EGYPTIAN DENTAL JOURNAL
www.eda-egypt.org
VOL. 70, 2365:2376, JULY, 2024
PRINT ISSN 0070-9484 • ONLINE ISSN 2090-2360
ORAL MEDICINE, X-RAY, ORAL BIOLOGY AND ORAL PATHOLOGY
Submit Date : 21-04-2024 • Accept Date : 16-05-2024 • Available online: 01-07-2024 • DOI : 10.21608/EDJ.2024.281230.2997

EFFECT OF 980 NM LASER PHOTOBIOMODULATION USING FLAT-TOP BEAM PROFILE MODIFIER IN ACCELERATION OF CANINE RETRACTION: A RANDOMIZED CLINICAL TRIAL

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ABSTRACT

Objective: This study aimed to clinically investigate the effectiveness of laser photobiomodulation (laser PBM) using flat-top beam profile modifier in acceleration of canine retraction. The expression of nuclear factor kappa-B ligand (RANKL) that is involved in alveolar bone remodeling was additionally assessed.

Material and Methods: The current split-mouth randomized controlled trial involved twenty patients undergoing extractive orthodontic therapy due to the eruption of ectopic canines. A total of forty canines were assigned to two groups: Group I, which underwent laser irradiation, and Group II, which did not receive irradiation. The canines were evaluated at T0 (pre-retraction), T1 (one month post-retraction), T2 (two months), and T3 (three months) for total retraction displacement. RANKL gingival crevicular fluid samples were collected on days 0, 7, 14, and 30 during laser photobiostimulation sessions. Probing depth was also assessed as a secondary outcome at baseline and three months after the procedure.

Results: The results of orthodontic tooth movement of the canines after 3 months of follow-up indicate an average displacement of 3.48±0.2 mm for the irradiated group and 3.07±0.24 mm for the non-irradiated group. The results demonstrated that Group I achieved the highest mean RANKL level than Group II at different time intervals. No differences were observed between groups regarding the probing depth ($p > 0.05$).

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Conclusion: The results of this research showed that the laser photobiomodulation (laser PBM) using flat-top beam profile modifier with the parameters set was found to be a non-invasive tool capable of accelerating the orthodontic canine retraction with maintenance of periodontal health.

KEYWORDS: Laser photobiomodulation; accelerated orthodontic movement; RANKL, clinical Trials.

INTRODUCTION

The intricate process of orthodontic tooth movement (OTM) is characterized as an adaptive biologic reaction to an externally applied force interfering with the dentofacial structures' physiologic equilibrium.[1] During OTM, there is a biologic bone remodeling that results from the ordered remodeling of periodontal tissue following the application of mechanical stresses. This remodeling causes an immediate inflammatory reaction and increases the patients' feeling of discomfort.[2,3]

Numerous organizations have made an effort to date to identify methods for inducing bone remodeling that may speed up the OTM, such as corticotomy, physical stimulation, and local medication injection.[4] The general use of injections and corticotomies in clinical practice is restricted due to their unpredictable systemic effects, local pain, and discomfort. Laser photobiomodulation (laser PBM) has been suggested as a superior and safe solution. [5]

Through its photobiomodulation effects, low-level laser irradiation has been found to be successful in triggering remodeling processes in both hard and soft oral tissues, leading to properly directed healing pattern. [6,7] It has been demonstrated that using laser PBM during OTM is beneficial and efficient in decreasing orthodontic discomfort, preventing the release of pain mediators linked to analgesia, and modulating the remodeling process to achieve accelerated tooth movement. [8]

Many laser systems, including Nd:YAG, He-Ne, and diode lasers, are currently available on the market and can be used for laser PBM. Among these, it has been demonstrated that the diode laser energy in the near infrared spectrum can deeply penetrate the target tissue,[7,9] due to its reduced coefficient of absorption.[10] furthermore, a variety of clinical applications have been developed due to the low cost and ease of miniaturization of diode laser devices.[6]In addition, It was reported that, utilizing a collimated flat-top beam profile modifier can offer a uniform cross-sectional fluence with deeper penetration of the laser energy inside the target tissue. [11]

It has been shown that the diode laser can promote tissue healing and exhibits minimal mechanical stresses to the roots that are already receiving orthodontic tension.[12] According to Kawasaki and Shimizu in (2000),[13] during experimental OTM in rats, laser PBM was found to promote osteoclast development and tooth movement on the compression side. Some other studies [14] have demonstrated that laser PBM can accelerate OTM through the nuclear factor kappa B (RANK) receptor activator, RANK ligand (RANKL), and macrophage-colony stimulating factor receptor (c-fms).

