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Original Article

Effects of low-intensity laser therapy on the rate of orthodontic tooth movement: A clinical trial

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ABSTRACT

Background: Low-intensity laser therapy (LILT) can be utilized for different treatments in the field of orthodontics and dentofacial orthopedics. The aim of the present study was to evaluate the efficacy of LILT on (1) the rate of canine movement during canine retraction phase and (2) evaluate the radiographic changes occurring during LILT around the irradiated area.
Materials and Methods: A total of 10 patients of both genders were included for this study. One quadrant of the upper arch was considered control group (CG) and received mechanical activation of the canine teeth with 150 g. The opposite quadrant received the same mechanical activation and was also irradiated with a diode emitting light (gallium-arsenide laser) at 904 nm, for 10 s at 12 mW, at 4.2 J/cm^2. Laser application was done on 1st day, 3rd, 7th, 14th, 21th, 28th, 35th, 42nd, 49th, 56th day respectively during the canine retraction phase. Distance was measured on 1st day, 35th day and 63rd day and appliance activation was done on 1st and 35th day. Results were analyzed using *t*-test with the significance level set at $P < 0.01$.
Results: Mean value obtained from 1st to 63rd day was 3.30 ± 2.36 mm for CG and 3.53 ± 2.30 mm for laser group (LG).
Conclusion: There was no statistically significant difference in the rate of tooth movement during canine retraction between the LG and the CG. There was no evidence of any pathologic changes in the radiograph following LILT.

Key Words: Bone remodeling, canine retraction, gallium-arsenide diode laser, orthodontic tooth movement

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INTRODUCTION

Orthodontic treatment has its importance based on esthetic and functional rehabilitation of the masticatory system and the period of time required for fixed appliance treatment is about 2-3 years. In long-term treatment, there is an increased risk of root resorption, gingival inflammation, dental caries and bone necrosis. Hence, from the patient point of view, accelerating tooth movement is desirable.[1,2]

Acceleration of tooth movement can be produced by drug injection like prostaglandins,[3-5] 1,25(OH)$_2$D$_3$ (active form of vitamin D$_3$)[6-8] and osteocalcin,[9,10] electric stimulation[11,12] and an ultrasound application[13,14] around alveolar socket. These methods depend on injections that could be associated with discomfort and pain, or a sophisticated apparatus that demands application for a long-term for its therapeutic effects.[1]

Hence, there is a need for accelerating tooth movement without causing any discomfort to the patient. Keeping this in mind, different researchers have studied the results of low-intensity laser therapy (LILT) and found that it can be utilized for different

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treatments in the clinical practice of orthodontics and dentofacial orthopedics, including:
- Reduction of post adjustment pain.[15-18]
- Treatment of pain associated with orthodontic elastomeric separators placement.[19]
- Treatment of traumatic ulcer promoted by the appliance in the oral mucosa.[20]
- Wound healing process.[21-24]
- Inhibition of open gingival embrasure space after orthodontic treatment.[25]
- Aesthetic enhancement of smile.[26]

Further, researchers have found that its stimulatory effects can accelerate bone regeneration in the mid-palatal suture during rapid palatal expansion.[27] Also, it has been found that LILT stimulates synthesis of collagen, which is the major matrix protein in bone.[28,29]

Other studies found that low intensity laser irradiation can stimulate bone regeneration at the bone fracture and extraction site[30-32] and increase the rate of orthodontic tooth movement in animals such as rats and rabbits.[33-36]

There are six studies documented in literature which have analyzed the effect of LILT on orthodontic tooth movement in humans, with mixed results. Four studies showed acceleration of tooth movement in the experimental group,[1,37-39] whereas two studies showed no significant difference between experimental and control group (CG).[2,40]

Therefore, this study was designed to investigate the efficacy of LILT on the rate of canine movement during canine retraction phase and to evaluate any radiographic changes occurring during LILT around the irradiated area.

MATERIALS AND METHODS

A total of 10 young adult patients of both genders, seeking fixed orthodontic treatment in the Department of Orthodontics and Dentofacial Orthopedics, KLE V.K. Institute of Dental Sciences, Belgaum, who met all the case selection criteria, were included for this study.

