Review Article

Tooth Movement Alterations by Different Low Level Laser Protocols: A Literature Review

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Abstract:

Low-Level Laser Therapy (LLLT) provides several benefits for patients receiving orthodontic treatment. According to some literatures, Orthodontic Tooth Movement (OTM) can be enhanced but some investigators have reported contradictory results. This article reviews the literature regarding the different aspects of the use of LLLT on OTM and its alterations. The general data regarding the study design, sample size, wavelength (nm), power (mW), and duration were extracted and recorded independently. Electronic databases of PubMed and ScienceDirect from January 2009 to August 2014 were searched. Also Google Scholar and grey literature was searched for relevant references. Some investigators found that the amount of tooth movement in the Low-Energy Laser Irradiation (LELI) group was significantly greater than in the non-irradiation group by the end of the experimental period. Low-level laser irradiation accelerates the bone remodeling process by stimulating osteoblastic and osteoclastic cell proliferation and function during orthodontic tooth movement. But some researchers have reported that no statistical differences in the mean rate of tooth movement were noted between low energy and high energy experimental sides and their controls. Some evidence shows that low-level laser irradiation accelerates the bone remodeling process and some evidence shows that LLLT has not effect on OTM. In some investigations no statistical differences in the mean rate of tooth movement can be seen between low energy and high energy experimental sides and their controls. It has been shown by authors that laser irradiation can reduce the amount of OTM and a clinical usage for the inhibitory role of low level laser irradiation is enforcing the anchorage unit.
Keywords: laser therapies, low-level; movement, tooth; orthodontics.

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Introduction

Orthodontics has experienced a noticeable breakthrough with the introduction of diode lasers. The conservative nature of these lasers has created a platform for orthodontic tooth movement (OTM) control (enhancement or diminishing OTM as anchorage units) trend.[1] On the other hand, in the majority of the animal experiments on orthodontic tooth movement, the amount of force is not mentioned or measured at all. If it is measured at start, force will decay within the experiment (application of force by elastomeric materials in one-quarter of publication) period. To compare humans and rats, an estimation of root surface areas may give an indication of force magnitude to be used. A human molar is approximately 50 times larger than a rat molar, which means that the effect of a 20 centi-Newton (cN) force on a rat molar is comparable with a force of 1000 cN (equal to 1 Kilogram) on a human molar. It is surprising to note that 80 percent of the reported studies used forces over 20 cN or forces of unknown magnitudes on rats and in only 20 percent of the studies, forces of 20 cN or less were applied.[2] Apart from the magnitude of force, the protocols of laser beam irradiations are variant too. Youssef et al. have reported a significant increase in movement rate for the irradiated canines when compared to the control group i.e. four times more. They treated 15 patients (age between 14 and 23) by four bicuspid extraction and studied the tooth movement in both maxilla and mandible. The split-mouth design was used for the study and the laser type was a semiconductor Gallium Aluminum Arsenide (GaAlAs) laser with 809 nm wavelength operated at 100-mW output according to the manufacturer's recommendation (Quanta, Italy). The laser beam was delivered to the tissue by a special handpiece. The tip of the handpiece was held in contact with the tissue during application. The areas chosen to be irradiated were the lingual and buccal PDL of the canines. These areas were divided into: cervical, middle, apical. The cervical area was lased for 10 s. The middle area was lased for 20 s. The apical area was lased for 10 s. The total energy density (dose) at each application was 8 J (2×40 s×100 mW). The laser was applied using intervals of 0, 3, 7 and 14 d. The retraction coil was activated on day 21 for both sides and both jaws. [3] Cruz et al. published a research on "Effects of Low-Intensity Laser Therapy on the Orthodontic Movement Velocity of Human Teeth" and concluded that a 33% increase in the rate of orthodontic tooth movement can occur. The equipment used in their study was a Gallium Aluminum Arsenide (GaAlAs) semiconductor diode laser emitting infrared radiation at 780 nm, operating in continuous wave mode with a cylindrical quartz tip of 4 mm^2 surface. The sample of Cruz et al. study consisted of 11 patients who received a 150 gram maxillary canine retraction force bilaterally for 2 month as split-mouth technique, one side was irradiated and the other side served as a control. Irradiation standards were wavelength 780 nm, power 20 mW, energy flow 2 J, energy density 5 J/cm^2, and total dose 8 J. [4] Sousa et al. studied the "Influence of low-level laser on the speed of orthodontic movement". Twenty-six canines were retracted using NiTi spring (force of 150 g/side). Thirteen of those were irradiated with diode laser (780 nm, 20 mW, 10 sec, 5 J/cm2) for 3 days, and the other 13 were not irradiated and thus were considered the control group. Patients were followed up for 4 months, and nine laser applications were performed (three each month). The authors concluded that the diode laser used within the protocol guidelines increased the speed of tooth movement. [5] Camacho et al. in a prospective cohort study, started at 5 mm crowding non-extraction and finished with a sample of 45 patients between 20 and 30 years old. The experimental group was irradiated at each appointment 1 mm away from the mucosa on the buccal and palatal sides, following the long axis of the tooth for 22 s on each surface. The control group did not receive laser irradiation. The measurement unit used was days of treatment, the dosage and parameters of irradiation were: 830 nm, 100 mW, energy density 80 J/cm2, an active laser point of 0.028 cm2 and the energy was 2.2 J. These parameters allowed a reduction of 30% in the Low-Level Laser Irradiation (LLLI) treated group during the total treatment time.[6]