During bone remodeling, there is a cycle of bone resorption and formation carried out by osteoclasts, which are stimulated by RANKL for osteoclastogenesis. Osteocytes play a crucial role by serving as the primary source of RANKL during the process, making RANKL a dependable marker for bone remodeling. Additionally, orthodontic forces can trigger alveolar bone remodeling to guide teeth towards a specific position.

Overall, bone resorption is suggested as the rate-limiting step in OTM,[13] and photo-therapy

became a reliable tool in assisting OTM in modern dentistry; nevertheless, there is a great controversy regarding the most suitable parameters used for laser PBM and role of the degree of distribution homogeneity of laser irradiation. Given that laser irradiation using the flat-top beam profile modifier was reported to uniformly cover the lased site [11] when compared to the standard-Gaussian profile, this study was directed to clinically evaluate the effect of laser PBM using flat-top beam profile modifier on the acceleration of canine retraction. The expression of RANKL release in gingival crevicular fluid (GCF) was also monitored to assess the osteoclastic activity.

SUBJECTS AND METHODS

This randomized clinical trial was approved from the research ethical committee (REC) of the Faculty of Dental Medicine for Girls, Al-Azhar University, Cairo, Egypt, (REC-CL-24--02). The patients and /or guardians were fully informed about the procedure and informed written consents were signed.

All subjects met the following **inclusion criteria**

1. Systemically free patients. [16]
2. Patients with malocclusion requiring extraction of maxillary first premolars and retraction of the maxillary canines as a part of the orthodontic treatment plan.
3. Presence of fully erupted permanent teeth except the third molars.

The following subjects were excluded: History of orthodontic treatment or periodontal treatment within the last year, patients suffering from active periodontal disease, patients under medical treatment within the last 3 months or with any systemic condition that affects the rate of orthodontic tooth movement, smokers, pregnant or lactating women. In general, when the follow up schedule of this study was not convenient; patient was excluded.

Sample size calculation

Based on the average canine retraction displacement reported by the previous clinical study field (Sedky et al., 2019) [17], the difference of 1.4mm with a standard deviation of 1.11 was assumed as the clinically relevant limit for proving non-inferiority. For each group, it was estimated that 15 patients would be required under the significance level of 5% and the power of 80%. The number will be increased to 20 in each group to compensate for follow up attrition.

Sample randomization and grouping

20 subjects were recruited and forty canines in a split mouth design were randomly allocated into Group I (Irradiated Group) (number of canines = 20, Laser application + Orthodontic treatment) and Group II (Control Group) (number of canines = 20, Orthodontic treatment only).

A block randomized approach was undertaken to balance age, gender and clinical severity. The primary investigator (M Sh) made and concealed the allocation sequence, while the examiners performing the follow up were blind to subject assignments.

Clinical procedures

Patients were given oral hygiene instructions to ensure plaque control and to maintain good oral hygiene.

After the separation phase, molar bands with buccal tubes (0.022" x 0.028") (Washbon first molars. Ormco Corp, California, USA); were selected for the right and left maxillary first molars. Transpalatal arch (TPA) with Nance appliance was placed to achieve anchorage for canine retraction banded and cemented to the upper first permanent molar with glass ionomer cement (Medicem. Promedica Corp, Germany).

In every patient, the upper arches were treated with an orthodontic device equipped with brackets featuring a slot size of (0.022" × 0.028") (Atlas Mini, Dynaflex, Missouri, USA). The brackets were

attached using light cure composite (Green glue, Ormco Corp, California, USA) and then solidified with an LED light curing system. These brackets were affixed from the right second premolar to the left second premolar, excluding the maxillary first premolars on both sides, which were planned for extraction.

