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Effect of 940-nm Low-Level Laser Therapy on Tooth Movement Rate during Orthodontic Treatment: A Split-Mouth Double-Blind Randomized-Controlled Trial

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Abstract

Objective: *This study aimed to evaluate the effect of low-level laser with wavelength of 940 nm on acceleration of orthodontic tooth movement.* ***Materials and Methods:*** *This study was a double-blind randomized-controlled trial with split-mouth design. Fifty-five patients whose four first premolars were extracted for orthodontic treatment were randomly allocated to group A (n = 27) and group B (n = 28). Canine retraction was performed using the force of 150 g in every patient. The patients of group A received active laser irradiation (wavelength of 940 nm, power output of 50 mW, energy of 5 J/cm^2) on the right side, no active irradiation on the left side. And those of group B received active laser therapy on the left side, no active irradiation on the right side. Irradiation was performed at two weeks interval. The amount of canine retraction was assessed on dental cast at four weeks interval (T1, T2, T3). And overall canine retraction time was also evaluated.* ***Results:*** *There was a significant difference in the canine retraction rate between laser and placebo groups. At T3, canine retraction speed in laser irradiation side was about 1.6 times faster than that in no laser side. And our results showed that laser irradiation shortened canine retraction time by 21.8% in maxilla and 23.4% in mandible.* ***Conclusion:*** *Low-level laser with wavelength of 940 nm can accelerate the orthodontic tooth movement and reduce the overall treatment time when applied at 2 weeks interval.*

Keywords: Orthodontic, laser, canine retraction, tooth movement acceleration, accelerated orthodontics, low-level laser therapy (LLLT).

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INTRODUCTION

Orthodontic treatment requires a long treatment duration lasting between two and three years for proper completion. Prolonged treatment times can lead to a loss of patient cooperation and development of dental diseases such as caries, periodontal diseases, and root resorption. Therefore, accelerating tooth movement rate and reducing the total treatment time is desirable for both patients and clinicians [1, 2].

For past two decades, many attempts have been made to accelerate orthodontic tooth movement，including invasive methods and non-invasive technical methods such as local injection of biomodulators, electrical stimulation, and ultrasound therapy [3].

One of the non-invasive methods, low-level laser therapy (LLLT), is attracting more interest among orthodontists in recent years. LLLT is known to be an easy method to use with no adverse effect [4]. LLLT has been introduced in orthodontic practice to accelerate tooth movement and to reduce post-adjustment pain because of its bio-modulatory, anti-inflammatory, and analgesic effects. The several human and animal studies have shown that the application of LLL is effective not only to reduce the overall orthodontic treatment time but also to reduce pain during orthodontic treatment [5]. However, other studies have concluded that LT was not effective in acceleration of tooth movement [6, 7]. These contradictory results may be due to the difference in parameters, including wavelength, dose of irradiation, exposure time, and application method.

In a systematic review on LLLT studies, it was found that most of studies used Ga–Al–As diode laser with a wavelength of 780–904 nm and 20–100 mW of power output, and that the favorable range of energy density for orthodontic tooth movement was 4.2–8 J/cm^2 [8]. And recent studies on animals have shown that laser with higher wavelengths allows too deeply penetrate through soft tissue to reach hard tissues [9].

Therefore, the present study was planned to evaluate the efficacy of 940 nm LT (power output: 50 mW, dose: 5 J/cm^2) on acceleration of orthodontic tooth movement. The primary objective of the research was to compare the velocity and overall time of canine retraction of laser irradiation group with that of the non-irradiation group.

MATERIALS AND METHODS

Study Design

The study was a double blind, randomized-controlled trial to evaluate the effect of LLLT on acceleration of tooth movement. Ethical approval was obtained from the ethic board of the public health office in Pyongyang People's Committee (0039–2020). The sample size was calculated based on a preliminary power analysis, which showed that 32 patients (16 for each group) were required to detect a difference of 30 days in overall canine retraction time between laser group and placebo groups. Nevertheless, we inflated the sample size to be 27 patients per group to increase the robustness of data.

