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

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Abstract

Introduction: Methods to accelerate orthodontic tooth movement have been the topic of research to minimize the side effects related to increased treatment time. This study has been conducted to investigate the influence of low-level laser therapy with wavelength 980 nm on orthodontic canine retraction rate.

Methodology: This was a single center split-mouth randomized control trial. 45 patients planned for bilateral first premolars extraction with indirect anchorage, reporting to Orthodontics Department requiring bilateral maxillary first premolar extractions with critical anchorage were included in the study. One side of the maxillary arch was being irradiated by diode laser (aluminum-gallium-arsenide) of 980nm on three points both buccally and palatally and the opposite side of the arch was acted as placebo (control). Laser irradiation was done at initial appointment of premolars extraction (T0), followed by doses and measurements at three weeks interval (T1, T2 and T3).

Results: 53 patients were included in the study. There were eight drop outs leaving 45 patients for analysis. The speed of canine retraction was significantly faster on the experimental side (1.86 ± 0.48mm) compared with the control side (1.24 ± 0.03mm) (P-value < 0.001).

Conclusions: LLLT has a significant effect on OTM by reducing the duration of orthodontic treatment at 3 weekly intervals keeping the energy dose minimal.

Keywords: low-level laser therapy, Orthodontic tooth movement, 980nm wavelength, canine retraction rate, accelerated tooth movement, randomized control trial.

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Introduction

Malocclusion is prevalent all around the world indicating the need for orthodontic treatment. A systematic review by Alhammadi that the traits of malocclusion are distributed in all populations and ages highlighting the orthodontic care need.[1] The major concern of the patient nowadays in orthodontic treatment is its prolonged time.[2] Long treatment time conjointly causes higher predilection to caries, gingival and bone loss with tooth mobility and root resorption and white spot lesions.[2-4] Patients as well demand treatment of shorter duration due to social and esthetic concerns.[5] All this has lead to introduction of methods to accelerate orthodontic tooth movement.

Tooth movement achieved by orthodontics is a mechanically initiated biologic process in the periodontal ligaments and surrounding bone leading to remodeling by creating tension and compression areas. This activates bone forming and resorbing cells by inflammatory reaction with resorption being dominant on the compression area and bone

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formation on the tension area. This bone resorption and formation cascade is mediated by RANK/RANKL/OPG signaling pathway, which converts the mechanical force applied on the tissued to the biologic response of tooth movement.[6] As orthodontic tooth movement is a biologic response, technique to enhance tooth movement should aim at modulating the cellular responses without any adverse effect on surrounding sort or hard tissues.

Various techniques have been introduced to accelerate accelerate orthodontic tooth movement (OTM) pharmacologically,[7,8] surgically[2,9] or by physical agents such as electrical currents, electromagnetic fields, vibration, and low-level laser therapy (LLLT)[7-10] LLLT is advantageous as it is localized, user-friendly, painless, requires less chairside time and it is non-invasive, non-surgical but highly expensive.[4,11,12]

It has been reported that low-level laser therapy enhances the rate of tooth movement by bone remodeling, through photochemical reactions during which cellular photoreceptors absorb light energy and convert it into adenosine triphosphate by mitochondria. Inflammatory cytokines are stimulated to release RANKL which regulates osteoclast sequentially inducing bone remodeling during orthodontic tooth movement. Cytochrome c-oxidase is the primary photoreceptors, being able to absorb low-power red and near-infrared light irradiated at the appropriate wavelength, activating the respiratory chain in the mitochondria.[4,10,13,14]

Numerous studies have been reported on laser application but they are conducted at a low wavelength with more exposure time and at many sites with numerous intervals of laser application. This study has been conducted using the wavelength of 980nm which has been reported to possess the highest absorption spectrum and deepest bone penetration depth, thus it helps us to achieve the maximum efficiency of laser with minimum exposure at low dose.[3,7,12]

Methodology

To investigate the influence of low-level laser therapy with wavelength 980 nm at low dose on orthodontic canine retraction rate.

It was single-center study, conducted at the department of Orthodontics, Dr. Ishrat-ul-Ebad Khan Institute of Oral Health Sciences (DIKIOHS) at Dow University of Health Sciences (DUHS).

