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Original Research Article

Efficacy of low-intensity laser therapy in accelerating the rate of orthodontic tooth movement - A clinical investigation

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Abstract

Background: Prolonged treatment time can cause potentially harmful side-effects to the patient. It is also not beneficial to the health care system in terms of cost efficiency. This leads to motivate the Orthodontists to indulge more research in the field of accelerated orthodontics.
Aim: To evaluate the effect of low-energy laser irradiation on rate of lower molar protraction using fixed orthodontic appliances by friction mechanics using mini-implants as a direct source of anchorage.
Materials and Methods: Ten orthodontic patients in whom alignment and levelling were completed and treatment protocol warrants lower second premolars extraction were selected. A split mouth design was used with the right side as the laser group and the left side being non-laser group. A Diode laser of 810nm, in contact mode, with an output of 200mW was exposed for 10 seconds on 0, 3rd, 7th, and 15th day of the first month and the 15th day of the second and third month. Impressions were taken before and after three months of laser application and dental models were poured. The rate of orthodontic tooth movement on both sides was calculated as the amount of tooth movement divided by the time period. For the overall comparison of the laser and non-laser groups Unpaired t test was used. While within the laser and non-laser groups comparison was done using Paired t-test.
Results: Diode laser group showed an overall mean amount of Mandibular Molar mesialization i.e. 2.75+/-0.83 mm with a statistically significant difference ($p<0.029$). The highest molar protraction achieved was 3.58mm i.e approximately 1.19mm/month.
Conclusion: Diode laser showed increased efficiency i.e. 29% compared to the Non-Laser group in protracting the mandibular molars.

Keywords-Diode-laser, Friction mechanics, Mini-implants

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1. Introduction

Every prospective orthodontic patient is ardent about knowing the total duration of the treatment anticipated, as it involves commitment, compliance, financial and logistic implications for the patient and family. Judicious completion of treatment satisfies the patient, which allows for more precise prediction of required clinic visits. Prolonged treatment time can cause potentially harmful side-effects to the patient. It is also not beneficial to the health care system in terms of cost efficiency and efficacious service to the public.

A multitude of factors may influence the duration of orthodontic treatment. Generally, these factors may be divided into four main categories, namely; socio-demographic characteristics, diagnostic characteristics, treatment modalities, and patient behavior.[1] Some factors were related to the orthodontist, such as when to start and whether to extract. In contrast, others were related to patient behaviour, such as compliance with appliance care and keeping to appointments. At present in orthodontics, there is a stern vacuum of advancements in concern with the speedening of the treatment procedures. The typical 2 to 3-year treatment period was a burden for some patients and in the mean-time, it would also cause a hindrance to clinician's efficient patient management. [2]

Diverse treatment modalities have been tested in a considerable number of studies for a significant outcome of this problem. The treatment modalities can be broadly categorized into mechanical, electrical, chemical, surgical,

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and non-invasive methods. Although those procedures had been successful from the clinician's point of view, they remained a burden to the patient's perception of pain and discomfort. Novel methods for accelerating the rate of tooth movement have been in search these days. One such option that more or less en suited the ideal criteria of a novel method was soft tissue laser which is Low Level Laser Therapy (LLLT). This therapy via the mode of bio-stimulation effects on the tooth movement opened a new vista of opportunities in the field of orthodontics. Biostimulative doses recommended in the literature ranged between 0.001J/cm^2 - 10J/cm^2 and cytostatic effects were registered above 240 J/cm^2.[2,3] Studies concerning the effects of low-energy laser irradiation on human bone remodeling showed encouraging results which remunerated a new pathway for research in the biology of orthodontic tooth movement. Very little literature on the Photo-therapy universal dosage parameters was present to date concerning the orthodontic tooth movement in humans.

The main objectives of this present study were

1. To evaluate the effect of low-intensity laser on the rate of mandibular molar protraction.
2. To compare the rate of tooth movement using friction mechanics and friction mechanics combined with low intensity laser therapy.

2. Materials and Methods

2.1. Study design and approval

A Split-mouth design was used for the study. Ten orthodontic patients (6 females, 4 males) with an age group between 18 to 24 years old were selected. The sample size was calculated using G* power software, considering the effect size of 0.28 and the power of the study at 95% (considering the sample size from the previous similar studies done by Jivrajani and W. Bhad (2020) and Da Silva Sousa et al. (2011)). In each patient, the extracted right and left quadrants were divided into 2 groups. Laser and non-laser groups respectively.

