The Effect of Low Level Laser Therapy on the Rate of Tooth Movement and Pain Perception during Canine Retraction

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Abstract

Aims: This study investigated the effect of an 810 nm gallium-aluminum-arsenide (Ga-Al-As) laser on tooth movement velocity and pain perception during canine retraction in orthodontic patients.

Methods: This single blind study included 20 patients requiring upper first premolar extraction on both sides. One half of the upper arch was irradiated with a GaAlAs laser (810 nm, 200 mW, 10 points, 21.4 J/cm^2/point) and the other half served as the placebo group. Irradiation was performed just after loading canine retraction forces and on days 3, 7, 11 15 over the first month. At the 28th day, the coil spring was adjusted and the same protocol was continued. The extension of tooth movement and the degree of mesiodistal inclination of canines were measured on the study models prepared at 0, 28 and 56 days. The patients were also asked to bite on plastic blocks to examine the degree of pain perceived on canines at both sides.

Results: There was no significant difference either in the speed of canine movement or in its degree of mesiodistal inclination between the laser and placebo sides. The pain perception did not differ significantly between the two groups at any of the treatment appointments.

Conclusion: Low level laser therapy (LLLT), with the parameter settings used in this study, did not affect canine movement velocity and its degree of mesiodistal inclination and did not influence pain perceived by the patients.

Key Words: Low Level Laser Therapy, Low power laser therapy, Pain- Tooth movement, Orthodontic, Canine Retraction

Introduction

The long treatment duration and painful teeth are among the major concerns of patients undergoing fixed orthodontic therapy. So far, great attempts have been made to find approaches for enhancing orthodontic tooth movement and decreasing pain. The injection of prostaglandins [1,2], active form of vitamin D3 [1,3] or osteocalcin [4,5] around the alveolar socket and the application of electric currents [6], resonance vibration [7], or ultrasound waves [8] are among the methods that have been used to stimulate bone resorption/absorption and thus the rate of tooth movement. Although these methods showed successful results in some studies, they have their own disadvantages such as painful injection and dependence on a special apparatus which should be modified for this application and may also require frequent applications to induce the desirable effect. Non-steroidal anti-inflammatory drugs, which are usually used to decrease pain resulted from activation of orthodontic appliances, may be associated with deleterious health effects and may also reduce orthodontic tooth movement [9]. Therefore, finding an optimum supplementary approach to achieve faster tooth movement and decrease pain is still considered as a subject of interest.

Low Level Laser Therapy (LLLT) is a simple and inexpensive method that can be used easily in the dental practice for different purposes such as pain reduction [10], enhancement of wound healing [11] and alleviating inflammation [12]. Some studies investigated the efficacy of low power lasers in reducing pain during orthodontic treatment [12,13], promoting bone regeneration in the midpalatal suture during expansion [14] and stimulating tooth movement. The results of studies on the rate of tooth movement are controversial. Some animal and human studies reported a significant acceleration of tooth movement in the laser group compared to the placebo application [15-17], but others reported no difference [18-20] or even indicated the inhibitory effect of laser therapy on the rate of tooth movement [21].

One of the problems that clinicians frequently encounter is tipping of canine teeth during retraction. The type of tooth movement (bodily versus controlled tipping) affects the degree of mesiodistal angulation of the tooth and may have a remarkable effect on the final esthetics of the treatment. It can be assumed that by changing the remodeling rate and alveolar bone resistance during canine retraction, it would be possible to affect the degree of tooth tipping.

The purpose of this study was to determine the effect of a gallium-aluminum-arsenide (GaAlAs) low-power laser on pain perception, the magnitude of movement and the degree of mesiodistal inclination of canines during retraction.

Materials and Methods

The sample consisted of twenty patients (3 male, 17 females) attending for orthodontic treatment in a private office. The patients were ranged in age from 15 to 31 years (mean age 22.1 ± 5.3 years). Based on complete orthodontic records, the treatment plan of all patients included extraction of upper first premolars with/without mandibular premolar extraction. Patients who had any systemic diseases and those with periodontally compromised teeth as well as subjects who were under medications that could interfere with tooth

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movement such as anti-inflammatory drugs were excluded from the study. The study design was approved by the Ethics Committee of Mashhad University of Medical Sciences. The research protocol was described clearly for the patients and an informed consent was obtained from each participant or his/her legal responsible before the commencement of the treatment.

