Influence of Low-Level Laser Treatment on Tooth Movement in Orthodontic Treatment

Lam Nguyen Le[1,*], Thao Thi Do[2], Khanh Phuong Vu Le[3]

1. Department of Pediatrics Dentistry and Orthodontics, Faculty Odonto-Stomatology, Can Tho University of Medicine and Pharmacy, Vietnam.
2. Oral Pathology and Periodontology, Faculty Odonto-Stomatology, Can Tho University of Medicine and Pharmacy, Vietnam.
3. Faculty Odonto-Stomatology, Can Tho University of Medicine and Pharmacy, Vietnam.

Abstract

The amount of time necessary for therapy is one of the most worrisome concerns for patients. Orthodontic treatment normally lasts 2 to 3 years, which increases the risk of gingivitis, dental cavities, and root resorption in extraction cases. As a result, minimizing treatment time is critical, and one key feature is speeding tooth movement. Several studies have shown that low-level laser therapy (LLLT) can boost the activity of osteoclasts, osteoblasts, and fibroblasts both in vitro and in vivo; these reactions result in bone remodeling and improve the pace of tooth movement.

To assess the effects of LLLT on tooth movement in orthodontic treatment by comparing canine retraction distance and time in two groups at T1 (4 weeks), T2 (8 weeks), and T3 (12 weeks), as well as three-time periods: T1-T0, T2-T1, and T3-T2.

This randomized double-blind split-mouth controlled clinical trial comprised 16 orthodontic patients who needed two maxillary first premolars extracted and canines retracted. The time required for canine retraction with LLLT (Group 1) vs the control quadrant of the same patients (Group 2) was measured, as was the distance of canine movement (on models), at three points: 4, 8, and 12 weeks after triggering canine retraction.

Group 1 had a greater total distance of canine movement (T1: 0.84 ± 0.08 mm, T2: 1.71 ± 0.11 mm, T3: 2.56 ± 0.11 mm) than Group 2 (T1: 0.80 ± 0.07 mm, T2: 1.66 ± 0.11 mm, T3: 2.38 ± 0.12 mm). Every four weeks, the change was substantial (p 0.001). The distance of canine movement every 4 weeks was bigger in Group 1 (T1: 0.84 ± 0.07 mm, T2: 0.87 ± 0.1 mm, T3: 0.85 ± 0.07 mm) than in Group 2 (T1: 0.80 ± 0.06 mm, T2: 0.86 ± 0.09 mm, T3: 0.72 ± 0.09 mm). Data were unequal in the first and last sessions ($p < 0.05$). Group 1's movement (0.853 mm/month) was much quicker than Group 2's (0.793 mm/month) ($p < 0.001$).

LLLT is an effective approach for accelerating tooth mobility in orthodontic treatments.

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Introduction

Orthodontics is a dental specialty that focuses mostly on improving face aesthetics and functional occlusion. Patient demand for aesthetics and occlusion has increased in recent years, resulting in an increased need for orthodontic treatment among Vietnamese patients. However, one of the most worrisome aspects for patients is the length of time necessary for therapy. Orthodontic therapy typically lasts 2 to 3 years, which increases the risk of gingivitis, dental cavities, and root resorption in extraction instances.[1-4] Reduced treatment time is required for the reasons stated above, and one of the important aspects is accelerated tooth movement. Much study has been conducted in a variety of domains, including biology, physics, biomechanics, and surgery, to describe strategies that can sustain the pace of tooth movement. Several papers indicate that injections of local prostaglandins or osteocalcin, cytokines, or parathyroid hormone around the alveolar bone can increase tooth movement.[1,5-8]

***Corresponding author:**
Lam Nguyen Le, DDS, MSc, PhD
Associate Dean, Faculty of Odonto-Stomatology,
Head of Department of Pediatrics Dentistry and Orthodontics,
Can Tho University of Medicine and Pharmacy,
Can Tho city, Vietnam;
E-mail: lenguyenlam@ctump.edu.vn

Corticotomy, a prominent procedure in recent years, primarily lowers cortical bone resistance and accelerates tooth mobility.[1, 8] However, because it takes more intervention and is more expensive, patients will only accept it if it is their only option.