To achieve leveling and alignment, nickel titanium archwires of 0.012", 0.014", and 0.016" (Nickel Titanium Archwire, Modern Orthodontics LLC, California, USA) were successively employed. Subsequently, stainless steel archwires of 0.016", 0.018" ("Acti-4S Stainless Steel Archwire, Modern Orthodontics LLC, California, USA") were utilized.

Following the initial alignment and leveling, an upper continuous archwire of 0.016× 0.022", 0.017x0.025" SS, and finally "0.019x0.025" SS" was inserted. This archwire remained in place for 3 weeks before commencing canine retraction, allowing for full arch wire passivity. The retraction of maxillary canines was preceded by the extraction of upper first premolars.

Before initiating the canine retraction phase, the right and left maxillary first molars and second premolars were connected through ligation using 0.009-inch wire in a figure of 8 configuration to enhance anchorage. A similar ligation approach using 0.009-inch wire in a figure of 8 was employed for stabilizing the upper incisors in the anterior segment. Canine retraction utilized a 9mm super elastic Nickel-Titanium closed coil spring (Vector Tas NiTi coil sprig, Ormco Corp, California, USA) with a force of 150 g, measured by a force gauge (Force gauge, VST Corp, China), activated biweekly.

Ligation of the distal wing of the canine bracket with 0.009-inch ligature wire was conducted to prevent canine rotation during retraction. Regular assessments of the appliance in each patient were conducted at every visit as part of quality control procedures. If a bracket, arch wire or a spring involved in canine retraction was damaged the subject was excluded from the study.

Laser Photobiomodulation Irradiation:

The laser device used in this study was an Indium Gallium Arsenide Phosphide (InGaAs) semiconductor diode laser with a flat-top beam profile modifier (Primo diode laser by Medency, Vicenza, Italy) by Medency, emitting continuous infrared radiation of wavelength 980 nm. Precautions were taken before laser application procedure where both the patient and the operator wore appropriate protective glasses specific for the wavelength used (980 nm) according to the safety rules. Before applying the laser energy, the target mucosa was air dried.

A power of 200 mw was directed with a continuous wave mode to the labial mucosa through the flat-top beam profile modifier with a spot area of 0.724 cm^2 and diameter of 9.65 mm in a non-contact mode (maximum working distance up to 40 cm). To cover the whole canine root periodontium, the laser energy was applied at tow different points along the root length for 25 seconds each. The resultant energy of 5 joules (j) was delivered through a flat-top beam profile modifier **(Figure 1)** at each point of application to produce an energy density of 6.9 j/cm^2. All irradiation was performed by the same operator after the application of the retraction force by the Ni-Ti closed coil spring (day 0). the laser applications were repeated on days 2, 4, 7 and 14.

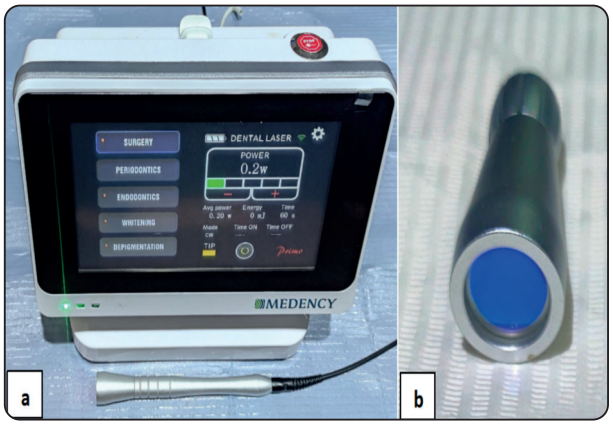

Fig. (1): a) Primo diode laser device (980 nm), b) Flat-top beam profile modifier.

a) Clinical and radiographic parameters

The following records were taken for each patient before treatment and completion of comprehensive orthodontic treatment:

i. Orthodontic study casts

ii. Extra oral photographs

iii. Intra oral photographs

iv. Lateral cephalometric radiograph

v. Panoramic radiograph

b) Immunohistochemical evaluation

Gingival crevicular fluid (GCF) samples were obtained utilizing periopaper points #35 (Protaper, Dentsply, USA) [18]. The region earmarked for sampling underwent isolation with cotton rolls and plaque elimination using cotton pellets was carried out in a delicate manner. Subsequently, the buccal aspect of the canine (mesial, distal, middle third) was rinsed with water and air dried preparatory to the sampling process.