Participants/Inclusion Criteria

The study was performed between April 2020 and September 2022. Participants were patients attending the Department of Orthodontics, Faculty of Dentistry at Pyongyang University of Medical Sciences. Clinical examination on 107 patients seeking orthodontic treatment was performed.

The inclusion criteria were: full permanent dentition (exception of third molars), requiring extraction of all first premolars in upper and lower jaw for the purpose of orthodontic treatment, and no dental or orthodontic treatment previously.

The patients with poor oral health and those with any systemic disease such as osteoporosis, vitamin D deficiency was excluded from the study. And the patients in chronic use of any medication affecting orthodontic tooth movement were also excluded.

Informed consent was obtained from all patients and their guardians.

Randomization

Patients were randomly divided into group A and group B. To prevent selection bias, the randomization was performed using a simple technique, coin tosses. The sides contralateral to the procedures served as group B.

For the patients of group A, active laser irradiations were performed on the right side of jaws and placebo laser irradiations were performed on the left side. In contrast, active laser irradiations on the left side and placebo laser irradiations on the right side were performed for those of group B. The patient side was blinded to the therapy.

At the end of study, for the statistical analysis, the data collected for laser irradiation sides were regrouped to LLLT group, and remaining sides to placebo group.

Intervention

Every patient underwent orthodontic treatment with a fixed appliance. A week after extraction of four first premolars, a straight wire appliance (Roth prescription 0.022-inch slot, Ormco) was bonded. Leveling and alignment of both dental arches with a 0.014 inch or 0.016-inch Ni–Ti wire was done as the initial orthodontic treatment. Then, 0.019 × 0.025-inch stainless steel archwire was left in situ for several weeks to ensure at least three months after removal of first premolars. Before starting to retract canines, a dental cast was obtained by alginate impression and temporary anchorage device (TAD, 1.8 × 8 mm, UnitekTM) was inserted buccally between second premolar and first molar. Canines were retracted using Ni–Ti closed coil spring extended between TAD and the hooks of canines with a force of 150 g. The magnitude of force was measured using a force gauge (CORREX, Swiss).

To determine the amount of canine retraction after application of orthodontic force, the distance between the cusp tip of canine and mesiobuccal cusp tip of the first molar was measured using a digital caliper on dental cast. Every four weeks upper and lower dental models were obtained.

For the patients of laser group, low level Ga–Al–As laser irradiation (940 nm, 5 J/cm^2) was applied to 10 points of each canine root (center of root, cervico-mesial, cervico-distal, apico-mesial, apico-distal, at buccal and lingual side of tooth, respectively.). Irradiation time for each point was 30 seconds. Follow-up visits were planned every two weeks for laser re-irradiation until the canine retraction was complete.

Statistical Analysis

All data tabulation and statistical evaluation were carried out using SPSS for windows version 20.0 by a statistician who was blinded to the study and T-test with significance level set at 0.05.

RESULTS

The flowchart of the participants through the study is shown in Figure 1. A total of 107 patients were invited to participate. Among them, 51 patients were excluded from the study because they didn't meet inclusion criteria or declined to participate. Remnant 56 patients were randomly allocated to group A or group B. During the study, 1 patient of group B discontinued the therapy.

Finally, 55 patients were analyzed. Among them, 21 were male patients and 34 were females in the average age of 18.2 (age range of 16~22 years). The demographic data of participants is shown in table 1.

Table 2 represents the amount of canine retraction at every stage of the study. Statistically significant differences were found in the amount of canine retraction between LLLT and control group in maxilla and mandible from T1 ($p < 0.05$). For the maxilla, the rate of canine retraction in LLLT group was 1.3 times at T1, 1.46 times at T2, and 1.8 times at T3 faster than that in control group. And for the mandible, when laser was applied， increment of canine retraction speed was 1.14 at T1, 1.32 at T2, and 1.44 at T3.

Total time needed to complete canine retraction is represented in Table 3. Comparing the overall time of canine retraction with control group, laser group showed 21.8%, 23.4% decrease in maxilla and mandible, respectively. There were significant differences in total time of canine retraction between LLLT group and control group ($p < 0.05$).