Method of collection of data

Inclusion criteria

Patient clinically indicated for extracting both maxillary first premolars, to get space required for complete alignment and/or correction of protrusion.

Exclusion criteria

1. Patients with systemic illness.
2. Patients taking medication that can interfere with orthodontic tooth movement.
3. Extractions other than premolar extraction in the maxillary arch.

Patients and each legal responsible were informed about the risks and written consent was taken at the beginning of the study. An ethical clearance for the study was taken from the Ethical Committee of the institute.

All 10 patients had their left and right first maxillary premolars extracted and fixed orthodontic appliances were installed to close the space created and to restore an ideal occlusion and facial aesthetics. A pre-adjusted edgewise appliance (MBT prescription-0.022 slot, Euro omni 0.022, GAC International, Inc. NY) was used for all patients and bonded with Transbond XT (Light Cure Orthodontic Adhesive, 3M Unitek, CA, USA). A transpalatal arch (from 0.9 mm stainless steel [SS] wire) was used for posterior anchorage.

Leveling and aligning procedures were carried out using nickel titanium wires, round SS wires and rectangular wires. Prior to retraction procedure, 19 × 25 SS wire was placed. The teeth were tied to the wire using elastic modules (10 ties ligature ties, Optima). Left and right quadrants of the upper arch were randomly divided into laser group (LG) and CG. The rectangular wire guided the canine retraction, which was done by E-chain (Flexi Chain, Encore, USA) positioned from the canine bracket to the first molar buccal tube. The total force used was 150 g after each activation, measured with the help of stress and tension gauge (Federwaage Dial type, Dentaurum) [Figure 1]. Same materials and procedures were applied for both groups except laser irradiation.

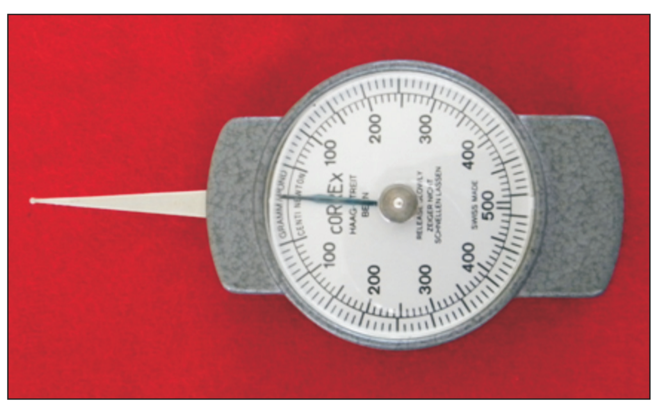

Figure 1: Stress and tension gauge

Laser irradiation

The equipment used in this study was a gallium-arsenide (Ga-As) semiconductor diode laser (ORALIA Dental Products, D-7750 Konstanz, Germany), emitting infra-red radiation at 904 nm. The study was conducted in the Department of Periodontics, KLE V.K. Institute of Dental Sciences, Belgaum [Figure 2]. All irradiations were done by the same operator with an output power of 12 mW, dose of 4.2 J/cm^2 and exposure time of 10 s. The tip was held perpendicular and in contact with the gingival mucosa during the laser irradiation procedure.

Total of 10 irradiations were carried out each time, five on the buccal side and five on the palatal side. In order to cover the periodontal fiber and alveolar process around the maxillary canine, the doses were distributed and ordered as follows [Figure 3]:

1. Two irradiation dose on cervical third (one medial and one distal).
2. Two on the apical third (one medial and one distal).
3. One on the middle third (on the center of the root).

Laser application was done on 1^{st} day, 3^{rd}, 7^{th}, 14^{th}, 21^{th}, 28^{th}, 35^{th}, 42^{nd}, 49^{th}, 56^{th} day respectively during the canine retraction phase.

Distance was measured on 1^{st} day, 35^{th} day and 63^{rd} day.

Appliance activation was done on 1^{st} and 35^{th} day.

The extent of canine movement was considered as the decrease of the distance between the distal slot of the canine bracket and the mesial opening of the buccal tube of the first molar, measured with a digital electronic caliper (Digimatic Caliper, Mitutoyo, China, with a measuring range of 150 mm, resolution of 0.01 mm and instrumental error of ±0.03 mm) [Figure 4].