The insertion of the filter paper point into the gingival sulcus, to a depth of 1-2 mm, was executed until encountering slight resistance over a period of 60 seconds, enabling absorption of GCF. Precautionary measures were taken to prevent harm to the soft tissues, following which the point was moved to a plastic eppendorf. Sampling took place on days 0, 7, 14, and 30, with subsequent storage at -80˚c until the time of analysis.

Detection of RANKL:

The identification of RANKL was conducted by employing the ELISA methodology utilizing the Fine Test kit with catalogue number (E-3-021-1). This approach relied on the technology of sandwich enzyme-linked immunosorbent assay.

The gingival pericrevicular miniprep test samples were immersed in phosphate-buffered saline (PBS) with a pH of 7.5 immediately post-collection, aliquoted, and stored at -80°C for prolonged periods while avoiding repeated freeze-thaw cycles. The reagents were allowed to equilibrate for a minimum of 30 minutes at ambient temperature (37°C); the samples were appropriately diluted and thoroughly mixed.

The standard, test sample, and control (zero) wells were positioned on the pre-coated plate accordingly, with their locations being recorded. The standard was introduced in various incremental concentrations as per the manufacturer's instructions and added into the designated wells at a volume of 0.1 ml; similarly, the samples were also placed in the test sample wells. The plate was covered and subjected to an incubation period at 37°C for 90 minutes. After removing the lid, the contents of the plate were discarded, and the plate was tapped onto absorbent filter papers or a similar material, ensuring the wells did not dry out completely.

A 0.1 ml of biotin detection antibody working solution was dispensed into the aforementioned wells (standard, test sample, and zero wells), with caution taken to add the solution at the base of each well without touching the sidewalls. The plate was sealed and underwent incubation at 37°C for 60 minutes.

Upon removal of the lid, the plate underwent three wash cycles with a wash buffer. Following this, 0.1 ml of SABC working solution was added to each well, the plate was covered, and incubated at 37°C for 30 minutes. The plate was then washed five times with the wash buffer, allowing the buffer to remain in the wells for 1–2 minutes each time.

A volume of 90 µl of TMB substrate was dispensed into each well; the plate was covered and incubated at 37°C in darkness for 15–30 minutes. After adding 50 µl of stop solution to each well and thorough mixing, an immediate color change to yel-

low was observed. The optical density (O.D.) absorbance was promptly measured at 450 nm using a microplate reader post addition of the stop solution.

The quantification of the parameter under scrutiny was computed utilizing the subsequent formula: (the relative O.D.450) = (the O.D.450 value of each well) – (the O.D.450 value of the Zero well); the development of the standard curve entailed graphing the relative O.D.450 value of each standard solution (Y) in relation to the corresponding concentration of the standard solution (X). The determination of the analyzed parameter in the specimens was estimated from the standard curve; the curve was formulated using specialized professional software. Ultimately, the computed outcomes of the specimens were corrected by the dilution factor for the concentrations derived from estimation to ascertain the concentration pre-dilution.

Probing depth assessment:

Probing depth[19] was assessed at baseline and after three months. It is the measurement of the depth of the sulcus ("the distance from the gingival margin to the base of the sulcus"). It was evaluated using a calibrated Williams periodontal probe with light force to avoid tissue damage and over-extension into healthy tissue.

Statistical description

Statistical analysis of the results was performed for parametric data ("Canine retraction displacement and RANKL results") by applying One-way ANOVA followed by Post Hoc test for multiple comparisons between different groups and time intervals.

The comparison of probing depth results between the two studied groups at different time intervals was done using "Kruskal-Wallis followed by the Mann-Whitney Test" for pairwise comparisons (Non-parametric test). "Statistical evaluation was performed using the SPSS statistical package (version 25, IBM Co. USA").