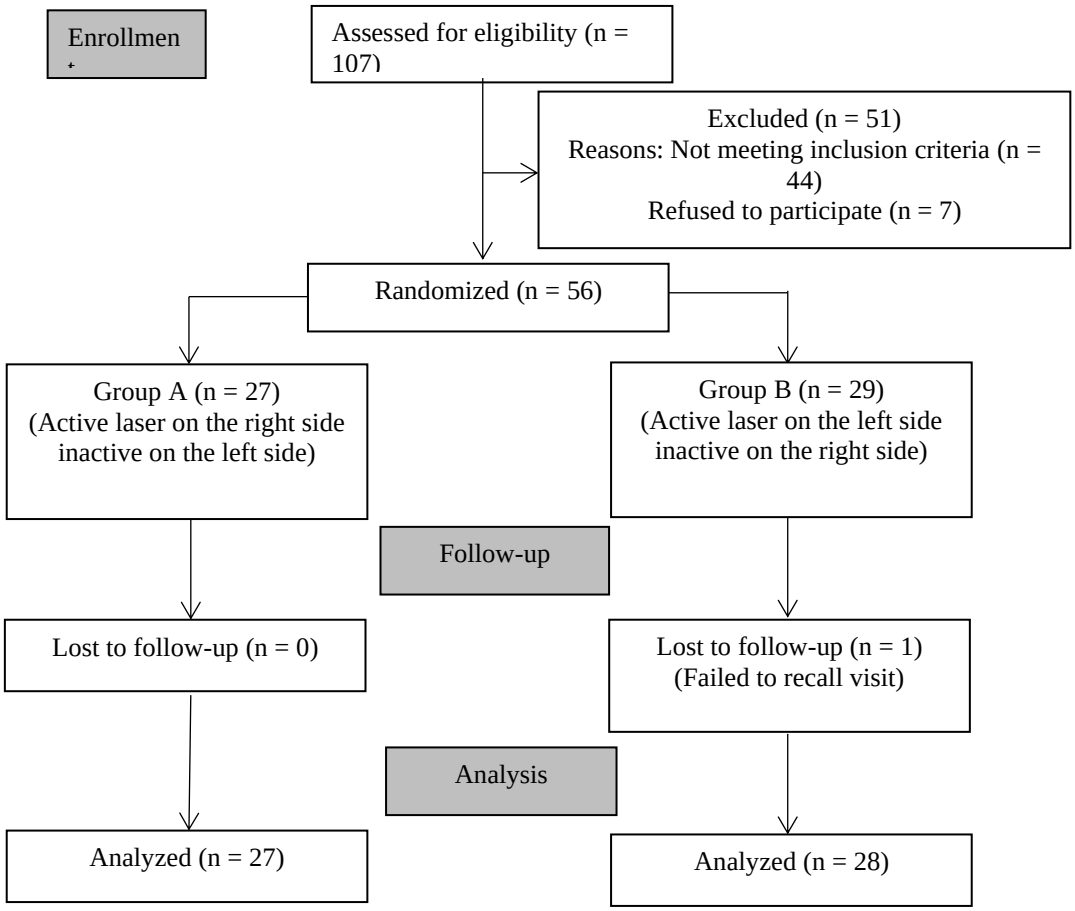

Figure 1. Flowchart of the trial participants.

Table 1. Demographic data of participants at the end of study.

Group	**Age** **Mean ± SD (years)**	**Sex**	
		Male	**Female**
Group A (n = 27)	17.3 ± 5.2	11 (40.7%)	16 (59.3%)
Group B (n = 28)	19.1 ± 3.7	10 (35.7%)	18 (64.3%)
Total (n = 55)	18.2 ± 4.5	21 (38.2%)	34 (61.8%)

DISCUSSION

The prolonged treatment duration is one of the major drawbacks of orthodontic treatment. To reduce treatment duration, various invasive and non-invasive methods have been introduced [10]. Because of limitation of traditional methods and invasiveness of several surgical methods, more orthodontists' interest in physical methods is growing up. Among them, LLLT, one of the non-invasive methods, is promising for accelerated orthodontics nowadays [11].

This study was performed to evaluate the efficacy of LLLT in accelerating tooth movement for canine retraction of extraction cases. Through the study, it was found that LLL shortened the total time needed for canine retraction by approximately 22~23%.