Total of 45 subjects were recruited in the study based on split-mouth design from September 2018 to October 2019. The recruitment was stopped when the calculated sample size was achieved. Sample size has been calculated by using PASS (V.11) with a 99% confidence interval and 99% power of the test, with mean ± SD of tooth movement in the experimental site 1.81 ± 0.26 mm and placebo site 0.79 ± 0.4mm.[15]Inclusion Criteria includes; Patients aged between 18-30 years. Patients planned for bilateral extractions of maxillary 1st bicuspids with indirect anchorage with mini implants.

All dentition till 2nd molars should be present in both arches.

Patients with good oral hygiene and Exclusion Criteria includes;

Patients with a history of chemotherapy or radiation therapy, or who have used long-term medications.

Patients who reported to have parafunctional habits.

Patients with severe tooth displacement (ectopic canine) and impacted canine.

Any morphological abnormalities, particularly in the maxillary cuspids, that is determined clinically or by OPG/periapical X-rays.

Patients who have a history of bone abnormalities or systemic or metabolic diseases. Study outcomes includes;

Primary outcome: Effect of Low Level Laser Therapy on rate of orthodontic tooth movement
Secondary outcome: canine retraction rate between intervals.

After the ethical board approval from Dow University of Health Sciences (Ref: IRB-941/DUHS/Approval/2017/162), the data collection procedure was started. When the patients were on 19x25-inch Stainless Steel arch wire and the anchorage was reinforced through mini implants (placed on both sides buccally between 1st molar and 2nd bicuspids), they were recruited in the study. Second premolars were ligated with mini-implants to provide anchorage.

The experimental side was randomly allocated in every participant using the chit method. The chits were concealed in a box and the participant himself was asked to pick one for allocation of experimental side. The allocation was noted in the list and was as well written on the patient record file for future reference. This record was kept in the department with the principal researcher unaware of the allotment.

First laser irradiation was done on experimental side just after first premolars extractions. Canine distalization was done by application of power chain from canine bracket hook to first molar band hook (indirect anchorage). (Figure I) The retraction force was kept optimal on both sides keeping a check using force measuring gauge.

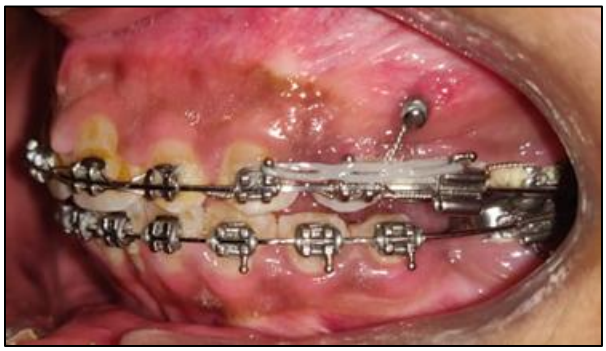

Fig. I: Canine retraction using indirect anchorage: implant placed between second premolar and first molar with implant tied to second premolar bracket for anchorage. Power chain spanning from canine to first molar for retraction of latter.

Each study participant was exposed to Gallium-Aluminum-Arsenic diode laser (Specification of K2 Mobile Diode Laser; Wavelength: 980 ±10 nm; Laser emission mode: CW, Coolpulse1, Coolpulse2, Output power: 3.5W / 6W Pulse; Rechargeable lithium-ion battery 3.7VDC, 1700mAh) on experimental side maxillary cuspid on six points, 3 buccally and 3 palatally, for 3secs each (Figure II). The radiation was done every third week till canine retraction was completed.

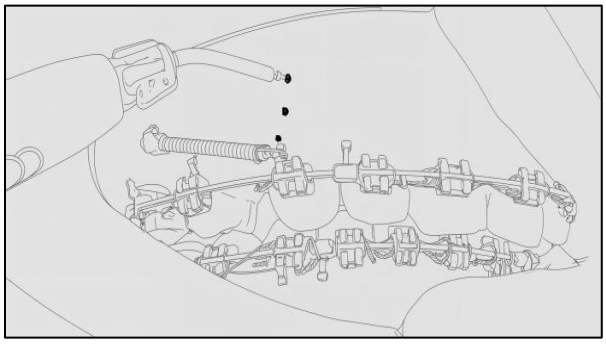

Fig. II: Diagrammatic representation of laser application on buccal side of canine at three different points represented by black dots. Similar points were irradiated on the palatal side as well.