Orthodontic treatment

The orthodontic treatment was performed with 0.018-in preadjusted edgewise appliances (Roth prescription; Dentsply GAC International, Bohemia, NY, USA). After complete leveling and aligning, which lasted for at least 3 months after appliance placement, the canine teeth on both sides were retracted through a 0.016-inch SS wire (Dentaurum, Ispringen, Germany). A vertical loop (3 mm) was incorporated in the mesial of each molar tube to serve as the posterior stop for anchorage reinforcement. The canines were tied to the arch wire with 0.010-in steel ligature wires to reduce tooth rotation during retraction. The central and lateral incisors were also consolidated with ligature wires. Canine retraction was accomplished by Ni-Ti closed coil springs with length of 9 mm (0.011×0.030-in, Ortho Technology, Tampa, Florida, USA). The spring was attached to the hook of the first molar by a stainless steel ligature wire, then stretched to give 150 g of force and secured to the canine with a second ligature wire. A force gauge (Dentaurum, Pforzheim, Germany) was used to determine that the 150 g traction force is delivered. The spring was adjusted 28 days later to give the same force value (150 g).

Immediately before starting canine retraction (T0), an alginate impression was taken from the maxillary arch to provide an initial dental model. This model also served as a base for a custom tray made from putty impression material (Speedex, Coltene, Alstatten, Switzerland). The retention and undercuts of the tray were then filled with sticky wax and the final impression of the upper arch was taken using a silicon wash (Speedex, Coltene). This final impression was poured with Vel-Mix stone (Kerr Co, Orange, CA, USA) to increase the precision of measurements. At the follow-up intervals of 28 (T1) and 56 (T2) days, the process of taking impression was repeated to allow measuring the changes occurred in the canine position during treatment.

Low level laser therapy (LLLT)

The low-intensity laser device used in this study was an infrared gallium-aluminum-arsenide (GaAlAs; Thor DD2 Control Unit, Thor, London, UK) diode laser, emitting a wavelength of 810 nm. The laser operated at the maximum output power of 200 mW and in continuous wave mode, and the beam was delivered through a hand piece with a surface area of 0.28 cm^2. The laser irradiated 5 points on the buccal side and 5 points on the palatal side of each canine tooth: 2 points on the cervical third of the root (one mesial and one distal), one point on the middle third of the root (at the center of the root), and 2 points on the apical third of the root (one mesial and one distal). The laser probe was held perpendicular for 30 seconds in direct contact with the alveolar mucosa on each of the mentioned areas. The energy delivered was 6 J with energy density of 21.4 J/cm^2 per point, considering the surface area of the probe. In each patient, one side was randomly allocated to the laser treatment and another side to the placebo application. On the placebo (control) side, the hand piece was placed on the same points for the same duration as the treatment side, but no irradiation was delivered. Both the patient and the operator wore safety goggles during laser irradiation. The therapist was aware that which side received the laser or placebo treatment, but the patient was blinded.

LLLT was started on the day of attaching coil springs (T0) and was repeated on days 4, 7, 11, 15 and 28 over the first month by the same investigator. On the 28th days (T1), laser therapy was done after adjustment of the coil spring, and the same intervals of irradiation were continued (days 32, 35, 39, 43, and 56). The third impression was taken at the 56th day (T2).

Preparation of Dental Models

The following reference points were marked on the dental models: the incisive papilla point, a point on the posterior part of the median raphe, the canine cusp tip, the most mesial point on the incisal edge of the lateral incisor, and the tip of the mesiobuccal cusp of the first molar (*Figure 1*). These points were marked by one investigator and confirmed by the second one. In cases of disagreement, they discussed until consensus was achieved. The initial and progress dental models were then mounted on an articulator in a manner that the occlusal surface of the model would be parallel to the horizontal plane. A metal plate was placed at the upper part of the articulator during mounting, so that when the articulator was closed, the metal plate made the final base of the dental cast to be in parallel position to the horizontal plane (*Figure 2*).