In this study, we used an LLL device with the wavelength of 940 nm. Many of studies have been conducted with lower wavelengths (670~904 nm), and efficacy of laser with higher wavelengths have not been well studied [12]. And it was shown that the laser with higher wavelength can penetrate the deep areas of periodontal tissues [4]. So, we selected LLL with wavelength of 940 nm and studied the efficacy of it on orthodontic tooth movement.

The dose of laser is also one of the important parameters of laser affecting orthodontic tooth movement. Too low dose of laser may not induce any positive biological effect, and in contrast, there could be bio-suppressive effect at too high dose [13]. There is no optimal dose defined yet. The dose used in this study was 5 J/cm^2.

In this study, we applied LT every two weeks. Intervals of laser application varied for different studies from one week to four weeks [13]. Current studies on LLLT for orthodontic tooth movement applied the laser either daily or at shorter intervals in between two applications [14]. And a systematic review showed that there was a significant increase in tooth movement rate at shorter intervals of laser application than long interval (once a month) [15]. So, we thought that laser exposure at every two weeks interval is appropriate.

Our results showed statistically significant differences (p-value less than 0.05) in the amount of canine retraction from T1 (Table 2). And when laser was applied, the greater increment of canine retraction speed in maxilla was observed compared with that in mandible. It seems to be the result that the laser penetrates the bone of maxilla more efficiently than mandible.

Table 2. The amount of canine retraction every four weeks.

Jaw	Group	T1		T2		T3	
		M ± SD (mm)	p-value	M ± SD (mm)	p-value	M ± SD (mm)	p-value
Maxilla	LLLT	0.67 ± 0.17	<0.05	1.24 ± 0.26	<0.05	1.69 ± 0.23	<0.05
	Control	0.52 ± 0.18		0.85 ± 0.21		0.94 ± 0.24	
Mandible	LLLT	0.50 ± 0.14	<0.05	0.96 ± 0.25	<0.05	1.27 ± 0.18	<0.05
	Control	0.44 ± 0.15		0.73 ± 0.23		0.88 ± 0.17	

Total time needed for canine retraction was 116.7 ± 24.5 days for laser group, 149.3 ± 35.2 days for control group in maxilla and 137.1 ± 22.8, 179.0 ± 31.6 days in mandible. Several researchers used higher wavelength radiation of laser and met with acceptable result for orthodontic tooth movement [16]. It showed 940 nm laser (dose: 7.5 J/cm^2) irradiation accelerated canine retraction when laser was applied at three weeks interval, which agrees with our results. It showed the increase in the rate of orthodontic tooth movement of 56% at the laser site (808 nm, 0.25 mW) when compared to control at the end of three months, which coincides with our results [17].

Our results also showed that laser application reduced canine retraction time by 21.8% in maxilla and 23.4% in mandible (Table 3) [4]. It was found that 35% reduction in overall canine retraction time when applied laser (810 nm, 5 J/cm^2), which is like that of our results but slightly higher.

Table 3. Total time needed to complete canine retraction.

Side	Total Time to Complete Canine Retraction (d)		Reduction Rate (%)	p-value
	LLLT	Control		
Maxilla	116.7 ± 24.5	149.3 ± 35.2	21.8	<0.05
Mandible	137.1 ± 22.8	179.0 ± 31.6	23.4	<0.05

From the study, we found that 940 nm LLLT is a promising method in accelerating orthodontic tooth movement and decreasing the overall duration of orthodontic treatment.

Future studies are needed to evaluate the efficacies of 940 nm laser comparing with other application interval and different doses.

CONCLUSION

This study demonstrated that LLLT with a 940 nm wavelength, applied at two-week intervals, effectively accelerates orthodontic tooth movement during canine retraction. The results showed a significant reduction in overall treatment time –by approximately 22–23% —in both the maxilla and mandible. Therefore, LLLT is a promising non-invasive method for shortening orthodontic treatment duration. Further research is recommended to explore the efficacy of different laser application intervals and doses.

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CONFLICTS OF INTEREST

There are no conflicts of interest declared.

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