A sheath was placed over the leading edge of the laser probe. The pseudo-irradiation component of the placebo side used a probe sheath with a black plastic end in place of the transparent plastic end used for the irradiation side. (Figure III and IV) A third party supervised the usage of the laser and dummy sheath tubing for the laser application, and the operator wore green acrylic laser-protective eyeglasses that prevented from recognizing the laser sheath

employed. This was done to introduce blindness in the study.

Fig. III: Armamentarium used for laser (left to right): Eye protectors, Laser machine, shield, Vernier caliper

Fig. IV: Armamentarium used for canine retraction (left to right): Examination set, Mathews, Weingart plier, orthodontic mini-implant, implant driver, archwire, scissors, powerchain.

At each visit, a 0.01mm digital Vernier caliper was used to record all research measurements from the tip of first molar mesio-buccal cusp to cusp tip of canine. To maintain blindness, the readings were taken by two observers who were unaware of the radiated and irradiated sides. To prevent bias, measurements were made three times during a single visit, and the mean was reported. Until the canines completely retracted, readings were obtained every three weeks.

Data was entered and analyzed with the use of Statistical Package for Social Sciences (SPSS) Version 16.0.
Descriptive analysis was executed to attain the mean readings for orthodontic tooth movement.

Statistical Analysis:
The normality of the data was checked by the Shapiro Wilk test. The net retraction rate for both cases and control was found to be non-normal; hence the Mann-Whitney U test was applied for their comparison.
Since the data follows a normal distribution according to the Shapiro-Wilk test, with a p-value ≤0.05 considered significant, the independent sample t-test was used to analyze the rate of tooth movement between the two groups and the mean comparison between the groups for continuous features.

Result

The average age of the study population was determined to be 21.38 ± 2.87 years. The average age of the subjects ranged between 18-29 years with a median = 21 and interquartile range (Q1-Q3) = 19 to 23.5 years.
Out of 45 subjects, 15 were males and 30 were females. Males represent 33.33% of the study population and females represent 66.66% of the study masses. (Fig. V)