Because it is a non-intervention therapy that is easy to obtain and does not require expensive equipment, low-level laser therapy (LLLT) has emerged as one of the most promising new supportive treatment approaches in recent years.[9] Several studies have found that LLLT can boost the activity of osteoclasts, osteoblasts, and fibroblasts both in vitro and in vivo, resulting in bone remodeling and faster tooth movement.[10-13] Animal studies have identified the effects of LLLT on accelerating tooth movement, but human studies are extremely variable,[14-18] and the number of studies is restricted. To begin addressing the difficulties raised above, we decided to undertake this study to assess the impact of LLLT on enhancing orthodontic tooth movement, with the following goals in mind: 1) Determine and compare the total distance of canine movement in three periods across two groups, with LLLT and a control quadrant of the same patients: T1 (4 weeks), T2 (8 weeks) and T3 (12 weeks); To evaluate the distance of canine movement between two groups at three intervals: T1-T0 (activating canine retraction), T2-T1, and T3-T2; and 3) To compare the speed of canine movement between two groups at T3.

Materials and methods

Study subjects and study design

From 01/2018 to 06/2019, 16 patients (8 males and 8 females) sought orthodontic treatment at the Faculty of Odonto-Stomatology, Can Tho University of Medicine and Pharmacy, with two maxillary first premolars extracted to create space for aligning and leveling the dental arch and/or retraction of protruding maxilla. Inclusion criteria include being between the ages of 12 and 35, having full permanent dentition, having two premolars removed at least three months before initiating canine retraction, and having symmetrical canine location, form, and size on both sides. Exclusion criteria: patients with systemic diseases (diabetes, kidney syndromes, bone defects), periodontitis, malignant or benign tumors, etc.; using medicines that are damaging to bone remodeling and repair (heparin, warfarin, non-steroidal anti-inflammatory drugs, cyclosporine, glucocorticoids, etc.); patients who required the extraction of more than two maxillary first premolars.

Model preparation

Impressions were obtained from the 16 patients using alginate in the proportions specified by the manufacturer (Tropicalgin, Zhermack®, Italy). Impressions were recorded three times before power chain activation: at the start of canine retraction (T0), 4 weeks later (T1), 8 weeks later (T2), and 12 weeks later (T3) (T3). The firm plaster mixture was then poured into the impression to form the dental castings, and measurements were taken on the model using an electronic caliper and palatal lock.

Orthodontic preparation

After an examination and clinical characteristics were recorded, frontal and lateral cephalometric and panoramic films were evaluated on both sides, and the patients were treated with fixed orthodontic bracket systems (Victory Series metal bracket system MBT 0.022" slot, 3M Unitek®, United States). After the aligning and leveling procedures were completed, two maxillary first premolars were removed to provide room for canine retraction.

Palatal lock preparation

Acrylic resins were pressed into the incisive papilla and middle area of the premaxilla procedure, and two reference stainless steel wires were used to cover the rugae palatine (0.9 mm in diameter). The mesials of the two reference wires were buried in the resins, and the laterals were sharpened and placed on the canine's mesial side. To superimpose and quantify the distances of canine movement, this palatal lock was put to match with the incisive papilla and medial palatal raphe on the following models (Figures 1 and 2).

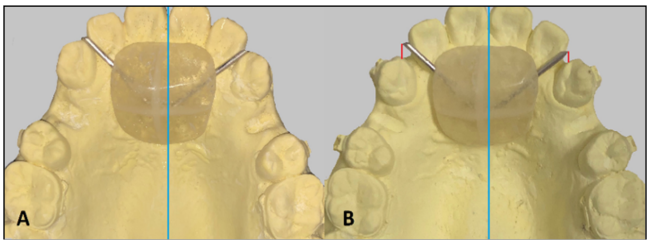

Figure 1. (A) Canine retraction phase study model and palatal lock; (B) canine movement measurement technique. The blue line represents the centre of the maxilla, and the red lines run parallel to it. The accumulable distance

of canines was calculated by measuring the distance between the top stainless-steel wire and the junction of the red line and the canine.

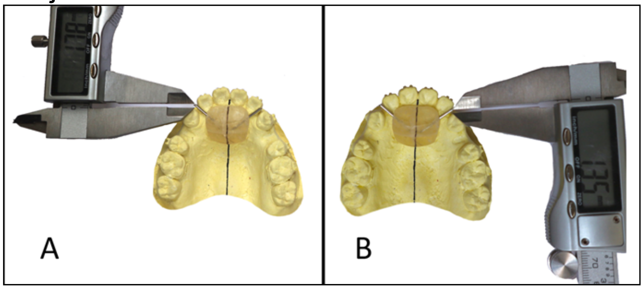

Figure 2. Canine retraction distance is measured with an electronic caliper. LLLT exposure site (A); control site (B).

