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Effects of low-level laser therapy on the rate of orthodontic tooth movement

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Structured Abstract

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Objectives – To test the hypothesis that mechanical forces combined with low-level laser therapy stimulate the rate of orthodontic tooth movement.

Study design – This study was a double blind, randomized placebo/control matched pairs clinical trial to test the efficacy of GaAlAs low-level laser therapy (LLLT) on 12 young adult patients who required retraction of maxillary canines into first premolar extraction spaces using tension coil springs with fixed edgewise appliance. LLLT was applied on the mucosa buccally, distally and palatally to the canine on the test side and using a pseudo-application on the placebo side. Dental impressions and casts were made at the commencement of the trial and at the end of the first, second and third months after starting the trial. Measurement of tooth movements was made on each stage model using a stereo microscope.

Results – There was no significant difference of means of the canine distal movement between the LLLT side and the placebo side for any time periods (p -value = 0.77).

Conclusion – The energy density of LLLT (GaAlAs) at the surface level in this study (25 J/cm^2) was probably too low to express either stimulatory effect or inhibitory effect on the rate of orthodontic tooth movement.

Key words: low-level laser therapy; orthodontic tooth movement

Introduction

Generally, the period of time required for fixed appliance treatment in orthodontic patients is around 2–3 years. In long-term treatment, there is an increased risk of root resorption, gingival inflammation and dental caries. Reducing orthodontic treatment time requires increasing the rate of tooth movement.

Dates:

Accepted 30 June 2005

To cite this article:

Orthod Craniofacial Res 9, 2006; 38–43
Limpanichkul W, Godfrey K, Srisuk N,
Rattanayatikul C:
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Many studies have tried to find methods that can increase the rate of tooth movement without damage to the tooth and periodontium at the same time. Recently, several papers showed that the acceleration of tooth movement can be produced by the local injection of prostaglandins (PGs) (1,2), $1,25(\text{OH})_2\text{D}_3$ (the active form of vitamin D_3) (3–5) and osteocalcin around the alveolar socket (6). Even though these substances stimulated the rate of tooth movement, they also caused undesirable side effects such as local pain and discomfort for the patient during the procedure of injection.

More recently, different researchers have studied the results of low-level laser therapy (LLLT) and found that its stimulatory effects can accelerate bone regeneration in a midpalatal suture during rapid palatal expansion (7) and stimulate synthesis of collagen, which is a major matrix protein in bone (8,9). Other studies found that laser irradiation can stimulate bone regeneration at bone fracture and extraction sites (10,11) and increase the rate of orthodontic tooth movement in rats (12). From all of these observations, LLLT seems to be a good choice for its stimulatory effects of accelerating orthodontic tooth movement because it increases alveolar bone remodelling without injuring the tooth and periodontium. However, until now no paper regarding the effects of LLLT on orthodontic tooth movement in a clinical trial has been published.

The objective of this study was to test the hypothesis that in a clinical trial orthodontic retraction of maxillary canines on the LLLT side was larger than on the placebo side at the end of the first, second and third months after the first radiation.

Materials and methods

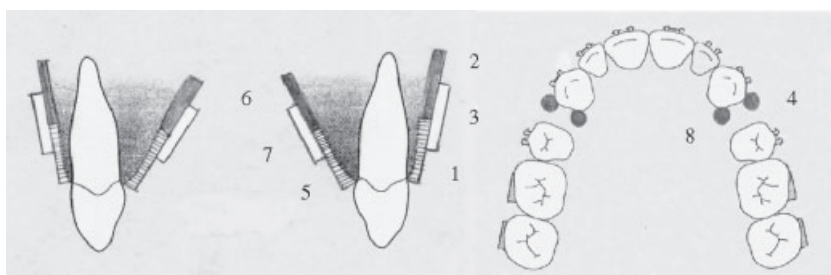
Twelve young adult patients (four males and eight females; mean age 20.11 ± 3.4 years) from the Orthodontic Department of Khon Kaen University, who had maxillary first premolars extracted on both sides and met all of the case selection criteria, were invited to participate in the study.