Study Groups	Side Assigned	No of Quadrants	Mechanics
Laser	Right	10	Friction
Non-laser	left	10	Friction

3. Patient Selection

Ten orthodontic patients with Angles Class II division 1 malocclusion (end-on-end molar relation on both sides initially), in whom the first stage of fixed orthodontic therapy that is, alignment and levelling stage was completed (by using a .022 MBT Slot prescription) and a treatment plan warranted bilaterally protraction of mandibular first molars were taken, from the Department of Orthodontics at a private dental college. For each patient, the diagnosis was based on standard orthodontic documentation with photographs, model casts, cephalometrics, and panoramic radiographs. The study design was approved by the institutional ethical committee. (VDC/RP/2012-67)

3.1. Inclusion criteria

1. Treatment with moderate anchorage.
2. Upright mandibular incisors of IMPA (90°-100°).
3. Patients undergoing lower second premolar and upper first premolar extraction as a part of comprehensive fixed orthodontic therapy.
4. Patients in the age group between 18 to 24 years old. Patients who consented to the research procedures and signed an informed consent.

3.2. Exclusion criteria

1. A history of long-term medication like NSAIDS, and steroids.
2. Unilateral chewing or parafunctional habits, skeletal crossbite, occlusal interferences, and periodontally compromised patients.

4. Preparation for Space Closure

The orthodontic treatment was performed with 0.022" pre-adjusted edgewise appliances (MBT prescription Ortho-Organisers, Carlsbad, CA, USA). After completion of the levelling and alignment, an alginate impression was taken for baseline measurement of the mandible. The mandibular first molar protraction was performed with a .019x.025 rectangular stainless steel (Classic Orthodontics) working arch form. Stainless steel ligature wires were used for ligating the brackets. Sliding type of mechanics with, NiTi closed coil spring (Prime Orthodontics –Inc-USA.) of length 9mm was used. A force magnitude of 150 gms was verified with a force gauge dynamometer during placement.

A careful evaluation of the intraoral radiographs in the interdental area of the canine and first premolars was done. Under local anesthesia, a titanium mini-implant (1.3mm diameter and 8mm length, Abso Anchor, [Dentos, Daegu, South Korea]) was placed bilaterally using the self-drilling technique. Immediate loading of the mini-implant was done with a Niti closed coil spring. A force gauge was used to determine that the 150 gms traction force was delivered. The spring was adjusted for 30 days.

*4.1. Diode laser application (**Figure 1**)*

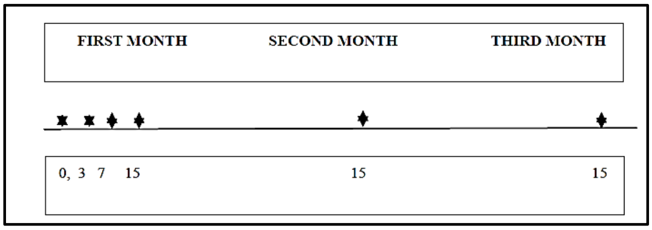
LASER specifications: Denlase Diode Laser (IDS Denmed Pvt. Ltd., India)

Type : Diode GaAlAs
Power : 7W
Dimensions : 13cmX19cmX18cm
Weight : 1.5 kg
Wave Length : 810±10 nm
Output Power : 200 mW
Delivery Fiber : 4 mm

The diode laser used in this study consists of semiconductor "chips" made from, Gallium, Aluminum and Arsenide, together commonly referred to as GaAlAs. The wavelength produced by the diode is approximately 810 nanometers (nm).

After taking necessary precautionary measures like safety glasses/goggles on the same day of immediate loading, a Diode laser was operated at an 810nm wavelength, with a maximum output power of 200 mW in continuous wave mode, and energy of 2J per spot for 10 seconds. The beam was delivered through an optical diameter of 4mm. On the right side of each patient, the laser was irradiated on the buccal and the lingual side of the mandibular first molar tooth: 3 points on the cervical third of the root (one mesial one distal and middle of the mesiodistal), 3 points on the middle third of the root, and 3 points on the apical third of the root. A total of 9 points were irradiated on both sides.