The involved area from both groups received radiographic documentation to verify any occurrence of damage to the adjacent periodontal and dental tissues. Conventional intraoral periapicals (IOPA's) were taken on 1^{st} and 63^{rd} day to check qualitatively any damage to the canine root, adjacent alveolar bone, or periodontal tissue.

Random selection was done by one operator, who conveyed to the person doing laser application as to which quadrant of the patient belongs to the LG. The distance measurement was done by third operator who had no knowledge about which quadrant had been considered in the LG. The two groups were subjected to statistical analysis by the statistician without knowing as to which group was laser and which one control. Hence, it was a triple blind study. The identities of the groups were revealed only after the results of the statistical analysis were obtained.

Statistical analysis

- The comparison of CG and LG with respect to the rate of tooth movement from 1^{st} to 35^{th} day, 35^{th} to

Figure 2: Gallium-arsenide laser

Figure 3: Distribution of laser irradiation doses

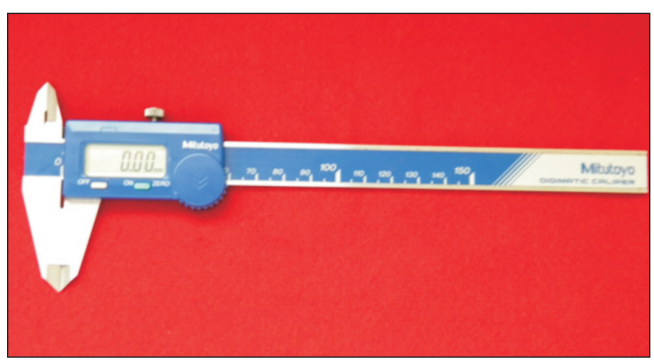

Figure 4: Digital electronic caliper

63rd day and from 1st to 63rd day movement was done using unpaired *t*-test.

- The mean value of the LG divided by CG was calculated using paired *t*-test.
- All the analysis were carried out using Statistical Package for the Social Sciences software version 16(SPSS Inc., Chicago, IL, USA) ($P < 0.01$).

RESULTS

The present study was designed to check the effects of LILT on the rate of orthodontic tooth movement in *in-vivo* conditions.

The results are presented under the following headings.

A total of 10 patients were selected for the study [Figure 5].

Two groups were made quadrant wise:

1. LG
2. CG

Out of the 10 patients, laser was applied on the right side in four patients (LG) and on the left side in six patients (LG). The contralateral sides acted as CG.

Mean, standard deviation (SD) and standard error were calculated on 1st, 35th and 63rd day for both the groups (LG and CG). Further, same values were calculated for the amount of movement from 1st to 35th day, from 35th to 63rd day and from 1st to 63rd day for both the groups [Table 1, Figure 6].

Comparison of CG and LGs with respect to rate of orthodontic tooth movement was done with the help of unpaired *t*-test [Table 2, Figure 7]. Statistically

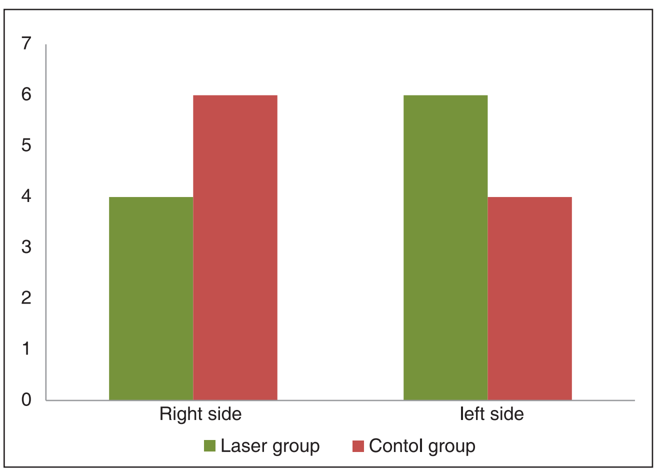

Figure 5: Quadrant wise distribution of groups

Table 1: Summary statistics according to treatment groups (in mm)