RESULTS

Canine retraction displacement

For group I, the mean of canine displacement was (1.41±0.12 mm) at T1, increased to (2.21±0.33 mm) after T2, and (3.48±0.2 mm) after T3. The percentage of change after T2 was -56.7% and -146.8% after T3.

For group II, the mean of canine displacement was (0.57±0.14mm) at T1, increased to (1.44±0.12mm) after T2, and (3.07±0.24 mm) after T3. The percentage of change after T2 was -152.6% and -438.6% after T3. *For both groups,* according to the Tukey post hoc test, there was a significant difference between the three time intervals.

For the three time intervals, the highest mean of canine displacement was achieved in group I, and the difference between the two groups was statistically highly significant (P-value ≤0.001) (**Figure 2**).

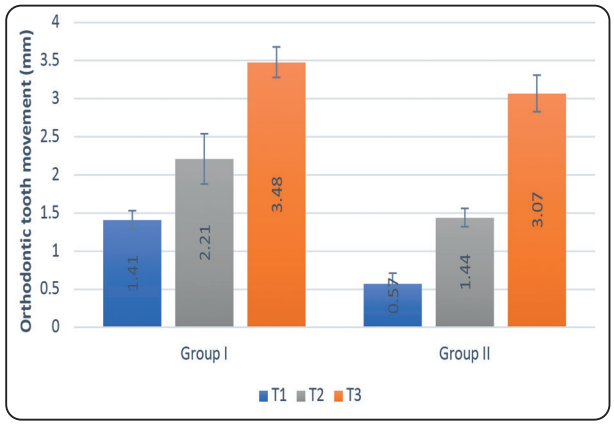

Fig. (2) A bar chart depicting the mean and SD of canine retraction displacement (mm) for the two groups at different time intervals

RANKL Level

For group I, the lowest mean of RANKL level was (139.7±10.2) at Baseline, while the highest one was achieved after 14 days (220.9±9.1). The highest percentage of change was -18.3% after 14 days. According to the Tukey post hoc test, there was

no significant difference between 7 and 14 days or between 7 and 30 days, while there was a significant difference between baseline and the other three time intervals. For group II, the lowest mean of RANKL level was (135.6±9.4) at Baseline, while the highest one was achieved after 30 days (152.7±12.5). The highest percentage of change was -12.7% after 30 days. Group I achieved the highest mean RANKL than group II, and the difference between the two groups was statistically highly significant (P-value ≤ 0.001), except at baseline (P > 0.05) **(Table 1).**

Probing depth (PD)

In both groups, the percentage of change was -7.8% in group I, and -7.8% in group II, a statistically non significant difference was shown (P > 0.05) **(Table 2).**

TABLE (1) Comparison Mean± SD of the RANKL level for the two groups at different time intervals

Groups	Baseline	7 Days	14 Days	30 Days	P- value*	Percentage of change		
						7 days	14 days	30 days
Group I	139.7±10.2^{c}	210.4±12.6^{ab}	220.9±9.1^{a}	204.6±12.6^{b}	0.000^{HS}	-12.7%	-18.3%	-9.6%
Group II	135.6±9.4^{c}	143.1±10^{ac}	145.8±10.8^{ac}	152.7±12.5^{a}	0.006^{S}	-5.6%	-7.5%	-12.7%
P- value**	0.07^{NS}	0.000^{HS}	0.000^{HS}	0.000^{HS}				

Small letters for intra-group comparison (Tukey post hoc test) and the means with different superscripts are statistically significant different at P ≤ 0.05

- HS= highly significant P-value ≤ 0.001

- S= Statistically significant P ≤ 0.05

-NS= Non significant P > 0.05

-* :Overall P-value for intra-group comparison:.

-** :Overall P-value for inter-group comparison:.

-The negative value of the percentage change means the baseline value changed to a higher value.