Limpanichkul et al. also studied the effect of LLLT on the rate of canine retraction with different standard (860 nm, 100 mW, 25 J/cm^2, 18.4 J around the experimental tooth (buccal mucosa, distal and palatal) four times over a month for a total dose of 294.4 J) and concluded that there was no significant difference of means of the canine distal movement between the LLLT side and the placebo side for any time periods. They also interpret the equality of the OTM on both side as: "the energy density of LLLT (GaAlAs) at the surface level in this study (25 J/cm2) was probably too low to express either stimulatory effect or inhibitory effect on the rate of orthodontic tooth movement". 7 Seifi et al. have reported diminished OTM following application of Low level laser therapy in experimental study i.e. in vivo of using Optodan® (Russian patent No 2014107 and certified by the Russian Ministry of Health) and KLO3® lasers (probe model=KLO3; http://www.magicray.ru/ENG/outfit/mustang.html). The members of the control group were not irradiated, while those in laser groups received the following doses within 9 days: 850-nm laser (Central Institute of Dentistry, Russia) applied with a power of 5 mW (repetition rate=3,000 Hz, pulse duration=100 ns) and continuous 630-nm laser (probe model =KLO3®, "Magic Ray" Moscow Center of Laser Medicine, Russia) set on 10 mW. During irradiation, the tips of the probes were placed on the lingual side of the teeth in contact with oral mucosa. The 850-nm laser was applied for 3 min per day, and teeth in the 630-nm laser group received 630 nm energy for 5 min. The total amount of energy in the infrared and red laser groups were 8.1 and 27 J, respectively. The mean value of first-molar teeth movement in control group was calculated in millimeter as 1.7 ± 0.16; in 850-nm laser group, 0.69 ± 0.16 mm; and in the 630-nm laser group, 0.86 ± 0.13 mm that can be interpreted as reduced OTM following laser irradiation.[1]

By considering the aforementioned articles and the variation in tissue response, in spite of the existence of similarity between protocols; a trend exist from 400% increase of tooth movement [3], to 30-33% increase [4-6], to no significant effect[7], and to 50-60% diminished OTM.[1]

As a result of differences, assessing the effects of low level laser therapy on the rate of orthodontic tooth movement have produced controversial results. Diode lasers have been used in different studies with different energies, frequencies, and doses. To eliminate the intervening factors and problems with matching the clinical cases, authors decided to review in vivo studies with predetermined inclusion criteria.

Methods

Inclusion criteria for included studies

Studies in any language that evaluate or compare interventions for low level laser therapy and orthodontic tooth movement in animals or in vivo research from January 2009 to August 2014 were included.

Exclusion criteria

Clinical studies with different protocols for laser low level laser therapy (LLLT) irradiation, in vitro studies, High-intensity laser therapy, and hard tissue laser therapies were not evaluated in this survey.

Data extraction and Analysis

The general data regarding the study design, sample size, wavelength (nm), power (mW), and duration were extracted and recorded independently. Electronic databases of PubMed and ScienceDirect from January 2009 to August 2014 were searched. Also Google Scholar and grey literature was searched for relevant references (Figure 1).