Treatment time	Summary	Control group	Laser group
1st day	Means	19.99	21.01
	SD	2.32	2.95
	SE	0.73	0.93
35th day	Means	18.23	19.33
	SD	2.23	2.83
	SE	0.70	0.89
63rd day	Means	16.69	17.48
	SD	2.30	2.85
	SE	0.73	0.90
Difference between 1st day and 35th day	Means	1.76	1.69
	SD	1.58	1.20
	SE	0.50	0.38
Difference between 35th day and 63rd day	Means	1.53	1.85
	SD	0.97	1.20
	SE	0.31	0.38
Difference between 1st day and 63rd day	Means	3.30	3.53
	SD	2.36	2.30
	SE	0.75	0.73

SD: Standard deviation; SE: Standard error

Table 2: Comparison of control and laser groups with respect to rate of orthodontic tooth movement (in mm) by unpaired *t*-test

Variable	Group	Mean	SD	*t* value	*P* value
1st day	Control	19.9880	2.3233	−0.8634	0.3993
	Laser	21.0140	2.9537		
35th day	Control	18.2260	2.2290	−0.9652	0.3472
	Laser	19.3250	2.8279		
63rd day	Control	16.6930	2.2975	−0.6803	0.5050
	Laser	17.4800	2.8470		
1st day to 35th day	Control	1.7620	1.5842	0.1161	0.9088
	Laser	1.6890	1.2012		
1st day to 63rd day	Control	3.2950	2.3642	−0.2290	0.8214
	Laser	3.5340	2.3020		
35th day to 63rd day	Control	1.5330	0.9707	−0.6381	0.5314
	Laser	1.8450	1.2034		

SD: Standard deviation

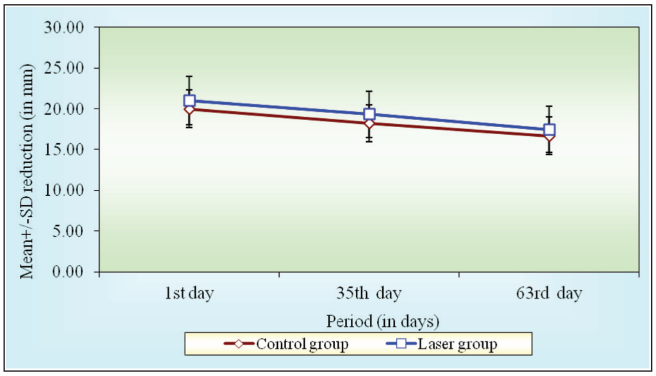

Figure 6: Summary according to treatment groups

insignificant results were found during different time periods.

Mean value of the LG/CG were obtained with the help of paired *t*-test [Table 3]. Mean value of (LG/CG) was found to be 1.05 ± 0.08 on 1st day, 1.06 ± 0.08 on 35th day and 1.05 ± 0.09 on 63rd day.

Radiographic evaluation of upper canine area using conventional IOPA showed thickening and thinning of the lamina dura on the mesial and distal side respectively. Widening of the periodontal ligament (PDL) space was found at apical one-third region with slight discontinuity of the lamina dura at the apex. The changes found in both the LG and CG were almost the same. Hence, there was no evidence of additional radiographic changes during LILT around the irradiated area.

DISCUSSION

Orthodontic tooth movement is a result of the remodeling changes in the bone adjacent to the PDL. It is a sum total of bone absorption by osteoclasts on pressure areas and bone deposition on tension areas of the root. When bone absorption and deposition occurs at different places of the same tooth, it results in movement of that particular tooth.[1]

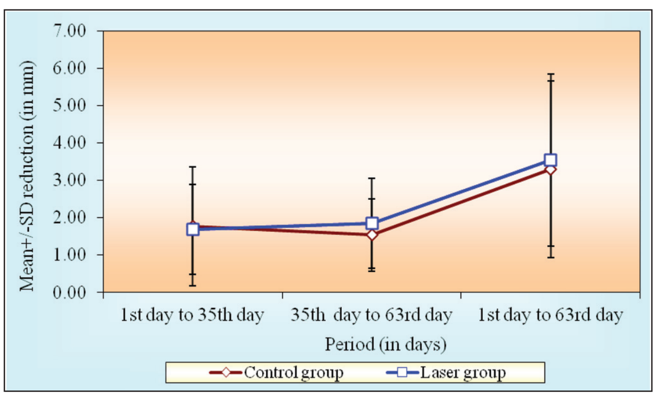

Figure 7: Comparison of control and laser group with respect to the rate of orthodontic tooth movement