The inclusion criteria were: 1) the maxillary first premolars had been extracted on both sides at least 3 months before starting to move canines distally after complete aligning and levelling. This period was allowed for bone fill-in of the extraction sockets before the study period (13,14); 2) left and right canines, second premo-



Fig. 1. The full edgewise arch set-up.

lars and first molars were present in the maxillary arch; 3) the patient had already well aligned and levelled, upper teeth and ready to retract maxillary canines; and 4) the subject gave informed consent to participate in the trial. Block randomization was used to allocate the side of the maxillary teeth (left and right sides) to be the LLLT and the placebo sides. The full arch set-up of orthodontics was the same on both the LLLT and placebo sides (Fig. 1). A pre-adjusted edgewise appliance (Roth prescription) was used for all teeth, except that self-ligating SPEED® brackets (Strite Industries Ltd., Cambridge, Canada) were used on both maxillary canines to standardize frictional effects during canine retraction. The maxillary canines were retracted distally after complete aligning and levelling on 0.018 in. Australian Premium Plus archwire in a 0.022×0.028 slot. Vertical loop (3 mm) stops mesial to the molar tubes combined with en-massed upper incisors by ligation on the main archwire provided the orthodontic anchorage for all patients. In addition, the vertical loop was ligated to the hook of the first molar instead of at the cinch-back of the archwire. The archwire was left *in situ* for at least 1 month to become passive before starting to retract canines, which was delayed for at least 3 months after extraction of the premolar teeth to allow alveolar bone consolidation at the extraction sites. A light NiTi closed coil spring (Ormco®, Sybron Dental Specialities Inc., Newport Beach, CA, USA) was used to retract each canine posteriorly (Fig. 1), secured with ligature wire to give an initial force of 150 g attached between the upper canine and the first molar. The force was activated once each month to reactivate the spring tension to 150 g set with a CORREX® tension gauge (HAAG-STREIT, Bern, Switzerland).



- Note:** 1 = probe positioned at the gingival margin of the canine at the buccal side
 2 = probe positioned at 8 mm from the gingival margin of the canine at the buccal side
 3 = probe positioned at 4 mm from the gingival margin of the canine at the buccal side
 4 = probe positioned at the gingival margin of the canine at the distolabial line angle
 5 = probe positioned at the gingival margin of the canine at the palatal side
 6 = probe positioned at 8 mm from the gingival margin of the canine at the palatal side
 7 = probe positioned at 4 mm from the gingival margin of the canine at the palatal side
 8 = probe positioned at the gingival margin of the canine at the distopalatal line angle

Fig. 2. Diagram of laser application.

A 860 nm continuous wave of GaAlAs laser (Top Laser 250 SIR 100, Medical Innovation, France) with power output 100 mW, spectral area 0.09 cm², power density 1.11 W/cm², energy dose 2.3 J/point and energy density 25 J/cm²/site was used to irradiate the alveolar mucosa at three points on buccal and palatal sides, and two points at the distal of the canine (23 s/point) (Fig. 2). This LLLT procedure was applied immediately after spring attachment, and reapplied on the next two days. This study simulated the application of Kawasaki and Shimizu, by contacting the laser on the soft tissue around the canines to be retracted (12).

For this double-blind trial the end of the laser probe was covered with a sheath. The probe sheath for the irradiation side had a clear plastic end, and this was replaced for the pseudo-irradiation for the placebo side with a sheath that had a black plastic end. The operator used dark-blue plastic laser-protective glasses to prevent identification of the laser sheath used, and a third person controlled the use of the laser and placebo sheath-tubes for the laser application as recorded in the chart, obtained from the block randomization as mentioned previously.

After the first day's application of the LLLT, the patients were asked to return for repeat applications on the next two days. This three-day LLLT application was then repeated at the end of the first, second and third months, the last being the final application.

At the beginning of each of these four sets of LLLT applications, before placing the archwire and retracting springs, a maxillary alginate impression was taken to

make a dental cast. The initial model was used to make a palatal plug with reference wires for making measurement of canine retraction (15–18).