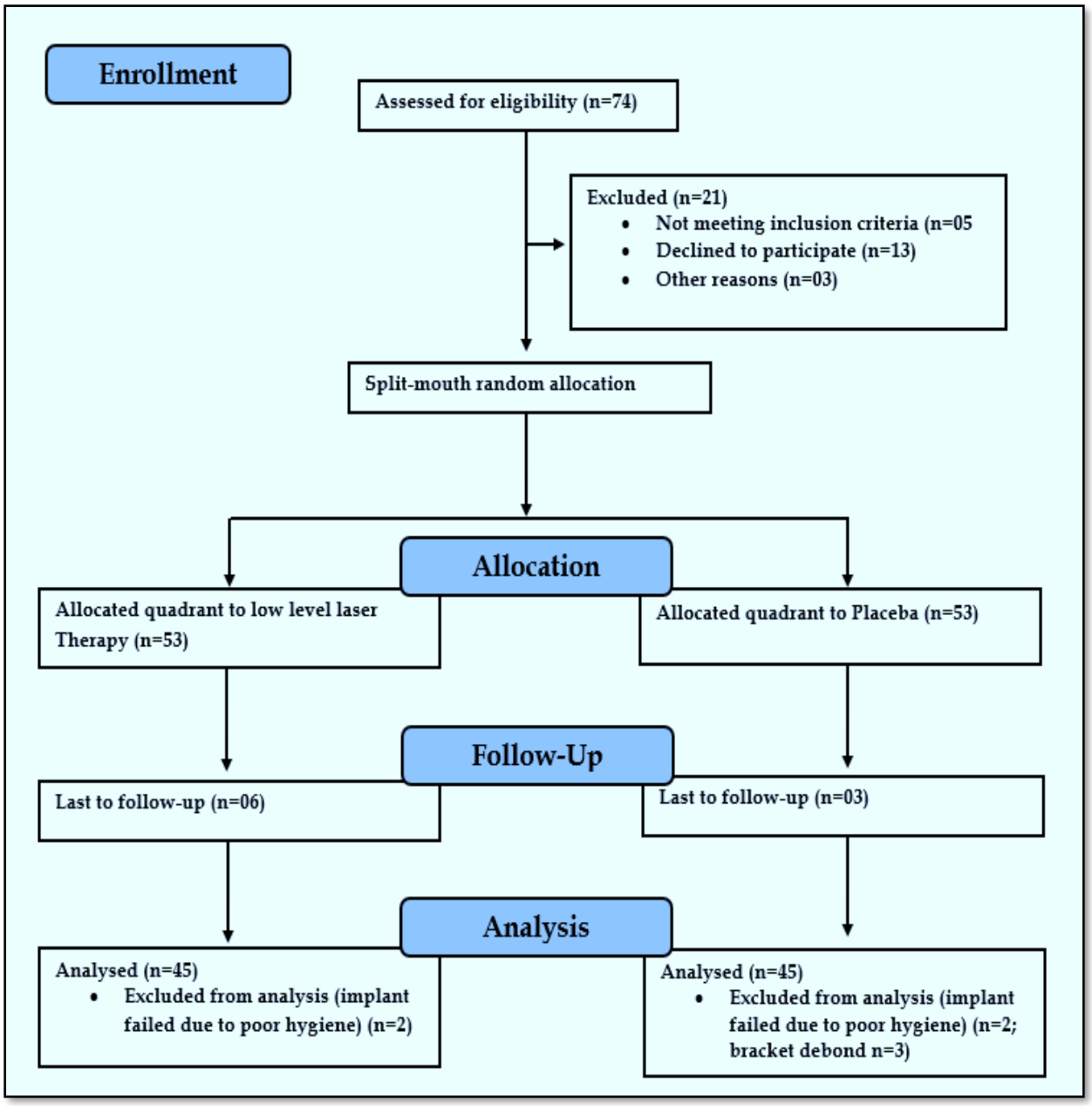

Fig. V: CONSORT flow diagram

The duration of complete canine retraction in the experimental group was 17.57 weeks with inter-quartile range between 15.83 - 17.89 weeks. Whereas in the control group, the time required for complete canine retraction was 26.26 weeks with inter-quartile range between 22.72-26.88 weeks showing a statistically significant difference between both groups with a p-value <0.001 at 95% confidence interval. (Table-I)

Net retraction duration	Cases	Control	p-value
Median (Q1-Q3)	17.5 (15.8-17.8)	26.2 (22.7-26.8)	<0.001

Table-I: Mann-Whitney U test for comparison of net retraction duration between groups

Comparison of canine movement between the experimental and the control side

Every three weeks, the distance from the canine tip to the molar mesio-buccal tip was measured. At every visit, the difference in canine distance between the two groups was statistically significant (P-value = 0.000), with the exception of T6, where there was no discernible difference between the experimental and control groups as shown in Table-II.

Time interval	Cases Mean ± SD (mm)	Control Mean ± SD (mm)	P-value
T0	21.11 ± 0.994	21.12 ± 0.946	0.968
T1	18.73 ± 0.916	19.87 ± 0.973	0.000*
T2	16.95 ± 0.952	18.67 ± 0.867	0.000*
T3	15.51 ± 0.802	17.40 ± 0.853	0.000*
T4	14.25 ± 0.704	16.22 ± 0.835	0.000*
T5	13.07 ± 0.602	15.03 ± 0.808	0.000*
T6	13.01 ± 0.731	14.03 ± 0.814	0.069

Table-II: Mann-Whitney U test for comparison of net retraction rate between groups

Comparison of the canine retraction rate in the experimental and the control group. The null hypothesis was declined as we have found out a significant difference in canine retraction rate between the experimental and control group during initial time (p-value < 0.05) but the difference became insignificant after twelve weeks as shown in Table-III.

Tooth movement	Mean ± SD (mm) Cases	Mean ± SD (mm) Control	Confidence interval 95%		Mean difference	P value
			Upper bound	Lower bound		
T0-T1	2.38 ± 0.47	1.25 ± 0.44	0.933	1.322	1.127	0.001*
T1-T2	1.78 ± 0.44	1.20 ± 0.38	0.581	0.755	0.407	0.001*
T2-T3	1.43 ± 0.31	1.26 ± 0.28	0.041	0.293	0.167	0.010*
T3-T4	1.26 ± 0.34	1.18 ± 0.31	-0.055	0.221	0.082	0.236
T4-T5	1.21 ± 0.25	1.13 ± 0.16	-0.006	0.175	0.084	0.068
T5-T6	0.79 ± 0.41	1.29 ± 0.34	-1.050	0.054	-0.498	0.071

Table-III: Comparison of the difference between intervals between groups (p-value ≤ 0.05)

Discussion

In this research, we used a Gallium-Aluminum-Arsenide Diode laser of 980±10nm wavelength to achieve maximum penetration. Numerous former researchers also used Ga-Al-As with the wavelength ranging from 650 nm to 940 nm.[16-19] The energy dose was set at 6 J/cm2 for each point with continuous pulse mode using 0.04 cm2 fiber optic tip to stimulate the photobiomodulation effect. Our study used a

power output of 3.5W, continuous wave (CW) mode, and exposure time for 3 seconds only.