Studies carried out on rats[33] and rabbits[35] using LILT has indicated an increase in tooth movement. This increase in tooth movement may be due to many factors like anabolic effects such as acceleration in bone formation,[33] expression of basic fibroblast growth factor in the periodontal tissue and alveolar bone remodeling,[32] and expression of macrophage colony-stimulating factor and c-fms in osteoclast precursor cells.[34] Some studies also show increase in velocity of tooth movement and increase in the number of tartarate-resistant acid phosphatase, matrix metallopeptidase-9, Cathepsin K and integrin subunits of a(v)β3.[34]

Due to the encouraging effects of LILT in animal studies, there were three studies documented in literature on the rate of tooth movement in humans. Cruz *et al*.[1] conducted 2 month study on 11 patients to assess the rate of tooth movement and showed significantly higher acceleration of canine retraction in laser treated group than in the CG. Limpanichkul *et al*.[2] studied maxillary canine retraction in 12 young adult patients and found no significant difference in the rate of tooth movement over a 3 month period. Youssef *et al*.[37] studied 15 adult patients undergoing canine retraction. He compared the rate of canine movement between LG and CG and also assessed the pain level. His findings suggest that LILT can highly accelerate tooth movement during orthodontic treatment and can also effectively reduce pain. Genc *et al*.[38] studied 20 adult patient (14 girls and 6 boys) undergoing canine retraction. They compared the effect of LILT (Ga-aluminum [Al]-As) on the velocity of orthodontic tooth movement and the effect of nitric oxide level in gingival crevicular fluid during orthodontic treatment and showed accelerated orthodontic tooth movement in the laser irradiated area and no significant changes in nitric oxide level

Table 3: Comparison of a mean value of 1st day, 35th day and 63rd day with respect to rate of the ratio of orthodontic tooth movement (i.e. laser group/control group) by paired a *t*-test

Treatment time	Mean	SD	Mean difference	SD difference	Paired *t* value	*P* value
1st day	1.0503	0.0760	–0.0094	0.0565	–0.5236	0.6132
35th day	1.0597	0.0764				
1st day	1.0503	0.0760	0.0030	0.0842	0.1123	0.9131
63rd day	1.0474	0.0919				
35th day	1.0597	0.0764	0.0123	0.0322	1.2110	0.2568
63rd day	1.0474	0.0919				

SD: Standard deviation

was observed. Doshi-Mehta and Bhad-Patil[39] studied the efficacy of LILT in reducing treatment duration and pain and found average increase in the rate of tooth movement in the laser irradiated group and pain scores were slightly lower in the experimental side. Hosseini *et al*.[40] studied the effect of LILT (Ga-Al-As) on 12 patients (four boys and eight girls) undergoing canine retraction. Results showed no significant difference in the amount of canine movement between LG and CG.

Since the above studies showed conflicting results, the present study was undertaken to compare the rate of tooth movement during canine retraction between the LG and CGs.

Only the upper arch was used in order to eliminate the bias between the bone densities of the maxilla and mandible. The right and left halves of the maxilla were used as CGand LG, hence the same patient acted as his own control, thus eliminating any bias. The right and left quadrants were assigned to either of the groups randomly at a coin toss to eliminate left and right side bias, if any. The appliance and the arch wires were standardized and E-chain from the same spool was used in all patients. A uniform force of 150 g measured using stress and tension gauge (Federwaage Dial type, Dentaurum, Germany) was applied on the canines in accordance with optimal orthodontic force values. E-chains were applied between 1st molar hook and canine for both control and LG. Application of 150 g was in accordance with a study done by Tanne *et al*.[41]

E-chain was applied on the 1st day and changed on the 35th day. Most of the elastomeric chains generally lose 50-60% of their initial force during the first day of load application and by 3 weeks they retain only 30-40% of their original force.[42]

Gallium arsenide laser with a wavelength of 904 nm utilizes semiconductor diodes and it comes under infrared spectrum lasers. This wavelength is longer than that likely to produce a direct photochemical effect and the power is too low to have any thermal consequences.[43] The depth of penetration of laser light depends on the light's wavelength, on whether the laser is super pulsed or not and finally on the basis of power output.[44] The Infrared radiation has a low absorption coefficient in Hb and water and consistently a higher penetration depth in the irradiated area.