Description of studies and interventions

Low level laser therapy (LLLT), in in vivo rat experiments; stimulates bone regeneration in the midpalatal suture during expansion, increases the amount of tooth movement, and LLLT irradiation facilitates the turnover of connective tissues with acceleration of bone remodeling process by stimulating osteoblast and osteoclast cell proliferation and function during orthodontic tooth movement.[8-10] On the other hand, authors found strong methodologies against the above

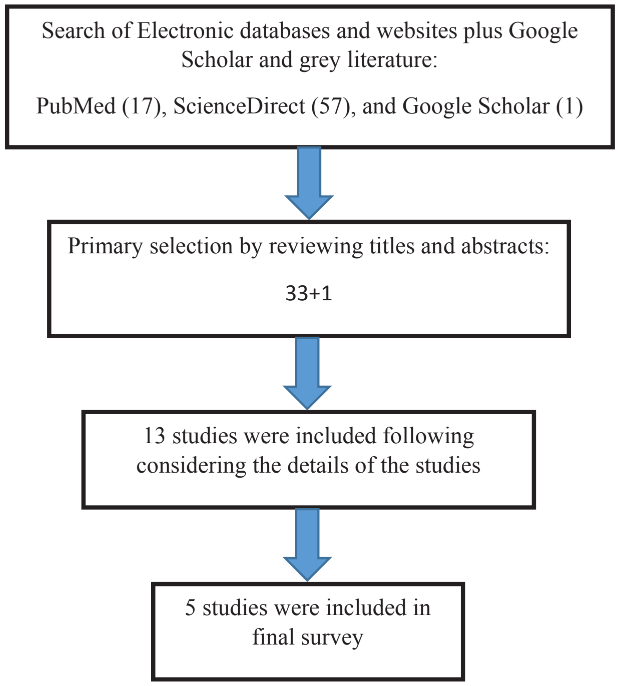

Figure 1. Systematic search for literature survey (Flow Chart)

mentioned articles, likewise what was seen in clinical articles of the introduction section.[11] The biostimulating effects of low level laser therapy have been shown in different studies but the varying experimental designs and results have produced many controversial issues (Table 1). Interpretation of these results is complicated by the fact that the laser parameters in each study differed greatly according to the number of applications, the time separating each application, the length of the experiment, laser wavelength, power output, mode of delivery, power density, and energy density. The experimental outcomes are further complicated because experiments were conducted on different subject models i.e. culture, rats, rabbits, dogs, and humans. The parameters used in these studies demonstrate great variability.

Yoshida et al. studied the Low-energy laser irradiation and showed that it accelerates the velocity of tooth movement via stimulation of the alveolar bone remodeling. [8] They detected a space between the first and second molars because the first molar was moved mesially. In contrast, there was no space between the second and third molars. The amount of tooth movement was significantly greater in the low-energy laser irradiation (LELI) group on days 3 (1.4-fold), 7 (1.19-fold), 14 (1.26-fold), and 21 (1.34-fold) than in the non-irradiation group.[8] Yamaguchi et al. investigated the role of low-energy laser irradiation on facilitation of the OTM velocity and the expressions of matrix metalloproteinase-9, cathepsin K, and alpha (v)

Table 1. General information of the five in vivo included studies

First Author Name	Year of Publication	Wave Length (nm)	Power	Sample Size	Results
Yoshida et al.[8]	2009	810	100	60	The amount of tooth movement in the Low-Energy Laser Irradiation (LELI) group was significantly greater than in the non-irradiation group by the end of the experimental period.
Yamaguchi et al.[9]	2010	810	100	50	Low-energy laser irradiation facilitates the velocity of tooth movement and MMP-9, cathepsin K, and integrin subunits of alpha (v) b3 expressions in rats.
Rowan [11]	2010	810	100	24	No statistical differences in the mean rate of tooth movement were noted between low and high experimental sides and their controls.
Altan et al.[10]	2012	820	100	38	low-level laser irradiation accelerates the bone remodeling process by stimulating osteoblastic and osteoclastic cell proliferation and function during orthodontic tooth movement.
Shirazi et al.[12]	2013	660	25	30	The results suggested that low-level laser can accelerate the rate of bone remodeling.

beta3 integrin in rats.[9] A Ga-Al-As diode laser was used to irradiate the area around the moving tooth and, after 7 days, the amount of tooth movement was measured. To determine the amount of tooth movement, plaster models of the maxillae were made using a silicone impression material before (day 0) and after tooth movement (days 1, 2, 3, 4, and 7). The models were scanned using a contact-type three-dimensional (3-D) measurement apparatus. They concluded that in the laser-irradiated group, the amount of tooth movement was significantly greater than that in the non-irradiated group at the end of the experiment ($P < 0.05$) and low-energy laser irradiation enhances the velocity of tooth movement.[9]

