control groups. He also finally concluded that low level laser therapy facilitates the turnover of connective tissue during tooth (26). Studies say that GaAlAs low-level laser was not able to prevent tooth movements following artificial socket preservations. Several investigations and studies have reported that low-energy irradiation with GaAlAs diode laser affects orthodontic tooth movement in the animals and humans when using the optimal laser dosage (25,27)

Studies by Kawasaki et.al showed higher values (1.3-fold) of orthodontic tooth movement in the laser-irradiated rat teeth than their control ones (27).In this study, total laser energy of 702 j was irradiated continuously during 13 days on rat's molars (output: 100 mw, wavelength: 830-nm). It also showed that low-energy laser application increased the number of osteoclasts in the pressure side during experimental tooth movement in rats.

Furthermore, the tooth movement differences between the experimental and control groups was found to be only 0.2 mm, suggesting lower standard deviation values being responsible for the significant differences which was explored as the differences was being reported to be 0.32 mm increase in rate of the tooth movement . Fujita *et al*. in a study reported that there was 50% increased rate of OTM following similar protocol used on lower dosage(23). Youssef *et al*. showed that the ratio of human canine retraction in the irradiated group was 1.98 (809-nm, 100-mW at 8 J/cm^2) on compared to the control ones (29).Abtahi and Mohaseni Eghdam showed insignificant effects of LLLT (12.5 J/cm^2) on the tooth movement induced by the separator loads on the human subjects (28). Cruz *et al*. applied GaAlAs diode laser (5 J/cm^2) for 10 s and found that positive canine tooth movements (25).On the contrast , Limpanichkul *et al*. suggested that LLLT with dosage of 25 J/cm^2 densities they do not to induce faster orthodontic tooth movement than the control group (27).

Coombe *et al*. says that low level laser therapy with GaAlAs diode laser (830-nm, 0.3-4 J/cm^2) did not stimulate cell population in both the short and long time intervals using the human cells culture of osteosarcom (30).

In another study, Goulart *et al*. noted that the canine and premolars irradiated at 5.25 J/cm^2 (780-nm) showed faster orthodontic movements initially, while the teeth irradiated at 35 J/cm^2 (780-nm) showed slow movements which signifies that higher dosage may cause inhibitory effect than acceleration of the tooth (31). Different effects of laser irradiation have been reported on tooth movement using different laser irradiation period, density and wavelength. Furthermore, more accuracy of application methods, sample selection and statistical calculations are required in the assessment of low-level laser effects on the tooth movement. In a study when GaAlAs laser (808-nm, 0.1 W and 6 J/cm^2) was irradiated on the teeth with the continuous method for 10 days being followed by 14 days of no irradiation. There was a positive outcome of accelerated tooth movement (32).

A optimum energy density is necessary is required to trigger biologic effects therefore, low outputs cannot be fully compensated by the longer exposures. The dosage limit follows the Arndt-Schulz law were the low dosages stimulate, while the higher dosages will have inhibitory effects (33), since the biological effects of laser irradiation depends on the parameters like as wavelength, output and laser density the difference of effects on tooth movements have been noticed .(34)

Although, the exact mechanism of the low-energy laser application on the bone is not completely understood yet, it is possibly photochemical in nature, with the light increasing cell proliferation through the photochemical alterations, after the light at a lower radiation dosage is absorbed by the intracellular chromophores in the mitochondria (32-34). This mechanism, is also multifactorial in nature which produces effects such as promotion of angiogenesis,collagen synthesis ,ostogenic cell proliferation and cell differentiation, mitochondrial respiration, and adenosine triphosphate synthesis(35-37). LLLT can also enhance the local blood flow, increasing the supply of the circulating cells, nutrition, oxygen, and inorganic salts to the bone lesions.(37) In this regard, Kobu showed that in tissues treated with LLL application, intraosseous blood flow increased approximately 80% and oxygen tension by approximately 15% (38). In a study it was reported that laser irradiation was seemed to be more effective in the maxilla when compared to the mandible, which is probably due to the difference in the type of bone (spongy vs. compact) and due to the absence of anatomical barriers (i.e. tongue) in the upper jaw. (39).

Since there are differences being found in the oxidation and consequent cellular pH change, a cell can demonstrate different responses to the specific laser types in different times, so that, the laser effects would be more complicated when complex mechanisms being present or more than one cell is involved in the specific time. Furthermore, in some occasions, the irradiation effects would be subjected to decrease or increase showing different laser natures, i.e., inhibitory or accelerating affects being presented (40). The root resorption was significantly lower in the laser-irradiated teeth than control specimens, this has suggested that root resorption is the iatrogenic consequence of orthodontic movements being an main idiopathic problem of the treatments. However, this degree of root resorption has no significant clinical effect.

Furthermore, there are certain interfering factors which includes the host defensive system response against the laser irradiation, metabolic status and cellular pH during irradiation initiation, the contradictory and unclear influences of the tissue mediators and the more complicated effects of the different laser types remains unclear (41). That is why different studies and the results have been reported in apparently similar in vitro studies. The role of laser output and density, irradiation mode, cellular culture technique and histological assessments must be added to the find out correct effect of irradiation and the significant effect on the the tooth movement.

Conclusion:

Based on different studies and clinical trials it can be concluded that low level laser therapy may increase the rate of tooth movement during orthodontic treatment by the following mechanisms, it acts by Increasing levels of RANKL in PDL and also Macrophage-colony stimulating factor (M-CSF) which leads to increased osteoclastogenesis and causes resorption and tooth movement ,Increased osteogenesis by increasing osteoblastic cell proliferation on the tension site. More researches are needed on the humans to arrive a conclusion and to determine the effect of low level laser therapy on tooth movement with special attention to laser parameters.

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