Lasers Med Sci (2008) 23:27–33
DOI 10.1007/s10103-007-0449-7

ORIGINAL ARTICLE

The effect of low-level laser therapy during orthodontic movement: a preliminary study

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Received: 21 September 2006 / Accepted: 22 January 2007 / Published online: 15 March 2007

Abstract It has been emphasized that one of the most valuable treatment objectives in dental practice is to afford the patient a pain-free treatment. By the evolution of the laser applications, the dental committee aimed to achieve this goal without analgesic drugs and painful methods. Orthodontic treatment is one of these concerns, that one of the major components of patient to reject this treatment is the pain accompanied during the different treatment phases. Another great concern of the patient is not to get through prolonged periods of treatment. The aim of this study is to evaluate the effect of the low-level (GaAlAs) diode laser (809 nm, 100 mW) on the canine retraction during an orthodontic movement and to assess pain level during this treatment. A group of 15 adult patients with age ranging from 14 to 23 years attended the orthodontic department at Dental School, Damascus University. The treatment plan for these patients included extraction of the upper and lower first premolars because there was not enough space for a complete alignment or presence of biprotrusion. For each patient, this diagnosis was based on a standard orthodontic documentation with photographs, model casts, cephalometric, panorama, and superior premolar periapical radiographies. The orthodontic treatment was initiated 14 days after the premolar extraction with a standard 18 slot edgewise brackets [Rocky Mountain Company (RMO)]. The canine retraction was accomplished by using prefabricated Ricketts springs (RMO), in both upper and lower jaws. The right side of the upper and lower jaw was chosen to be irradiated with the laser, whereas the left side was considered the control without laser irradiation. The laser was applied with 0-, 3-, 7-, and 14-day intervals. The retraction spring was reactivated on day 21 for all sides. The amount of canine retraction was measured at this stage with a digital electronic caliper (Myoto, Japan) and compared each side of the relative jaw (i.e., upper left canine with upper right canine and lower left canine with lower right canine). The pain level was prompted by a patient questionnaire. The velocity of canine movement was significantly greater in the lased group than in the control group. The pain intensity was also at lower level in the lased group than in the control group throughout the retraction period. Our findings suggest that low-level laser therapy can highly accelerate tooth movement during orthodontic treatment and can also effectively reduce pain level.

Keywords LLLT · Low-level laser · Orthodontics · Tooth movement · Pain

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Introduction

Discomfort pain is a burdensome side effect accompanying orthodontic treatment due to force application for tooth movement. Clinical observation indicates that these sensations usually appear a few hours after force application [2, 27] or during the first day or first couple of days of treatment and that pain intensity falls to normal levels after 7 days [8, 16, 29, 34].

It has been emphasized that pain reduction without analgesic drugs is necessary in orthodontic treatment [3, 6, 8, 15, 21, 28]. Several studies showed an effective pain

reduction after different dental treatments by using low-level laser therapy (LLLT) [11, 22].

The long treatment period is another concern that makes patients neglect to go through orthodontic treatment. According to the previous studies [1, 5, 7, 9, 10, 12, 13, 17, 19, 24, 26, 30, 31, 33, 35, 37–39, 41, 42], the amount of tooth movement in response to the applied force is influenced by several factors such as gender, status of periodontal ligament (PDL) and, especially, the type of tooth movement, and the magnitude of the applied force. With a healthy canine and moderate applied force (150 g), Ricketts reported the movement to be 1 mm at the end of activation. In general, the mechanics applied produced canine retraction with velocities averaging 1.27 and 0.87 mm per month for 13 and 4 kPa of stress, respectively, with minimal linear or angular tooth movements [13, 14]. However, those studies used different magnitudes and durations of force, and thus, direct comparisons of their results are difficult to draw.

To avoid any confusion, we have used the same magnitude of force (150 g) with same reactivation duration for all our patients involved in the experiment.