The first who proposed that LLLT was capable of accelerating OTM were Kawasaki and Shimizu[20] by maximizing the extent of bone formation through cellular proliferation on the tension side and increased osteoclast on the compression side. M. Milligan et al,[21] revealed that there is a statistically significant increase in the speed of tooth movement in the lased group with increased expression of MMP-13 and RANKL similar to the findings of Gawish et al.[22] MMP-13 has been reported to rise in where there is an upsurge in extracellular matrix and bone deprivation. Eid et al[18] demonstrated elevated IL-1β levels in gingival fluid on the compression side related to accelerated tooth movement following laser application. Parekh et al[23] found a correlation of increased levels of β glucoronidase and Pentraxin 5 with laser irradiation.

In our study, we have found out 33% rise in the canine retraction rate in the irradiated side equated with the non-irradiated side. The mean time interval mandatory for complete canine retraction on the laser side was 16.88 ± 1.63 weeks and for the control side, it was 25.39 ± 3.10 weeks. Study conducted by Qamaruddin et al[15] found out the same result with 940nm diode laser but on self-ligating brackets (SLB). Youssef et al[24] and Sousa et al[25] found twice the rate of OTM. Guram et al[26] found out 65% faster tooth movement on the irradiated side following many studies.[25,27] In our study, there is 1.55 fold escalation in canine retraction rate in contrast with Qamaruddin et al,[15] who found 2.02 times faster movement in irradiated canine along with the use of self-ligating brackets (SLB) which might be the reason for accelerated tooth movement, whereas in one more study documented by Qamaruddin et al,[28] they found out 1.65 times speedy tooth movement in the irradiated group using MBT prescription of fixed appliance. Another article found out 1.4 times quicker tooth movement[18] and 1.6 times rise in the canine retraction rate in an investigation by Farhadian et al[10] and by Kochar et al.[29] Kharat et al[30] also obtained faster tooth movement but they used second premolar mesial surface as a reference point instead of molars. Kamboj et al[31] also documented 1.10 fold faster tooth movement following laser therapy compared with piezocision. Shirazi et al[32] found out 2.3 fold rise in OTM after irradiation than non-irradiation, but on animal study. Gawish et al[22] found a 1.13 greater canine retraction rate in laser group compared to non-irradiated side. However, other studies found a statistically insignificant difference between irradiated and non-irradiated groups.[33-35] Though, when assessing the differences among the following recorded intervals till ninth week, it can be witnessed that this difference was decreased over time, although statistically greater for experimental canine comparing with the control side, might be possible because of increased phagocytosis of leukocytes[36] and corresponding to normal lag phase in OTM. This is in harmony with many former pieces of research.[15,28] A systematic review[14] showed 30 to 40 percent acceleration in tooth movement following laser application.

The null hypothesis have been overruled as the study reported LLLT found to be an effective device to escalate the velocity of orthodontic tooth movement and reducing overall treatment time.

The depth of laser energy diffusion is regulated by many confounders such as the individuals' anatomical tissue characteristics of bone density and gingival thickness. Future researches should take it into consideration.

Conclusion

Low level laser therapy at 940nm wavelength when applied at 3 weekly interval with energy density at minimum, modulates orthodontic tooth movement minimizing the treatment duration.

Ethical Approval

The study was approved by the Ethical Review Board of Dow University of Health Sciences (Ref: IRB-941/DUHS/Approval/ 2017/162)

Disclaimer

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Conflict of Interest

It is declared that the authors don't have any conflict of interest.

Authors' Contribution

HMK: Data collection and data analysis
IA: Writeup
SR: Provide Guidance for Research
HT: Writeup and correspondence
AS: Data collection and writeup
TK: Proof Reading

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