4.2. Timeline of diode laser applications and tooth movement measurements



After 0, 3rd day of biostimulation with Diode laser, the laser regimen was applied on the 7th and 15th of the first month. Later the irradiation was done on the 15th day of the following second and third month. A total of a three-month period of evaluation was done with Diode laser for all 10 patients.

4.3. Study models measurements

A single investigator performed all measurements and was blinded to the experimental and control group assignments. Two models were made for each patient i.e. pre-treatment study models and after 3 months study models. The mesiodistal length was measured from the mesial highest contour point of the mandibular molar to the premolar distal-most highest contour point using digital vernier calipers (**Figure 2**). The rate of orthodontic tooth movement was calculated as the amount of tooth movement divided by the time period. The rate of tooth movement at the end of 3 months was recorded as T0-T1 divided by 3. The readings were calculated for both the experimental and control sides and compared.

4.4. Statistical analysis

All statistics were performed using the SPSS statistical program, version 16.0 (SPSS Incorporated) with a (p< 0.05). The normality of the sample has been established by using the Kolmogorov-Smirnov test. So, we opted for parametric tests. For the overall comparison of the laser and non-laser groups, an unpaired t-test was used. Within the laser and non-laser groups comparison was done by means of a paired t-test.

5. Results

The amount of mandibular first molar protraction was expressed in mm. Descriptive statistics like the mean and standard deviation were calculated for every group. A paired student t-test was done to analyze the differences within the same group prior to and post-intervention. When ($p<0.05$) the statistical test was regarded as significant.

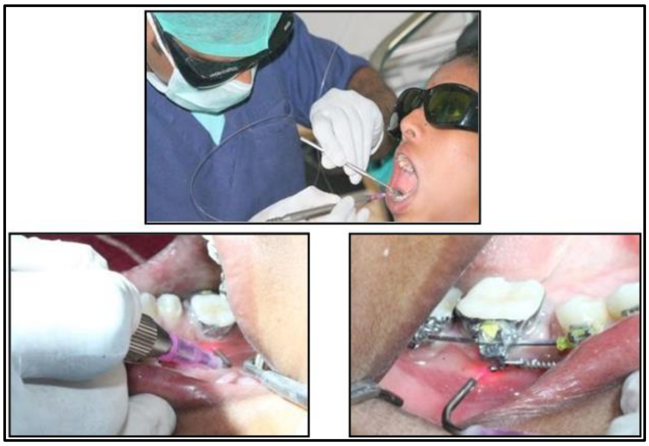


Figure 1: Diode laser application

Figure 2: Study models measurement using vernier calipers

Table 1: Mean amount of molar protraction after three months of diode laser application.

Laser group	Samples	Mean+/-std. Deviation	T value	p value	Inference
Before	10	4.76+/-.80	7.370	.000	S
After 3 months	10	2.00+/-.86	7.370	.000	S
*P value less than 0.05 Significance					

Table 2: Mean amount of molar protraction after three months in non- diode laser group

Non- Laser group	Samples	Mean+/-std. Deviation	T value	p value	Inference
Before	10	5.36+/-0.51	8.354	.000	S
After 3 months	10	3.35+/-0.55	8.354	.000	S
*P value less than 0.05 significance					

Table 3: Overall mean amount of molar protraction in laser & non-laser groups after 3 months.

Group	Treatment period	Samples	Mean +/- std. deviation	T value	p value	Inference
Laser(right)	3 months	10	2.75+/-0.83	2.366	.029	S
Non-laser(left)	3 months	10	1.94+/-0.68	2.366	.030	S
*P value less than 0.05 significance						

6. Intra Group Comparison

A paired Student t-tests of the laser group before and after three months of laser irradiation are described in (**Table 1**). The mean premolar extraction space present at the start of the intervention was 4.76 mm+/-.80 mm. Whereas, the mean premolar extraction space present after 3 months of mandibular first molar protraction was 2.00 mm+/-.86 mm.

Similarly, paired Student t-tests of the non-laser group before and after three months are described in (**Table 2**). The mean baseline premolar extraction space present was 5.3 mm+/-0.5 mm. Whereas, the mean premolar extraction space present after 3 months of mandibular first molar protraction was 3.35 mm+/-0.55 mm.