Methods of model preparation and making of the palatal plug

- The initial model was trimmed so that the functional occlusal plane and base of the model were parallel, checked using a spirit level.
- The progress models were also trimmed so that the functional occlusal plane was the same as the initial model.
- The incisive papilla point was marked and the median raphe line drawn on each model.
- The points at the most mesial surface of upper canines were marked on each model.
- The ends of the two reference wires made from 0.9 mm stainless steel wire were ground to sharp points and set in an acrylic plug on the model to point at the most mesial surface of each canine (Fig. 3).
- The acrylic palatal plug, covering only the medial portion of the palatal rugae with reference wires on the initial model, was prepared and a line marked on the exposed surface of the palatal plug coinciding with the incisive papilla point and the median raphe (Fig. 3), which was useful as a double check during superimposition of the plug on the progress models. The palatal plug was seated on the progress models by best-fit with the marked line coincident with the incisive papilla and the median raphe.

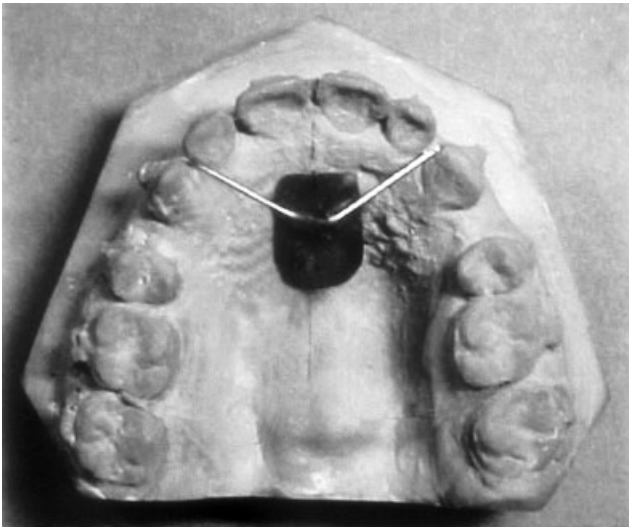


Fig. 3. The acrylic palatal plug with reference wires.

Method of measuring canine movement

The distance of the maxillary canine distal movement (mm) was measured with a stereo microscope (Nikon Measurescope 20, Japan) every 4 weeks from the beginning of the study. The palatal plug, covering only the medial portion of the palatal rugae with reference wires, was the reference device for all the study models of the same patient.

The Y-axis for linear measurement was set along the median raphe line transferred from the model to the upper surface of the palatal plug with the original points (0, 0, 0) at the tips of the reference wires. The distance of canine distal movement was measured on the Y-axis from the reference wire to the most mesial surface of canine at the new position (19–21). The stereo microscope used in this study was accurate to 0.001 mm.

The distances of canine distal movements for the 12 subjects were recorded as means and standard deviation (SD) including 95% confidence intervals at the end of the first, second and third months. Hypothesis testing was by using two-way ANOVA with one repeated

measures by univariate approach at the significance level of 0.05.tnj.

The CORREX[®] tension gauge for force measurement had been previously calibrated by comparing with a universal testing machine (LLOYD-LR 30K, Lloyd Instruments Ltd, Fareham, UK). Intraclass Correlation Coefficient (ICC) Model 2 was used to analyse the data (22). The reliability of measurements of the distance of tooth movement and force application by the researcher (W.L.) was tested by ICC Model 3 with mean ratings calculated by using variance estimates obtained through an ANOVA (22).

Results

The result of calibration of the CORREX[®] tension gauge showed that the average measure intraclass correlation was 0.96 (95% CI: 0.83–0.99), which indicated good validity of the CORREX[®] tension gauge compared with the universal testing machine (22). The result of the average measure intraclass correlation of the measurement of the distance of tooth movement and the force application were 0.99 (95% CI: 0.97–0.99) and 0.97 (95% CI: 0.89–0.99), respectively, which indicated good reliability (22).

The means of the accumulative distances of canine movement on the LLLT side and the placebo side by the time periods are shown in Table 1. The statistical analysis summarized in Table 2 indicates that there was no significant difference of the means of the canine distal movement between the LLLT side and the placebo side for any of the three time periods (p -value = 0.77 for tests of within-subjects effects by the univariate approach).

The mean difference of the accumulative distance of canine distal movement between the placebo side and the LLLT side for 3 months was 0.01 mm (SD = 0.17, 95% CI: –0.35 to 0.37), shown in Table 3. The power for comparison was 0.05.