Low-level laser therapy procedures

The left or right canines of the maxillary arch were randomly assigned to Group 1, which was treated with a GaAlAs Semiconductor Diode Laser with a wavelength of 810 nm, 100 mW output power, and a projector lens with a diameter of 400 m, projecting the laser on the canine root in three regions - cervical, middle, and apical root - on both the buccal and lingual surfaces, moving the irradiation period in each zone was 10 seconds (1 J/zone, 6 J/tooth, irradiation dose 5.1 J/cm^2), and the patient's remaining tooth was allocated to Group 2 (the laser was inserted into the mouth but there was no exposure). On the first and fourteenth days of each month, laser irradiation was performed (Figure 3).

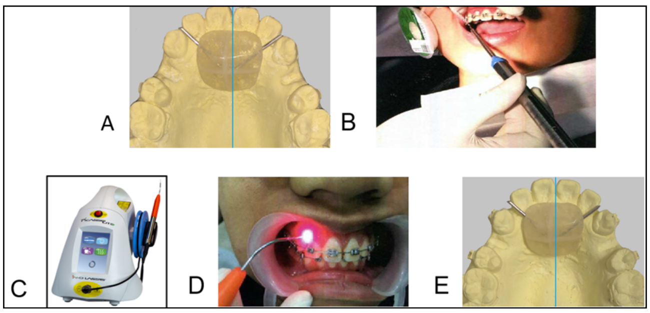

Figure 3. Examine the methods. (A) Impression and pouring of a dental model, as well as the fabrication of a palatal lock, following first premolar extraction and before canine retraction; (B) determining the number of pressures applied to the canines for retraction (150 g of force per side for translation movement); (C) projecting the laser onto the canine root in three one-third regions - cervical, middle, and apical root on both the buccal and lingual surfaces (each irradiation zone is 0.196 cm^2); (D) using the Picasso Lite+ Semiconductor Diode Laser with a wavelength of 810 nm, 100 mW output power, and projector lens with a diameter of 400 m; (E) every 4 weeks from the first day of LLLT exposure, take an impression and pour a dental model to measure the distance of canine movement, inserting the palatal lock on the model and calculating the distance from the mesial side of the canine to the reference stainless steel wire on each side.

Statistical analysis

The non-parametric Kolmogorov-Smirnov test was performed to determine the data's standard distribution. The Kruskal-Wallis non-parametric test and the paired t-test were used to compare data between periods in the same group. The t-test for two independent samples was used to compare data between the two groups at each time. All tests were run with a significance threshold of 5%. SPSS 16.0 software was used to process and analyze the data.

Results

Study subjects

The study's 16 patients (8 men and 8 females) had an average age of 22.53 ± 3.54 years. Figure 4 depicts the research design flow chart.

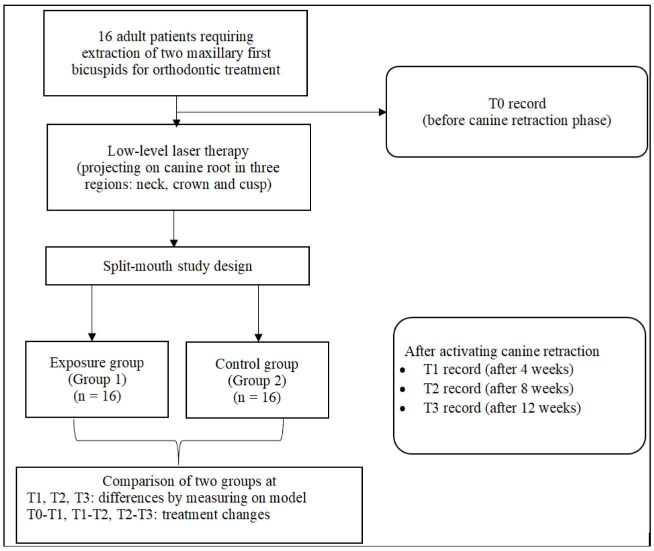

Figure 4. Design flowchart for research.

Canine movement in the two groups

The total distance of canine movement measured in Group 1 was substantially greater than that in Group 2 every 4 weeks ($p < 0.001$) (Table 1). The difference was about identical at T1, and subsequently, Group 1 teeth began to travel further than Group 2 teeth at T2 and T3.

As demonstrated in Table 2, the distance of canine mobility in Group 1 was significantly larger in the first and last four weeks than in Group 2 ($p < 0.05$). However, there was no significant difference between the two groups in the second period ($p > 0.05$).