By using the student's unpaired t-test, the overall mean amount of mandibular molar mesialization seen on the laser side was 2.75+/-0.83 mm (**Table 3**), and the highest molar protraction achieved was 3.58 mm i.e. approximately 1.19 mm/month. While the lowest molar protracted was 1.92 mm approximately 0.64 mm/month. On the non-laser side, the mean mandibular molar protraction observed was 1.94+/-0.68 mm (**Table 3**) for three months (0.64mm/month), while the highest mandibular molar protracted was 2.62 mm i.e. almost 0.8mm/month whereas the lowest molar protraction seen was 1.26 mm i.e 0.42 mm/month. There was a significant positive difference ($P < 0.029$) in the rates of tooth movement on the laser side compared with the non-laser side (**Table 3**). The overall net increase in the rates of tooth movement on the laser side at 3 months was 29% more closure than on the non-laser side.

7. Discussion

Striking facade and civilizing psychosocial status have been put forth as important motivating factors behind an adult's decision to initiate orthodontic treatment[1,2]. In order to meet these esthetic concerns, in some clinical situations like Class II malocclusions which indicate the extraction of lower second premolars[4], congenital absence of second premolars, and bilateral end-on molar relationships, protraction of the mandibular first molars is warranted to achieve a stable Angle's Class I molar relationship. This aspect of mandibular molar mesialization requires the extensive use of biomechanical procedures because of the presence of biological constraints like thicker cortical bone, dense, and radially oriented trabeculae, heavy musculature, post-extraction alveolar ridge resorption which are present in the posterior mandibular molar region[5]. The wider buccolingual roots of the mandibular molar tooth require reciprocal stable anchorage for protraction and to overcome unwanted tooth movements like the lingual tipping of the anteriors, root resorption, dehiscences[6], etc. Earlier it was stated by Kessler et al[6] that it was impossible to protract the mandibular molar for a distance of 10-11mm into the atrophic edentulous premolar spaces[7] but many studies done by Robert et al[8], Stepovich et al[7] showed that mandibular molar spaces of 10mm could be closed but at the same time the duration of treatment was seen to increase by an average of 30-40 months.

Hence to overcome these problems, many interventions like Prostaglandins and interleukin-1[9], osteocalcin, derivatives of vitamin D, Relaxin, infusion of parathyroid hormone (PTH), and L-arginine, mechanical methods like vibratory stimulation of gingival tissues, surgical interventions like corticotomy procedures and non-invasive procedures like the diode laser in the biostimulation mode were being used as adjuncts along with the biomechanics for reducing the treatment time.[9]

Although in the past decade, different interventions have been used to accelerate tooth movement[9], the low-level laser therapy stands tall in terms of patient compliance and comfort[10]. It was also shown in the meta-analysis study done by Nikolaos Gkantidis et al, that after corticotomy the most accepted procedure was low-level therapy. Hence in the present study, a Diode laser was used along with sliding mechanics for the protraction of the mandibular first molar.

In the present study, mini-implants were chosen as a direct source of anchorage so that they prevent the unwanted reciprocal lingual tipping of the anterior teeth.[5,8,11,12]. The rationale for using mini-implants was that in the previous study done by Stepovich et al[7], the mandibular molar was protracted through the atrophic edentulous ridge, which led to unwanted tooth movements which in turn increased the duration of the treatment period.

The diode laser was operated at a wavelength of 810 nm, a continuous wave mode, an output power of 200 mW, and an exposure time of 10 seconds as advocated by the studies of Yamaguchi[13], fujita[14], Yoshida[15] and Youssef et al[16], Ying-ying Huang et al[17]which showed significant bio-stimulatory effects on bone metabolism around this dosage, whereas higher dosages like 850nm had bio-inhibitory effects, and lower dosage (6J/cm2) showed non-significant results by Selfi et al[18].

In the diode laser group, the mean space present at the start of the intervention was 4.76mm+/-.80mm (**Table 1**, **Figure 1**) the highest premolar extraction space recorded was 5.56mm whereas the minimum was 3.96mm. In the non-laser group, the mean space present at the start of the intervention was 5.3mm+/- 0.5mm (**Table 2**, **Figure 2**). The highest recorded space was 5.8mm while the lowest was 4.8mm.

After three months of laser irradiation, the laser group showed the mean amount of mandibular first molar protraction was 2.75mm+/-0.83mm (p<0.029) **Table 3**) i.e. a mean rate of 0.91mm per month. Similar results were obtained by, Shirazi et al[19] which showed that the laser-irradiated group on the maxillary molars of rats showed an almost 2.3 fold increase compared to the control group.