The purpose of the present study was to determine the differences in the velocity of movement of the canines' retraction while applying LLLT. The other aim is to assess a visual scale of pain level during the experiment.

Materials and methods

Patients' selection

A group of 15 patients of both genders, with age ranging from 14 to 23 years, attended the orthodontic department at Dental School, Damascus University.

The treatment plan for these patients included extraction of the upper and lower first premolars to achieve treatment plan demands. For each patient, the diagnosis was based on a standard orthodontic documentation with photographs, model casts, cephalometric, and panoramic radiographics. An additional superior and inferior premolar periapical rays were obtained to ensure the absence of any problem that would impede the extraction procedures.

We considered the following standards for patients' selection:

(a) They should appear healthy.
(b) They should be free of any systemic disease.
(c) They should not be under medical treatment that could interfere with bone metabolism (the orthodontic movement mechanism) like non-steroidal anti-inflammatory.

After clearly explaining all the risks and benefits of the supposed treatment, the patients and each legal responsible approved to participate in this study. This approval was documented by a signed paper from each patient and authorized by the dean of our dental school.

Orthodontic treatment

The orthodontic treatment was initiated 14 days after the premolar extraction with a standard 0.018-in. slot edgewise brackets [Rocky Mountain Company (RMO)]. The canine retraction method chosen was Ricketts prescription by using the prefabricated 16×16 Blue Elgiloy Ricketts Spring (RMO). The spring was activated to deliver (150 g) force, which was measured by Forestadent force gauge. Spring reactivation was made every 21 days with the same force value (150 g) and repeated till the closing of the extraction space.

The amount of tooth movement in millimeters was prompted by measuring the distance between the following reference points on the model casts:

1. The tip of the mesial cusp of the first molar
2. The tip of the canine cusp

The measurement was done by using a digital caliper (Mitutoyo, Japan) before initiating the orthodontic treatment and recorded.

At each reactivation interval, new impressions for each patient of both upper and lower jaws were taken. Then a new measurement of the previous distance was recorded. This was maintained till the end of the retraction phase. All of these measurements were organized in schedule according to the measuring date.

On every reactivation date, the patient was asked about the pain experienced during the bygone period. These responses were ranked according to a visual pain scale and were also organized in a schedule.

Laser irradiation

The right side of the upper and lower jaws was chosen to be irradiated with the laser beam, whereas the left side was considered the control without irradiation. The laser type used was a semiconductor (GaAlAs) laser with 809-nm

Table 1 Tooth movement measurements

	Lased group			Control group	
Days	Step 1	Step 2	Step 3	Step 1	Step 2
0	DM	SA	Laser	DM	SA
3	DM	Laser		DM	
7	DM	Laser		DM	
14	DM	Laser		DM	
21	DM			DM	

DM Distance measurement, *SA* spring activation

Table 2 Pain levels

Degree of pain	Rank value
No pain	0
Mild pain	1
Moderate pain	2
Severe pain	3
Intolerable pain	4

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 three:

1. Cervical
2. Middle
3. 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).

– To omit patient's self-behavior about the pain, we have put the tip of the handpiece not only on the right side but also on the left side, without pressing the feet paddle that enables the laser beam. In this manner, just the red guiding light will be emitted.
– The laser regimen was applied on 0-, 3-, 7-, and 14-day intervals after every activation.

Data collection

Tooth movement

The sequence of steps carried out during each clinical attendance is shown in Table 1. At every 21-day interval, the distance measurement was compared between the lased and control group. The data were compared by two sample t tests at $P<0.05$. After 6 months, the lased and control groups' canines' areas were examined by periapical radiographs to see if any damage developed in the adjacent PDLs and dental tissues.

