Journal of Contemporary Orthodontics 2024;8(4):512–519

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Journal of Contemporary Orthodontics

Journal homepage: https://www.jco-ios.org/

Original Research Article

# Effectiveness of a customized intraoral photobiomodulator for accelerating orthodontic tooth movement

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ARTICLE INFO

*Article history:*
Received 04-04-2024
Accepted 01-07-2024
Available online 02-11-2024

*Keywords:*
Accelerated Orthodontics
Photobiomodulation
Low Level Light Therapy
Canine retraction
Light Emitting Diode

ABSTRACT

**Background:** The aim of this study was to evaluate effectiveness of a Customized Intraoral Photobiomodulator for accelerating orthodontic tooth movement using a split mouth design as only limited studies have been done to compare the effectiveness of LLLT and their iatrogenic effects between experimental and control group in the same individual (split mouth technique) with the help of a customised intraoral photobiomodulator.

**Materials and Methods:** Consented Patients (n = 15) undergoing orthodontic therapy, diagnosed with Class 1 bimaxillary malocclusion were subjected to experiment based on randomly assigned split mouth design for both experiments in all 4 quadrants. At retraction phase, a customized introral photobiomodulator was given to all patients and the amount of anterior teeth retraction was measured at 1 month interval for 4 months (T0-T4). Apical root resorption was measured by CBCT taken at the beginning of study phase (t0) and end of 4th month (t1).

**Results:** PBM showed an increase in the rate of tooth movement of 4.12fold in the 1st, 2nd and 3rd month. Mandibular canine showed the maximum amount of root resorption whereas the maxillary and mandibular premolars the least. There were similar results when pulp vitality was evaluated where all the teeth in experimental and control side showed positive results to cold test.

**Conclusion:** From our study, PBM is a better method compared to control group as it has shown increased rate of orthodontic teeth movement.



## 1. Introduction

One of the greatest concerns amongst the individuals seeking orthodontic treatment is the duration of the treatment which may last for about 18-20 months depending on the malocclusion and treatment plan. Prolonged orthodontic treatment is associated with an increased risk of gingival inflammation, decalcification, dental caries and root resorption.[1]

One of the potential ways of reducing treatment time is to accelerate the tooth movement. This is achieved by the stimulation of bone remodelling and is called as accelerated orthodontic tooth movement.[2]

Surgical methods like corticision, peizocision, micro-osteoperforations are based on the principle of regional acceleratory phenomenon. Pharmacological approach include injection of vitamin D, prostaglandins, osteocalcin and relaxin. Although, these procedures accelerate the tooth movement they are associated with discomfort, pain and invasiveness. Hence, there is a need for truly non-invasive and user-friendly methods for reducing the treatment time and accelerating the tooth movement.

Infrared light therapy or photobiomodulation (PBM), is a non-invasive technique which is dependant upon the

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https://doi.org/10.18231/j.jco.2024.077

amount of tissue exposure to therapeutic wavelengths of light, specifically in near and far infrared ranges (600 to 1200 nm).[3]

Photobiomodulation has an influence on the production of ATP. Cytochrome oxidase C, a mitochondrial enzyme mediates the ATP production and gets upregulated by infrared light. There is a resultant increase in the ATP levels and elevated metabolic activity at a localized site which induces a cell remodeling process. This increased energy level within the bone cells intensify both cell proliferation and differentiation , thus, creating a favorable environment for tooth movement.[3]

Light therapy can be administered using two types of sources of light, i.e., low-intensity lasers and light-emitting diodes (LEDs). Low intensity lasers produce coherent light whereas the LEDs produce incoherent. LEDs are comparatively lighter in weight and cost effective. Multiple wavelengths arranged in large, flat arrays that allow for the effect to spread over a larger area can be produced using LEDs; thus, LEDs can be easily constructed on the basis of the field to be irradiated.[4]

Studies in the literature, reported confounding results for Accelaratory Orthodontic Tooth Movement using extra-oral PBM device.[5–7] Most of the studies in literature have been done to compare the efficacy of PBM between experimental and control group in different individuals. However, only limited studies have been conducted based on split mouth technique.