Similar results i.e. more mesial movement of molar were observed in the study by Koichiro Kawasaki et al[20], in which the result showed almost 1mm of space closure in the span of 13 days almost a 1.3-fold increase than the control group when diode laser wereirradiated on the maxillary molars of wister rats. In addition, acceleration of the tooth movement by diode laser was also noticed in the animal studies done by Yamaguchi et al[13], Duan. J et al[21], Yoshida et al[15], Fujita et al[14], in their laser group compared to their control groups.

A few animal studies done by Selfi et al[18], Mariana Marquezan et al[22] and Burca A Altan et al[23] showed contradictory results, in which laser group showed a no significant change in their mean space closure when compared to their control groups. Varying factors such as the dosimetry[24,25] frequency of applications[26] and differential biostimulatory effects on osteoclast and osteoblasts[27,28] might led to these conclusions.

When the efficiency of diode laser was compared with surgical procedures like corticotomy-assisted tooth movement, low level laser application in the present study showed some improved constructive findings. Flavio Uribea et al[29], have done protraction by means of selective decortications and it took almost 32 months to close 8 mm of space(0.25mm/month). This value was lower than the lowest molar protracted (0.65mm/month) by the diode laser intervention group in this study. In a similar study by Supang Samansukumal et al[30], the rate of molar protraction was 1.22 millimeters per month which was comparatively higher than the previous study (p <0.01).

In the present study, diode laser group showed 0.91mm/month which was comparatively less than the selective decortications study by Supang Samansukumal et al[30]. Hence, these contradictory results still need more clinical reports for evaluating the efficiency of the diode laser over the corticotomy procedure.

The present study showed some promising results over the conventional mechanics, and surgical interventions like corticotomies, but in the study done by Hiroshi Mimura et al[31] protraction of the mandibular second molars was done by a procedure like corticision, which showed an increased rate compared to the diode laser by a difference of 0.3mm. Although the difference seems to be less, the procedural technique sensitivity and surgical invasiveness remain greater discomfort in terms of patient compliance and pain perceptions when compared to the diode laser group.

On the non-laser side, the mean molar protraction observed was 1.94+/-0.68mm (**Table 1**, **Figure 1**) i.e. 0.64mm/month. It was higher when compared with the study done by Robert et al[5] in which the space closure done with keyhole along with supported endosseous implant showed a mandibular molar protraction of 0.29mm/month. It was also higher than the closing loops used by Tom and Hurley[32] in their study which resulted in an amount of molar protraction of 0.17mm/month. In another study by Baik et al[33], the amount of protraction recorded was 0.24mm/ month.

The highest molar protraction observed on the non-laser side was 0.86mm/month which was relatively higher than studies done by Nagaraj et al[8], Kyung et al[34], and Stepovich et al[7] in which 0.53mm/month, 0.69mm/month, and 0.23mm/month respectively.

One of the foremost queries raised by the general public about orthodontic treatment is the duration of the treatment time[1,2]. Mandibular Molar Protraction is one such procedure that prolongs the duration of the treatment period. As diode laser therapy low level laser therapy is non-invasive, patient compliant and comfortable for the patients it can be used for molar protraction clinically for faster tooth movement.

The small sample size is one of the limitations of this study. Furthermore, the present study did not consider the bone thickness and density and only conducted for 3 months duration. The total treatment time for complete molar protraction was also not considered. Further studies are needed to be conducted on a larger sample and for the long term to assess the efficacy of LLLT on Molar Protraction. It would be interesting to evaluate the combination effect of other procedures used to accelerate tooth movement like corticision, piezocision, and micro-osteoperforations with LLLT.

8. Conclusion

Despite conflicting research, our study was noteworthy due to the type of tooth movement we looked at—mandibular first molar protraction, which is one of the most challenging and difficult types of tooth movement. Our findings suggest that LLLT is an appropriate adjuvant therapy for molar protraction, as it can increase the rate of orthodontic movement of lower molars and subsequently shorten treatment times. Nevertheless, more research that focuses on the specifics of the laser used on a large number of patients is required to validate the findings.

9. Source of Funding

None.

10. Conflict of Interest

None.

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