The average speed of canine locomotion was computed after measuring the distances traveled every four weeks. It was 0.853 ± 0.08 mm/month in Group 1, which was significantly quicker than the rate in Group 2 during 12 weeks (0.793 ± 0.08 mm/month; $p < 0.001$) (Figure 5).

Moment	The total distance of canine movement		p
	Group 1 (mm)	Group 2 (mm)	
T1	0.84 ± 0.08	0.80 ± 0.07	< 0.001
T2	1.71 ± 0.11	1.66 ± 0.11	< 0.001
T3	2.56 ± 0.11	2.38 ± 0.12	< 0.001

Table 1. The total distance of canine movement of two groups in three periods: 4, 8, and 12 weeks.
(T1: 4 weeks after activating retraction of canines, T2: 8 weeks after activating retraction of canines, T3: 12 weeks after activating retraction of canines)

Period	Distance of canine movement		p
	Group 1 (mm)	Group 2 (mm)	
∆1	0.84 ± 0.07	0.80 ± 0.06	< 0.001
∆2	0.87 ± 0.1	0.86 ± 0.09	0.195
∆3	0.85 ± 0.07	0.72 ± 0.09	0.001

Table 2. Canine movement distance (mm) in Group 1 was greater than in Group 2 in the first, middle, and last four weeks.
(∆1: distance of canine movement at T1, ∆2: distance of canine movement at T2, ∆3: distance of canine movement at T3)

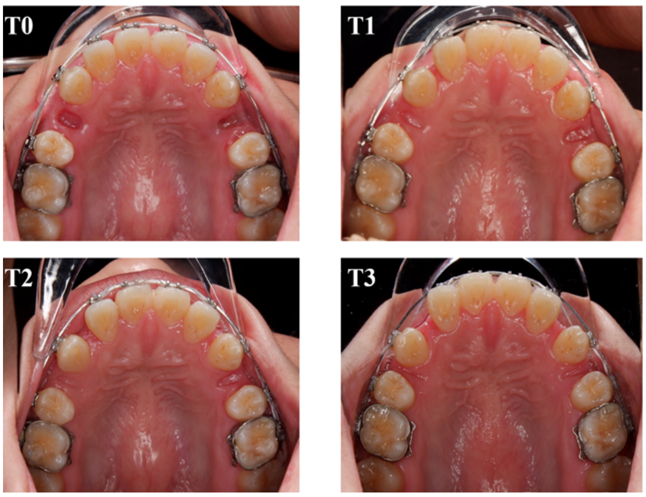

Figure 5. Photographs of intraoral maxillary occlusal views were taken at four different times: (T0) before the canine retraction phase, (T1) 4 weeks after activating canine retraction, (T2) 8 weeks after activating canine retraction, (T3) 12 weeks after activating canine retraction.

Discussion

Our research included 16 patients, with an equal proportion of males and females. The patients in this research ranged in age from 17 to 31, with a mean of 22.53 ± 3.54 years. The age of the patients in our study is higher than in other studies throughout the world, for example, in Doshi-study, Mehta's age ranged from 12 to 23 years,[15] since the necessity for fixed orthodontic treatment differs by nation, depending on socio-economic development. People in greater socioeconomic development nations prioritize orthodontic treatment and seek it sooner. Our research findings originally revealed good outcomes, similar to the majority of prior authors' investigations. Doshi-Meta, Garg, and Sousa's research found that the total distance of canine movement in Group 1 was considerably greater than that in Group 2 at all periods.[15, 16, 19]

We opted to initiate canine retraction at least 3 months after the first premolars were excised rather than retracting the canines immediately. The extraction socket heals for three months. In Hasler's study, canine migration into recently removed compared to healed sockets was quicker, although the tooth was tilted more because canine roots are longer than premolar roots.[20] Our study outcomes were initially good, as were the majority of prior authors' investigations. When the distance of canine movement was compared between groups 1 and 2, it was discovered that it was considerably greater in Group 1 than in Group 2 at the beginning and conclusion of the evaluation. Kawasaki and Shimizu found that using an 830 nm diode laser with a power of 100 mW at three points within three minutes for each position around the moving molars, the tooth movement was 30 percent faster in the laser group than in the control group, because the LLLT stimulates cell operations, increasing bone formation. In the early stage, immunohistochemical labeling revealed that the number of osteoclasts in the pressure zone was 1.6 times higher than in the control group, and the cells were more differentiated in the tension zone.[10] When comparing each time, the distance of canine movement in Group 1 was considerably greater than that in Group 2 in all periods, although the highest difference was in the middle four weeks and the lowest difference was in the initial four weeks. The cells in Group 1 were in the window period and sensitive during the middle four weeks, therefore they reacted to LLLT dosages. Furthermore, because the cell proliferation activity was higher, the tooth movement was quicker than in Group 2. There was much less movement of exposed canines in the first four weeks than in the middle four weeks, which might be explained by the cells still being in the first stage of partial activation caused by LLLT. The canine movement in Group 1 was significantly reduced in the last 4 weeks compared to the middle 4 weeks (Table 2) due to the systemic efficacy of LLLT, which occurred in the last 4 weeks when the laser stimulated the release of biologically active substances, allowing the circulatory system to act on the non-irradiated contralateral canines. Some investigations, such as Mester's, have also reported on the systemic effects of LLLT.[21]