Table 1. The means of the accumulative distance of canine distal movement (mm) between the LLLT side and the placebo side by the time periods (at the end of the first, second and third months)

Intervention	Month 1			Month 2			Month 3		
	Mean	SD	95% CI	Mean	SD	95% CI	Mean	SD	95% CI
LLLT group	0.32	0.08	0.16–0.48	0.73	0.13	0.46–0.99	1.29	0.21	0.86–1.73
Placebo group	0.38	0.08	0.22–0.54	0.74	0.13	0.48–1.00	1.24	0.21	0.80–1.67

Table 2. Tests of within-subjects effects (univariate test) at a significance level of 0.05

Source	Type of analysis	F	Sig.	Observed power
Time	Greenhouse–Geisser	40.80	0.00	1.00
Time * intervention	Greenhouse–Geisser	0.16	0.77	0.07
Error (time)	Greenhouse–Geisser			

Table 3. Comparison of the difference of the means of the distance of canine distal movement (mm) between the placebo side and the LLLT side during 3 months (significance level of 0.05)

Mean difference between sides			95% CI of the difference between sides	
(placebo – LLLT)	SD	Sig.	Lower limit	Upper limit
0.01	0.17	0.97	–0.35	0.37

Discussion

The study of Kawasaki and Shimizu (12) in rats showed that, in their laser irradiation group, the amount of tooth movement was 30% more than that of a non-irradiated group. The laser parameters of Kawasaki and Shimizu were 830 nm, 100 mW, 0.6 mm diameter, 35.3 W/cm², with an energy density of around 6000 J/cm² from calculation (12). The energy density was very much higher than it should be for the stimulatory effects according to previous knowledge (23–26). The present study used the continuous wave GaAlAs (860 nm), 100 mW, at 1.11 W/cm², 25 J/cm²/site, because the results from previous papers of Bradley and Groth (820 nm, 25 J/cm², rabbits) (24) and Takeda (904 nm, 20 J/cm², rats) (11) had indicated significant biostimulatory effects on bone metabolism around this dosage whereas higher dosages presented bioinhibitory effects (24–27), and lower dosages showed non-significant results (28–30). However, whether there are dose-response differences between tests of LLLT in humans and various animal studies remains to be determined.

The statistical analyses of this study showed that there were no significant differences of means of the canine distal movement between the LLLT side and the placebo side for any time periods at significance level of 0.05 (*p*-value = 0.77). Because of the low statistic power for the comparison of the study (0.05), a type II error is

possible. However, from the calculation of the required sample size, it was found that the low power for the comparison was because of the small effect size between the two sides and not from the small sample size.

From the above-mentioned observations, it is likely that LLLT in the parameter settings of this study does not affect the rate of tooth movement for any time periods. This suggests that the energy density of LLLT was too low to express either a stimulatory effect or an inhibitory effect.

There have been some studies of the effects of LLLT in clinical trials, but mostly used to test the inhibitory effects to reduce pain or inflammation, the dose being very high, such as 100 J/cm² (24). Until now, there has been lack of knowledge about the optimal dose for the stimulatory effect in human tissues. Some studies of the stimulatory effect have been done on human culture cells. However, it is not applicable to the human body because of some loss of energy density during penetration through soft tissue and the bone, which is different from plate cultures. Thus, it is quite difficult to find the optimal dose in the individual patient.

Significant unknowns in attempting to optimize the application of LLLT to orthodontic tooth movement are the cellular secretions and secretory molecular responses in the PDL to combined LLLT and orthodontic force.

Conclusions

LLLT (GaAlAs) at the parameter settings in this study had no effect on the rate of orthodontic tooth movement for any time periods, between one and three months. 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.

The science of cellular and molecular biology is essential to detect what actually happens in the human body, related to the stimulatory dose or the inhibitory dose of LLLT at the surface level. The study of the effects of LLLT on the cells in the PDL areas of premolars to be extracted (as required in an orthodontic treatment plan) comparing between the LLLT side and the placebo side could reveal useful information. Another suggested study is detecting the molecular biology aspects of the gingival crevicular fluid (GCF), such as PGE₂ and IL-1 β , in the human body (31,32).

Acknowledgements: The authors would like to express their gratitude to Prof. M. Ali Darendeliler and Associate Prof. Sajee Sattayut for their advice and help for the construction of this study.

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