TABLE (2) Comparison Mean±SD of the Maximum Probing Depth (mm) for the three groups in the upper and lower teeth

Groups	**Baseline**	**3 Months**	**P- value***	**Percentage of change**
Group I	2.6±0.82	2.8±0.42	0.352^{NS}	-7.8%
Group II	2.4±1.02	2.7±0.57	0.342^{NS}	-7.7%
P- value**	1.000^{NS}	1.000^{NS}		

-* Overall P-value for intra-group comparison.

-** Overall P-value for inter-group comparison.

- S= Statistically significant P ≤ 0.05

-NS= Non significant P > 0.05

-The negative value of the percentage change means the baseline value changed to a higher value.

DISCUSSION

This study aimed to evaluate the influence of laser PBM using flat-top beam profile modifier on the acceleration of canine retraction.

The choice of a split-mouth design in this study was deliberate, as it is a recognized study design favored by many researchers in order to minimize initial discrepancies among participants. An important benefit of this design is the reduced sample size needed in comparison to a parallel-group design. This is because each subject serves as their own control, thereby eliminating much of the variance between subjects, leading to increased statistical power, with each patient undergoing just one type of intervention. It has been calculated that the sample size necessary for a split-mouth randomized controlled trial is roughly half that of a parallel trial under equivalent conditions. The maxillary arch was specifically chosen due to the presence of identifiable landmarks on the palate, facilitating more direct and precise measurements.[20, 21]

Despite the generally positive outcomes observed in numerous studies regarding the biostimulation of orthodontic tooth movement, discrepancies in results may arise from differences in the photobiostimulation parameters utilized. .[22-23] Various energy parameters such as wavelength, energy output, exposure duration, and radiation mode have been explored for this purpose. In this particular investigation, a continuous wave mode near infrared 980 nm Indium Gallium Arsenide Phosphide (InGaAsP) semiconductor diode laser was employed, selected for its ability to penetrate deeply into the target tissue.[24]

A laser energy density of 6.9 J/cm^2, which belong to the recommended therapeutic window of photobiomodulation;[25,26] was delivered through a flat-top beam profile modifier fitted to the laser hand-piece. This delivery system offers the most consistent and uniform power distribution over 90% of the treatment area compared to the standard one through which only a surface area less than 50% of the laser spot size could be effectively illuminated. The non-homogeneous distribution of the laser energy delivered by the conventional optical system may result in different photobiomodulatory responses (positive, null or negative) in an area of only 1 cm^2. Therefore, unpredictable results would be expected at the cellular level due to the received uneven power densities.

On the contrary, the used flat-top beam profile modifier can offer the most uniformly achieved biological responses, in addition to the benefit of a deeper penetration depth.[27] Furthermore, the flat-top beam profile modifier used in this study was able to maintain constant power from contact and up to 40 cm away from the target tissue, allowing for improved clinical consistency during laser PBM.[24]

The diameter of the flat-top beam profile modifier used in our study was 9.65 mm, so to allow the laser energy to cover the whole canine periodontal support homogeneously, two-point irradiation was adopted along the canine root labially. In the present study, laser PBM was applied on days 0, 2, 7, 14. This rate of applications was used previously by Sedky et al., 2019 [17] who compared the effect of laser PBM and corticotomy on RANKL release during orthodontic treatment. Multiple sessions were applied upon knowing that all biostimulation protocols require repeated applications of the laser as the biological effect, once activated, must be maintained.

In relation to the evaluation of the distance of orthodontic canine movement in this investigation, it aligned with comparable researches.[20,28] Utilization of a digital caliper facilitated the measurement of the linear span between the canine's cusp and the mesiovestibular cusp of the initial molar on the gypsum casts. The potential compromise of anchorage was also taken into account, as the contraction of the post-extraction area could be influenced not solely by the distalization of the canine but also by the mesialization of the posterior segment, underscoring

the significance of the statistical examination of this factor for result credibility.