The tooth movement speed ratio in Group 1 was 1.07. In other words, canines in Group 1 moved quicker than canines in Group 2. This is consistent with the findings of the Doshi study, Mehta's which found that canine movement in the upper and lower jaws was quicker in the laser group than in the control group.[15] Garg's study found that canine movement was faster in the laser group than in the control group,[16] because the LLLT irradiation parameter in Limpanichkul's study (25 J/cm2),[3] was too high for the bio stimulating effect to increase tooth movement speed when compared to a lower irradiation dose such as 5 J/cm^2 in Doshi-Mehta and Sousa's study or 8 J/cm^2 in Youssef's study.[15, 19, 22] According to Amdt-law Schulz's irradiation dose for bio stimulating effect, a low dose generates an effect, a medium dose improves the impact, and a large dose might prevent the effect.[21]

Our findings are similar to those of Garg, who discovered in his 84-day study that there was a significant increase in canine movement speed in the laser group compared to the control group in the 3rd interval (from the 43rd to the 63rd day) in the upper jaw, and in the 3rd (from the 43rd to the 63rd day) and 4th intervals (from the 64th to the 84th day) in the lower jaw.[16] We discovered that if research is conducted for a long enough period, there is a very good chance that there will be a difference between Group 2 and Group 1. Studies that show differences are frequently conducted over weeks rather than months.[23] Furthermore, other investigations done over a shorter period revealed variations in tooth movement speed with LLLT.[10, 24] Notably, other research groups, such as Fujita et al. on rat molars, found a substantial difference between the control group and the laser group after only a few days of investigation. After 3, 4, and 7 days, tooth movement speed rose by 2.2 times, 2.0 times, and 1.5 times in the laser group compared to the control group, respectively. Kawasaki and Shimizu's investigation of mice revealed that tooth movement in the laser group was 1.4 times quicker than in the control group on the second day, 1.2 times faster on the 4th day, and 1.3 times faster on the 12th day.[10, 25] After 7 days, Genc's human investigation revealed a difference between the two groups.[26] The method used to measure tooth movement, the patients, the force in the tooth movement, and the age of the patients can explain most of these differences, but it also raises questions about the effectiveness of LLLT during different periods of treatment because the researcher used a high dose of 25 J/cm^2 to avoid a stimulating effect. It is also difficult to compare outcomes between research since various orthodontic appliances, mechanical anchoring designs, measuring methodologies, and, most significantly, laser wavelengths and irradiation parameters are used. Although the optimal dose of irradiation is uncertain, it appears that low energy densities (2.5, 5, and 8 J/cm^2) are more effective than high energy levels (20 and 25 J/cm^2).

Much research has been conducted to assess the influence of LLLT on orthodontic tooth movement speed. The majority of published study data show that LLLT speeds up orthodontic tooth movement.[10, 15, 16] Meanwhile, two studies have concluded that the laser slows tooth mobility.[11, 23] In our study, there was an increase in tooth movement speed following LLLT irradiation. Many factors complicate a direct comparison of the current study and previous studies, including different laser irradiation parameters (wavelength, power, energy density, irradiation mode, time, and multiple exposures), different animal samples (dogs, rabbits, mice), and different canine retraction mechanisms, as well as the method used to measure tooth movement. Our research has several limitations. The research model size was modest, and at the end of the study, other effects such as discomfort, canine tilt, and root resorption were not compared between the two groups. There have been no comparison research at various therapeutic energy levels, wavelengths, powers, or frequencies. There are no histology studies available.

Conclusions

LLLT with the settings utilized in our study (GaAlAs diode laser with a wavelength of 810 nm, power of 100 mW, continuous mode, twice-a-month irradiation, irradiation dose of 5.1 J/cm^2) initially demonstrated a beneficial effect on tooth movement speed in orthodontic therapy.

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Declaration of Interest

All authors have no conflict of interest relevant to this article.

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