Table 3 Velocity of movement of the tooth

Group	Number of studied teeth	Mean tooth movement velocity	SD
Lased	30	2.027	0.114
Control	30	1.019	0.110

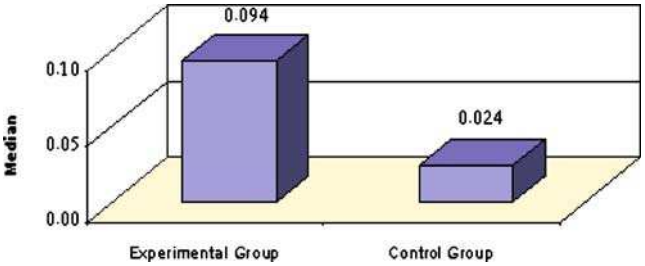

Fig. 1 The effect of laser on the amount of velocity of tooth movement is reported by median of two experimental and control groups ($n=60$)

Pain questionnaire

The pain level was assessed as the shown rank values in Table 2. Every patient was asked about the pain experienced after spring activation. All these data were recorded in a schedule.

Results

Velocity study

The velocity of the movement was obtained from the following formulation:

$$V = d/t$$

where V is the velocity of the canine movement, d is the amount of canine movement in millimeters at the end of treatment, and t is the time passed to accomplish the movement.

Table 3 shows the mean velocity of those movements in both lased and controlled groups. Figure 1 shows that the velocity of tooth movement was bigger in the experiment (lased) side than in the control side (non-lased). Figure 2 shows that the velocity of tooth movement was bigger in the lased group in both jaws. Figure 3 shows that there was not any significant statistical difference between the mean velocity values of the upper and lower canines and the jaw position did not have an effect on the velocity of tooth movement.

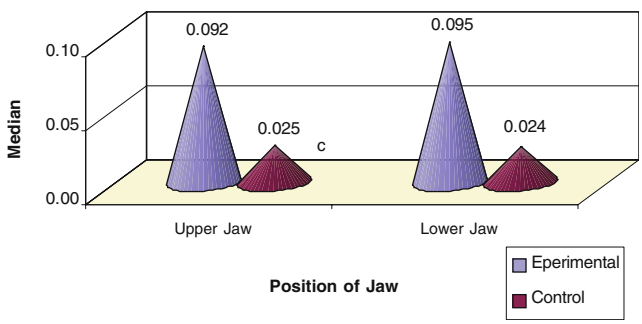

Fig. 2 The effect of laser on the velocity of tooth movement regarding the jaw position is shown ($n=60$)

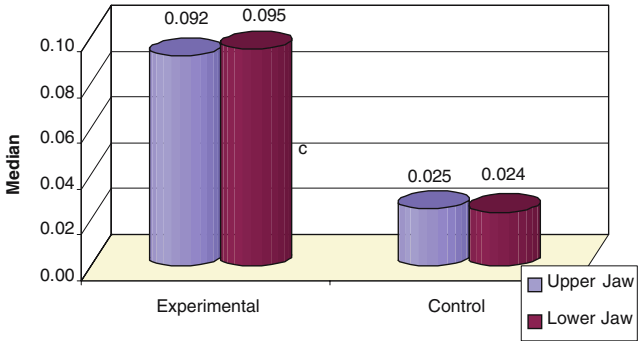

Fig. 3 The effect of jaw position on the velocity of tooth movement is not statistically significant ($P>0.05$)

Pain study

Figure 4 displays the pain level during different treatment stages of lased and control groups.

To study the differences in pain levels between the lased and control groups during combined treatment stages, Man–Whitney *U* test was done. Table 4 shows mean rank values for the degree of pain during combined treatment stages. Table 5 shows Mann–Whitney *U* test results.

In Tables 4 and 5, we can observe the following:

- $P \ll 0.05$ at every combined treatment stage.
- There is a significant difference in the degree of pain between the control and the experimental sides.
- Mean *U* values of the control side are higher than the experimental side.
- The degree of pain is higher in the control side during the first, second, and third stages.

Discussion

Orthodontic tooth movement involves both modeling and remodeling activities that are modulated by systemic factors such as nutrition, metabolic bone diseases, age, and drug usage history [5, 7, 13, 17, 19, 26, 38, 39].