Specimens of GCF were acquired to ascertain the RANKL level as an indicator of bone remodeling in the alveolar process. Various studies have adopted a similar approach for GCF composition sampling in adult and adolescent populations undergoing orthodontic interventions. [17,29] There is mounting evidence pointing towards the substantial role played by RANKL in osteoclastogenesis; upon binding to its designated receptor (RANK), RANKL triggers intracellular signaling pathways that culminate in bone resorption. This binding process is obstructed by a soluble decoy receptor known as osteoprotegerin (OPG). In the majority of prior clinical investigations, OPG concentrations tended to decrease or remain stable, while RANKL levels displayed an upward trend during the initial phases of orthodontic tooth adjustments. [30–31]

The results of this study revealed that patients in both groups exhibited similar mean of probing depth throughout the study with no significant change. Given that probing depth is a soft tissue parameter, the continued patient education and motivation are the leading factors for this clinical finding.

The laser PBM resulted in a significant acceleration in canine retraction, and a significant expression of RANKL level with no deleterious effect on periodontium in different treatment time intervals compared to the control side.

These results regarding acceleration of orthodontic tooth movement were in agreement with other authors, [20,32] who demonstrated a positive effect of the laser PBM on accelerating the speed of the distal displacement of the canines but obtained with different rates. On the other hand, the findings of the present study was in contrast to some previous studies that showed no statistically significant effect of laser PBM on acceleration of orthodontic tooth movement,[33, 34] which could be attributed to the laser parameters and the type of the laser beam profile (Gaussian beam profile) used in these studies.

In fact, the selection of the laser parameters has an association with the amount of tooth movement, which explains the conflicting results as some trials found an effect of laser on tooth movement while other trials did not. [12, 33]

In the present study, there was a statistically significant increase in RANKL level in the irradiated group than the control one at days 0,7,14 and 30 days. These findings were consistent with the results of Hosseinpour et al. [35] who investigated the effect of laser PBM on accelerating the rate of orthodontic tooth movement, pain and RANKL concentration in GCF; they reported remarkable increase in RANKL level and rate of orthodontic tooth movement in the laser group while pain perception was higher in the control group.

Moreover, at the end of the present study (3 months) laser side showed statistically significant higher mean RANKL level than control side which indicates the biostimulatory effect of laser PBM on bone cells. The outcomes of this research were in alignment with previous studies conducted by Suzuki et al.,[36] and Milligan et al.[37] focusing on the impact of different wattage parameters of laser PBM on teeth undergoing orthodontic movement. Their findings indicated that the groups exposed to laser irradiation demonstrated a notable and significant rise in RANKL concentration levels compared to the non-irradiated control groups. Conversely, the findings contradicted those of Kim et al. [38] who observed that intermittent laser PBM following decortication around a moving tooth led to a decrease in the rate of tooth movement and alveolar remodeling activity. This discrepancy could potentially be attributed to individual variances in the composition and cellular function of the periodontal ligament and alveolar bone, [39] impacting the response to low-level laser irradiation.

Furthermore, our discovery of escalated RANKL levels echoed the results of Sedky et al.[17] who analyzed the impact of laser PBM versus corticotomy on RANKL release during orthodontic tooth movement, demonstrating an increase in RANKL levels within the laser-treated group. Recent findings by Saleem et al.[(40)] similarly showed a beneficial influence of laser PBM on RANKL concentration, correlating with swifter orthodontic tooth movement and greater canine retraction displacement in the irradiated group compared to the control group.

Lastly, the utilization of a split-mouth design for laser application has exhibited enhanced movement velocity in human canines by utilizing one side as a control and the other as the experimental side, a concept supported by Cruz et al.[(41)] Nonetheless, it is crucial to exercise caution when evaluating measurements in split-mouth designed human trials due to potential systemic effects of phototherapy. (42) Uncertainty remains regarding whether the dosage of irradiation applied may have impacted the control site.

At last, the laser PBM protocol used in this study gave several noteworthy performances in terms of safety, good patient's acceptance, and reduction of the overall time for orthodontic treatment; however, it remains to decide the dose limits that produce biostimulatory effects.

CONCLUSION

Within the limits of the present study, laser PBM using the flat top beam modifier, that provides homogeneous energy distribution over the target area; can be used as a promising aid in accelerating tooth movement owing to its unique ability in bone remodeling. More studies are needed to investigate different irradiation parameters, longer experimental periods, and more frequent time points to find out the optimal laser settings.

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