The treatment with LILT is also referred to as therapeutic laser treatment and the more appropriate terminology should be "photobiomodulation" as the effect of laser can be both stimulatory as well as inhibitory.

As the intention of LILT was to stimulate bone cells, which are placed under the hypodermic layer, the Ga-As laser (super pulsed) was selected for the study, because of good penetration depth; greatest being 30-40 mm, which is considerably higher than penetration depth of In GA-Al-P laser and Ga-Al-As probe under same output power.[5]

The mean and SD for both the groups on 1st day, 35th day and 63rd day were calculated [Table 1]. The values show that there was a movement of 1.76 ± 1.58 mm in the CG when compared to 1.69 ± 1.20 mm in the LG from 1st to 35th day. However, the values were statistically insignificant (P = 0.9088) when compared using unpaired t-test. During the period from 35th to 63rd day, however, there was increased tooth movement in the LG which was 1.85 ± 1.20 mm as compared to 1.53 ± 0.97 mm in the CG. However, this difference is also statistically insignificant (P = 0.5314). When the total amount of tooth movement during the entire study period (1st to 63rd day) was considered, it was found that the LG had a total movement of 3.53 ± 2.30 mm, when compared to 3.30 ± 2.36 mm in the CG. This difference was again statistically insignificant (P = 0.8214). The results of the present study were in accordance with the study conducted by Limpanichkul *et al*.[2]

The mean values of (LG/CG) were found to be 1.05 ± 0.08 mm on 1st day, 1.06 ± 0.08 mm on the 35th day and 1.05 ± 0.09 on 63rd day. The above results showed a mean increase in the rate of tooth movement by only 7.13% as against 34% increase shown in the study by Cruz *et al*.[1]

One more objective of this study was to determine any radiological changes seen in the conventional IOPA's, which were taken at the beginning (1st day) and at the end (63rd day) of study for each patient. These radiographs were assessed by an oral radiologist to look for any pathological changes in each case because of laser irradiation. The radiographs were only qualitatively assessed and no parameters were assigned for standardization. However, there were no pathological changes seen in any of the radiographs. The thickening and thinning of the lamina dura on the mesial and distal side respectively was observed. Widening of PDL space at apical third was observed with slight discontinuity of lamina dura at the apex. All these changes are commonly seen when orthodontic forces are applied.

Since the study showed statistically insignificant results in the rate of tooth movement between the LG and CG, an attempt was made to determine the possible reason. As the sample size in this study was only 10 patients, it was possible to assess each patient individually. Looking at the data obtained from the individual patient, it becomes obvious that there is a vast variation in the amount of tooth movement amongst individuals, as 8 out of 10 patients showed clinically more movement on the LG side. This could be attributed to variations in biology, bone characteristics, position of the canine root in the cortical plates. These variables could probably have been minimized by taking a much larger sample in each group. The results of the study done by Limpanichkul *et al*.[2] were also insignificant. According to them, it is likely that the LILT parameter settings of the study do not affect the rate of tooth movement, which means the energy density was too low to express either a stimulatory or inhibitory effect. Until now, there has been a lack of knowledge about the optimal dose for the stimulatory effects in human tissues. Some studies on the stimulatory effects 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 bone. It is quite difficult to find the optimal dose in the individual patients. Significant unknowns in attempting to optimize the application of LILT to the orthodontic tooth movement are the cellular secretions and secretary molecular responses in the PDL.

Though, there was an increase in tooth movement on application of laser therapy, it was statistically insignificant. Furthermore, the cost of application of laser therapy and the number of visits could not justify the benefits to the patient in terms of decreased treatment time.

CONCLUSION

The study showed that:

1. There was no statistically significant difference in the rate of tooth movement during canine retraction between the LG and the CG.
2. There was no evidence of any pathologic changes in the radiograph following LILT.

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