Rowan et al. conducted a research on the effect of two energy densities and dose applications of low level laser therapy on orthodontic tooth movement. Twenty-four male Wistar rats were divided into two groups of 12 rats each. Animals were randomly assigned to a low laser group, with an energy density of 5 J/cm² and total dose of 2.38 J, or a high laser group, with an energy density of 50 J/cm² and total dose of 23.84 J. Closed-coil springs delivered a force of 10 g to the right and left first molars. An 810 nm diode laser functioning in continuous wave mode with a power output of 100 mW delivered the laser doses. LLLT applications were delivered nine times over 22 days. Tooth movement measurements were taken with digital calipers at four time periods. Significant tooth movement was observed on all sides between each of the three time period, with greater movement recorded in the initial and third periods compared to the second. No statistical differences in the mean rate of tooth movement were noted between low and high experimental sides and their controls. Using a conventional surgical laser frequently found in orthodontic offices to deliver two low level laser doses; does not influence the rate of orthodontic tooth movement in rats.[11]

Altan et al. studied the metrical and histological effects of low-level laser therapy on orthodontic tooth movement. Thirty-eight albino Wistar rats were used for the experiment. Maxillary incisors of the subjects were moved orthodontically by a helical spring with 20 g force. An 820-nm Ga-Al-As diode laser with an output power of 100 mW and a fiber probe with spot size of 2 mm in diameter were used for laser treatment and irradiations were performed on 5 points at the distal side of the tooth root on the first, second, and 3rd days of the experiment. Total laser energy of 54 J (100 mW, 3.18 W/cm^2, 1717.2 J/cm^2) was applied to group II and a total of 15 J (100 mW, 3.18 W/cm^2, 477 J/cm^2) to group III. The experiment lasted for 8 days. The number of osteoclasts, osteoblasts, inflammatory cells, capillaries, and new bone formation were evaluated histologically. On the basis of these findings, low-level laser irradiation accelerates the bone remodeling process by stimulating osteoblastic and osteoclastic cell proliferation and function during orthodontic tooth movement.10

Shirazi et al. published an article entitled: "The effects of diode laser (660 nm) on the rate of tooth movements: an animal study". The aim of the study was to evaluate the effects of Indium Gallium Aluminum Phosphorus (InGaAlP) laser with a wavelength of 660 nm on the rate of tooth movement and histological status. Thirty male Wistar rats 7 weeks old were selected for the study. The rats were randomly divided into two groups of 15 each to form the experimental (laser-irradiated) and control (non-irradiated) groups. The control group received unilateral orthodontic appliance design (one quadrant), but the laser-irradiated group received split-mouth design, with orthodontic appliance on both sides and laser irradiation on one side only (group b) and on the contralateral side (group c). The diode laser (660 nm) was irradiated with an output power of 25 mW in continuous mode for a total time of 5 min in the laser-irradiated group. After 14 days of orthodontic tooth movement, the amount of tooth movements was measured. In the laser irradiated group, the amount of tooth movement was significantly greater than that of the non-irradiated group (2.3-fold), but there was no significant difference between the nonirradiated and indirectly irradiated groups.12 (Table 1)

The transduction of force into a meaningful cellular response is one of the most intriguing aspect of tissue reaction in OTM. The behavior of all eukaryotic cells is modulated by internal signaling systems which translate a wide array of external stimuli such as hormones or mechanical forces, into a very narrow range of internal signals (second messengers). Classically, the second messenger associated with mechanical force transduction is adenosine 3′5′ cyclic monophosphate (cAMP).[13] There is some evidence to support the theory that laser can inhibit Prostaglandin E release and subsequent joint pain i.e. it decreases the blood level of PGE2 and controls pain. On the other hand, PGE2 is released during tooth movement and it acts as a primary messenger. By contrasting these two evidences, authors believe that laser may have an inhibitory role in the phenomenon of OTM from a theoretical perspective.

Conclusion

Some evidence shows that low-level laser irradiation accelerates the bone remodeling process by stimulating osteoblastic and osteoclastic cell proliferation and function during orthodontic tooth movement. The resultant tissue reaction leads to accelerated orthodontic tooth movement.

Some evidence shows that LLLT has not effect on OTM. No statistical differences in the mean rate of tooth movement can be seen between low energy and high energy experimental sides and their controls. These finding rejects the theory that inhibition of tooth movement by laser is due to entering inhibition zone of the Arndt-Schulz curve or biostimulation is not enough.

Authors have shown that laser irradiation can reduce the amount of OTM [1] and a clinical usage for the inhibitory role is enforcing the anchorage unit. In addition to the mentioned property, according to the findings of the selected articles; biostimulation can reinforce the bone around the miniscrews as absolute anchorage.

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