The dental models were then photographed by a digital camera using constant settings. The camera was fixed at a distance of 50 cm over the casts. All images were taken perpendicular to the occlusal plane. The images were later imported into the Photoshop CS software for drawing lines and to the Smile Analyzer software [22] for taking linear measurements. The amount of magnification in the Smile Analyzer software was set by taking an image from a 10-millimeter scale at the same distance that the dental models were photographed, and then comparing the true measurement with that displayed by the software.

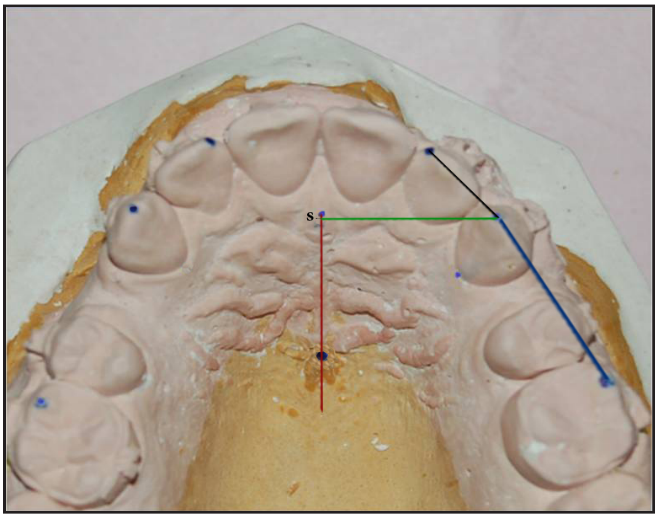

Figure 1. *The points and lines used for linear measurements on the dental models (S indicates the intersection of the canine perpendicular to the median raphe line).*

Measurement of canine distal movement

Tooth movement was measured on dental casts prepared on the first day of the experiment (T0) and on days 28 (T1) and 56 (T2). For calculating the extension of canine distal movement, the point on the posterior part of the median raphe was attached to the incisive papilla point to create the median raphe line, and then a perpendicular was drawn from the canine cusp tip to this line (*Figure 1*). The distance of the incisive papillae to the intersection of the canine perpendicular to the median raphe line [S point, (*Figure 1*)] was measured on the laser and control sides at different treatment intervals. The determination of canine tooth movement was also achieved by calculating the distance between the most mesial point on the incisal edge of the lateral incisor and the canine cusp tip at the same side (*Figure 1*). The last method of evaluating canine tooth movement was by measuring the distance between the mesiobuccal cusp tip of the first maxillary molars to the tips of the canine cusps on the laser and placebo sides (*Figure 1*). The measurements were repeated on the dental models taken at the 28th (T1) and 56th (T2) days following canine retraction. The difference between the measurements at the two observation periods represented the amount of canine movement in millimeters.

Measurement of canine tipping

In order to evaluate the amount of distal tipping of the canine during retraction, the amount of mesiodistal angulation of the tooth was measured by using the Tooth Inclination Protractor (TIP) device [23-25]. The TIP device was applied on the dental models prepared at the beginning of canine retraction (T0) and at T1 and T2 time points. The difference between the measurements at the two observation periods displayed the amount of canine tipping in degrees.

Pain assessment

To measure the amount of pain, a plastic block bite holder was sequentially placed beneath the canine teeth on the laser and the placebo sides and the patients were asked to bite with the same amount of force as possible on the two sides. Immediately after biting, a 100-mm visual analogue scale was given to the patients and they were asked to mark the degree of perceived pain on the scale for the pressured side. The pain intensity was recorded at the day of starting canine retraction and at all the appointments that patients referred for laser irradiation. The measurement was accomplished before laser treatment at each appointment.