Biologically active substances, such as cytokines, interleukins (IL-1ß, IL-1RA), and enzymes, are expressed by cells within the periodontium in response to mechanical stress from orthodontic appliances [1, 5, 7, 9, 10, 12, 13, 17, 19, 26, 31, 33, 35, 37–39, 41].

IL-1ß is more potent for bone resorption and the inhibition of bone formation, and its role in orthodontic tooth movement has been the focus of previous studies [31, 37].

Inflammatory cytokines have been administered to enhance orthodontically induced bone modeling. Similar effects have been demonstrated with prostaglandin E2 (PGE2) osteocalcin administration to primates [20, 43], and the results have been confirmed clinically [36]. However, in the clinical practice, this needs to be injected within the mucosa, which is associated with pain and discomforts the patients.

Strain-induced catabolic modeling at the bone PDL interface limits the rate of tooth movement [13, 17, 26, 38].

According to several studies, LLLT is an effective tool used to prompt bone repair and modeling post-surgery. This has referred to the biostimulation effect of the LLLT. This effect had been well studied in the medical field and proven to have an enhancement effect on fibroblast growth enhancement, wound healing, and bone repair. This enhancement can be the result of osteoblasts proliferation and differentiation and intracellular changes in these cells [4, 6, 15, 18, 23, 25, 28, 32, 40]. Shimizu et al. studied the effects of low-power laser irradiation on bone regeneration in midpalatal suture during expansion in the rat and concluded that one-time or late irradiation (days 4–6) had no effect. However, irradiation during days 0–2 was most effective. Another research by Skinner et al. showed that fibroblast procollagen produc-

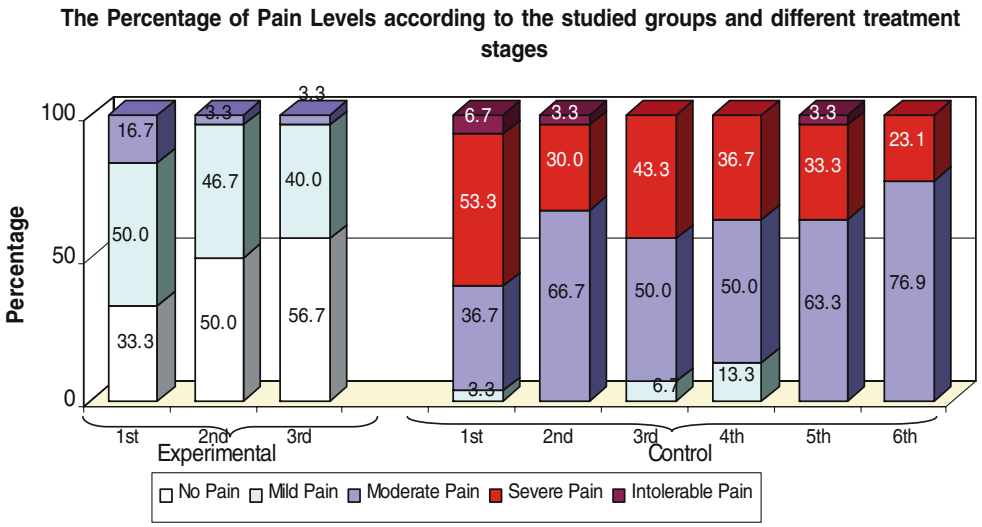

Fig. 4 The pain levels during different treatment stages are reported ($n=60$)

Table 4 Degree of pain reported in different groups (n=60)

Studied variable	Combined stages	Number of canines			Mean rank values	
		Experimental	Control	Total	Experimental	Control
Degree of pain	First stage	30	30	60	16.83	44.17
	Second stage	30	30	60	15.83	45.17
	Third stage	30	30	60	16.22	44.78

tion was increased by using GaAs doses between 0.099 and 0.522 J/cm^2.