The statistical Analyses

The Kolmogorov-Smirnov test revealed that the data regarding canine movement and its mesiodistal inclination were normally distributed ($p>0.05$), while the pain intensity data were not ($p<0.05$). Therefore, a student t-test was used to compare the distance of canine movement between the laser and control sides as well as to determine any significant

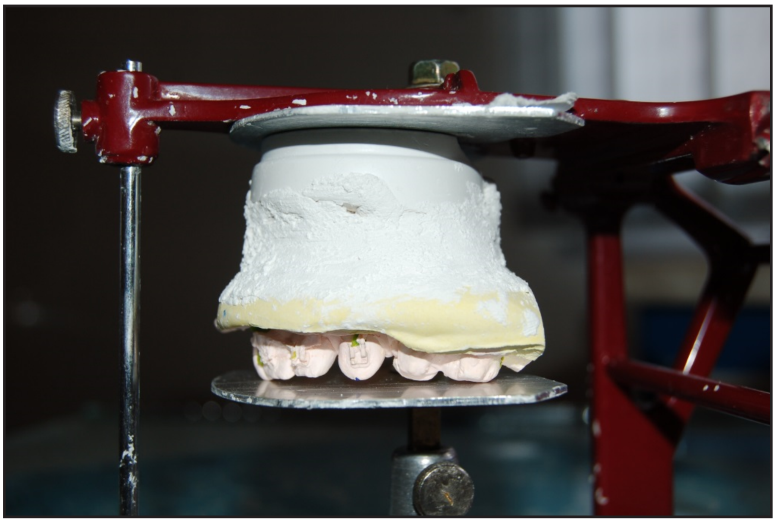

Figure 2. *Mounting the dental model on an articulator with the occlusal plane and the base in parallel position to the horizontal plane.*

Table 1. *Descriptive statistics and the results of student t-test analysis for comparison of canine retraction (mm) between the laser and placebo sides at the different treatment intervals.*

		T0-T1		T1-T2		T0-T2	
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Canine cusp tip to mesioincisal point of lateral	laser	1.16	0.57	0.91	0.64	2.07	1.01
	placebo	1.00	0.63	0.84	0.53	1.84	1.01
	P-value	0.434		0.686		0.522	
Canine cusp tip to mesiobuccal cusp of the 1st molar	Laser	1.32	1.12	0.79	0.57	2.11	1.14
	Placebo	1.31	1.55	0.82	0.57	2.13	1.16
	P-value	0.979	0.865	0.973			
The distance of the S* point to the incisive papilla	Laser	1.18	0.89	1.02	1.07	2.20	0.98
	Placebo	1.32	0.91	1.12	0.99	2.44	1.16
	p-value	0.618	0.754	0.211			

*S indicates the intersection of the canine perpendicular to the median raphe line difference in the mesiodistal inclination of canines between the two groups. The difference in pain intensity between the experimental and control groups was tested by Mann-Whitney U test. The data were analyzed by SPSS (Statistical Package for Social Sciences, version 16, SPSS Inc. IL, USA) and the significance level was predetermined at $p<0.05$.

Results

Table 1 presents the descriptive statistics regarding the distance of canine retraction relative to the first molar, the lateral incisor and the incisive papilla in the laser and control groups. As noted in the table, the amount of tooth movement was greater than 1 mm in both groups in the first month and then was slightly declined in the second month. No significant difference was found in the extension of canine distal movement between the control and irradiated sides by any of the measurement methods (*Table 1*).

The amount of tooth tipping as measured by the TIP device is presented in *Table 2*. The statistical analysis revealed no significant difference in the mesiodistal inclination of the canines between the laser and placebo sides (*Table 2*).

Figure 3 illustrates the pain intensity perceived on the canine teeth while biting on a plastic block in the experimental and control groups. There was no significant difference in pain level between the two sides at any of the treatment appointments ($p>0.05$).

Discussion

In the present study, a GaAlAs diode laser was applied for enhancement of orthodontic tooth movement and reducing pain, because this wavelength has low absorbance in hemoglobin and water and thus provides enough penetration depth to affect the alveolar bone and other periodontal tissues. The first laser irradiation was done immediately after activation of the coil spring and it was reapplied twice a week over the first two weeks after spring activation in order to maintain any biomodulation effect of LLLT on the periodontium. The application of putty-wash technique and Vel-Mix stone combined with the use of software for calculating linear distances resulted in high precision in measurements. In order to eliminate any possible error that may occur in the measuring process, three methods were used for calculating the distance of canine movement, whereas in most of the previous studies, only one method has been employed to indicate the rate of tooth movement. Some authors [26] calculated the distance between the mesial cusp of the first molar and the tip of the canine cusp as the only criterion to indicate the extension of tooth movement, but the molar teeth may rotate during canine retraction, which can cause error in the measurements.

Different biological mechanisms have been explained for the effect of LLLT on stimulating alveolar bone remodeling and thus the rate of tooth movement. Kawasaki and Shimizu [27] were the first to propose that LLLT was able to accelerate orthodontic movement by increasing the amount of bone formation and rate of cellular proliferation in the tension side and the number of osteoclasts in the compression side. Fujita et al. [16] and Aihara et al. [28] demonstrated that LLLT enhanced differentiation and activation of osteoclasts through induction of receptor activator of nuclear factor kappa B

Table 2. *Descriptive statistics and the results of student t-test analysis for comparison of the difference in mesiodistal inclination of canines (degree) between the laser and placebo groups at the different treatment intervals.*

	T0-T1		T1-T2		T0-T2	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Laser	1.05	4.45	1.15	3.58	2.20	4.67
Placebo	2.05	4.09	1.20	4.01	3.25	4.46
P-value	0.464	0.575	0.472			

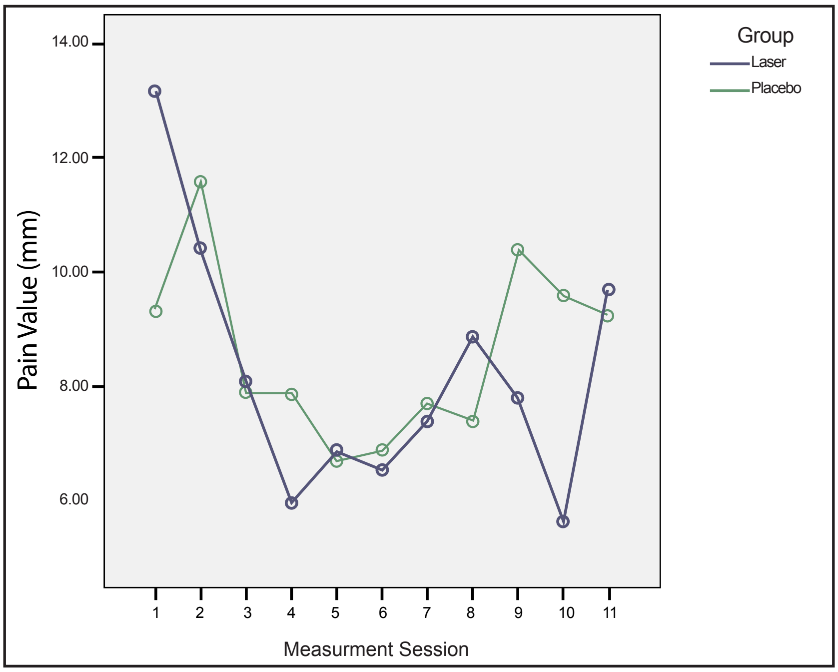

Figure 3. Pain intensity (mm) in the laser and placebo groups at the treatment appointments.

(RANK) and its ligand (RANKL), which is considered as the key osteoclastogenic cytokine. Others reported a relationship between LLLT and expression of Macrophage Colony-Stimulating Factor (M-CSF) and its receptor, a cytokine which facilitates proliferation, survival and differentiation of osteoclast progenitors [29]. Another study reported that LLLT stimulates cell proliferation in human osteoblast-like cells and importantly increases the expression of proteins essential for bone formation [30].