Biostimulation effects on the bone repair are directly dependent on the dose applied [4, 25, 40]. Different parameters have proven to be effective for several different lasers, inducing changes within cell cultures and leading to an increased healing effect. Nevertheless, the optimal parameters have yet to be determined [4, 40].

Luger et al. used doses of about 64 J/cm^2 during 14 days, and although this dose could be excessive within the focused area, the authors believe that the scattering reduces the energy level of the laser beams to between 3 and 6% of its original intensity. In our study, the dose of 8 J/cm^2 (the irradiated area was about 1 cm^2) at each of the different points around the tooth is lower than the dose used by Luger et al. (64 J/cm^2), but the distribution of energy into six points surrounding the canine teeth could be more adequate due to a more homogeneous distribution of the energy.

Infrared radiation has a low absorption coefficient in hemoglobin and water, and consequently, a high penetration depth in the irradiated tissue. It is well known that infrared radiation at 750 nm can penetrate more than visible radiation at 650 nm into soft tissues. As the objective of our study was to stimulate bone cells, which are placed deeply under the soft tissue (e.g., gingiva) in the PDL space, the infrared laser was selected for our study.

Some authors have analyzed the effects of LLLT during orthodontic treatment in animals. Saito and Shimizu [32] studied the effects of LLLT on the expansion of midpalatal sutures in rats, comparing the bone regeneration obtained with and without laser treatment. Their results showed that the therapeutic effects of laser are dependent on the total dosage, the frequency, and the duration of the treatment. Their laser-irradiated group showed 20–40% better results when compared to the CG. In another study, Kawasaki and Shimizu [18] showed that the orthodontic movement of laser-irradiated rats' teeth was 30% quicker than the non-irradiated rats due to acceleration of bone formation as a result from the cellular stimulation promoted by LLLT. Our findings are similar to these reports. However, the ratio lased group/control group (LG/CG) obtained in our study was 1.98 (Table of Velocity). This ratio could be the biostimulation factor promoted by LLLT.

In Fig. 1, we can observe that the velocity of tooth movement was bigger in the experiment (lased) side than in the control side (non-lased). Also, we can see in Fig. 2 that the velocity of tooth movement was bigger in the lased group in both jaws. Analysis of the laser effect on the upper and lower jaw reveals that there was not any significant statistical difference between the mean velocity values of the upper and lower canines and the jaw position did not have an effect on the velocity of tooth movement (Fig. 3).

Tooth movement is dependent on a painful, inflammatory adaptation of the alveolar process. To relieve such pain, several methods have been used in the literature. One of those is to use drugs (non-steroidal anti-inflammatory drugs). Although these drugs could be effective in relieving pain, they may also reduce the rate of tooth movement [3, 6, 15, 21, 28]. The application of low-energy lasers in the field of dentistry and oral surgery has been described since the 1970s. Low-energy laser light is supposed to reduce pain, to accelerate wound healing, and to have a positive effect on inflammatory processes. Harazaki et al. [11] and Lim et al. [22] showed that the low-level laser therapy is an effective tool to manage the post-adjustment orthodontic pain. Our findings in this research confirmed the previous findings. Figure 4 displays that, during different treatment stages, the pain level of the lased group was less in amount than the control group.

Table 5 Mann–Whitney U test results are presented

Studied variable	Combined treatment stages	Mann–Whitney U test value	P value	Significance
Pain degree	First stage	40.0	0.000	Significant differences
	Second stage	10.0	0.000	Significant differences
	Third stage	21.5	0.000	Significant differences

In this study, radiographies showed no evidence of damage in the dental and periodontal tissue promoted by the LLLT. Further studies are required to explain the mechanisms of laser biostimulation and clinical trials to optimize treatment parameters and discover other effects promoted by LLLT.

Conclusion

The (GaAlAs) low-level laser used in this study is considered to be an effective tool during orthodontic treatment, as: the rate of tooth movement raised significantly, and the pain level reduced significantly.

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