The three methods used for examination of canine distal movement showed comparable results to each other. With the parameter settings used in this study, there was no significant difference in the extension of canine distal movement between the laser and placebo groups at any of the observation periods. This finding is in agreement with the outcomes of Limpanichkul et al. [18], Marquezan et al. [20] and Gama et al. [19] who indicated that LLLT had no stimulatory effect on the rate of orthodontic tooth movement. Seifi et al. [21] found that tooth movement was retarded in rabbits after LLLT using two different wavelengths. In contrast, a number of studies [15-17,26,27,31-33] demonstrated that tooth movement was significantly greater in the laser-irradiated group compared to the placebo application. Youssef et al. [26] found a 1.98 fold increase in the rate of tooth movement in the laser group compared to the placebo treatment, while Kawasaki and Shimizu [27] and Cruz et al. [15] reported the ratio of about 1.3 in the lased- compared to the non-lased group.

The controversy observed between the results of previous studies can be attributed to the different irradiation dosage employed, which can cause variable biostimulation effects on laser-treated tissues. Furthermore, the point of laser application, and the frequency and interval between the irradiations were different among the studies. The differences in the method of tooth movement measurement and the use of human versus animal samples were also variables that can affect the treatment results. In the present study, six J of energy was applied to each of the different points around the canines which caused an energy density of 21.4 J/cm^2/point. Luger et al. [34] used doses of about 64 J/cm^2 for enhancing bone mechanic properties in rats, as they believed that the scattering diminishes the energy level of the laser to 3% - 6% of its original intensity. Kawasaki and Shimizu [27] found acceleration of tooth movement in laser-irradiated rats after applying an 830 nm low power laser (100 mW, 0.6 mm diameter) with a high energy density of around 6000 J/cm^2. On the other hand, Goulart et al. [35] indicated that LLLT (780 nm, 70 mW, area 0.04 cm^2, single spot irradiation) caused a stimulatory effect on orthodontic movement in dogs if the energy density of 5.25 J/cm^2 was employed, whereas the 35 J/cm^2 dosage from the same laser retarded tooth movement when compared to the control side. Youssef et al. [26] applied the dose of 8 J/cm^2 distributed over 8 points around the canine tooth and believed that this distribution of energy provided a more adequate result compared to the studies that used a single-point laser application. Cruz et al. [15] applied 5 J/cm^2 dosages on each of the 10 points around the canine teeth and found significant acceleration of tooth movement in human subjects. Considering the laser parameters used in this study, it appears that the total energy and the total irradiation dosage was higher compared to those employed by Youssef et al. [26] and Cruz et al. [15], and this may prevent from obtaining the desirable stimulatory effect on alveolar bone remodeling and diminution of pain perception.

In the current study, no significant difference was found in VAS scores between the laser and the placebo groups at any of the treatment appointments. In contrast, Youssef et al. [26] demonstrated that LLLT was not only capable to increase the rate of canine retraction but also to cause a significant decrease in pain perceived during treatment. Since we did not observe any positive effect of laser irradiation on biostimulation of alveolar bone remodeling, this finding should be expected. Another reason for the lack of statistical significance in pain scores between the two groups may be that we did not measure pain intensity at intervals that the release of pain-related mediators is greater, for example after 24 hours of activating the spring. It should be noted that the method used by most previous authors for measuring pain intensity during treatment was different from that used in this study. For example, Youssef et al. [26] evaluated pain and discomfort by a questionnaire given to the patients on every reactivation date of the coil spring (every 21 days), while we used plastic blocks and asked the patients to record any pain perceived over biting.

In this study, it was demonstrated that the changes in tipping of canine teeth during treatment were not significantly different between the laser and the placebo groups. So far, no study evaluated tooth tipping while using low level lasers for enhancing canine retraction. Generally, two factors affect the degree of tooth tipping: the extension of tooth movement and the level of resistance of the alveolar bone to movement. When the tooth movement increases, the tipping is usually increased. In the present study, we did not find any acceleration of tooth movement in the laser group compared to the placebo treatment and therefore, the difference in tipping of canine teeth was not significant between the two groups.

Further long-term studies are warranted to determine the optimal dose, frequency and duration of laser irradiation to increase the rate of tooth movement and reduce pain resulted from activation of orthodontic appliances during treatment.

Conclusions

With the parameter settings applied in this study, LLLT neither accelerated orthodontic tooth movement nor affected the degree of mesiodistal inclination of canines over retraction. LLLT also did not influence the pain resulted from activation of orthodontic appliances.

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