Hence this study was conducted to evaluate effectiveness of a Customized Intraoral Photobiomodulator for accelerating orthodontic tooth movement using a split mouth design. Also no studies in literature evaluated the side effects of Photobiomodulation technique.

## 2. Materials and Methods

This experimental study was conducted in the Department of Orthodontics at Faculty of Dental Sciences, Ramaiah University of Applied Sciences, Bangalore, India with the Institutional Ethical Committee approval (Reference Number EC-2020/PG/18) and Clinical Trial Registration India (Reference Number- REF/2021/08/046681/AU).

The sample size was calculated by using the below mentioned formula: N=(r+1) (Zœ/2 + Z1-ß)2 ($\sigma$)2 / rd2

The obtained sample size after substitution was 15 with 90% power of the study,

Study was carried out for a period of 8 months. A signed informed consent was taken. Randomization of both the maxillary and the mandibular quadrants was done into experimental and control groups (Figure 1). Diagonally opposite quadrants were assigned by the recruiter into experimental/control group based on the allotment concealment sequence in order to manage unequal masticatory forces. Hence each subject had two experimental and two control quadrants (Table 1).

Allocation concealment was obtained using sequentially numbered and sealed envelopes. Blinding was done for the study participants and the operators about the experimental and control sides. Labelling the quadrants as experimental side and control side was done by the $2^{nd}$ author. The photobiomodulation was then performed by the 1st author to the allocated quadrants.The $1^{st}$ author conducted the pulp vitality test and calculated the amount of root resorption on CBCT .

The treatment plan was to extract the first premolars in all 4 quadrants and reinforce anchorage using transpalatal arch/lingual arch. Bonding of pre-adjusted edgewise appliance of MBT prescription with a 0.022-inch slot was done. After levelling and aligning, 19 × 25inch stainless steel wire with power arms distal to lateral incisor was placed. En-masse retraction was initiated after 21 days of placement of 19×25 stainless steel wire. LED photobiomodultors were given to the quadrants which were previously assigned by the recruiter and retraction was initiated by applying a force of 150g per side on all sides. A CBCT was taken just before commencing retraction.

The intraoral photobiomodulator was fabricated by making a wax pattern of the design and then converted into an acrylic model using cold cure acrylic by sprinkle-on method in two sizes to fit arches. The prepared acrylic appliances were then duplicated by putty impression material from which 15 models were duplicated. (Figures 2 and 3)

Three holes were drilled into the acrylic model with a size of an LED light so that it can be inserted into the holes and sealed.The lights were seated accurately in the position of central, lateral incisors and canines on the experimental side. To these LEDs a micro USB board was installed from which an USB cable was connected to a power bank for power supply. The subjects were exposed to an average of 3min per arch per day, with a wavelength of 850nm using an average power density of 38.49mW, with a mean energy density of 6.9J/cm2 on the surface of LED light generating on 30 days of every month. The patients were advised to use the device daily after brushing and before breakfast as it would be more convenient to the patient. The device was inverted to use on the contralateral side which was the control side.

Vernier calipers was used to measure the tooth movement intra-orally from the disto-incisal surface of the canine to the mesio-incisal surface of the 2nd premolar. T0 is considered as the $1^{st}$time interval before the commencement of the study, whereas, T1 is the end of $1^{st}$ month, T2 is the end of the 2nd month, T3 is the end of the 3rd month and T4 is the end of the 4th month.

The amount of root resorption was measured using CBCT (CS 3D Imaging v3.5.7 Carestream Health Inc.). Measurement of the length of the tooth was made from the mid-incisal point of the crown to the apex of the root.

The difference between the length of the root at t1 and the length of the root at t2 in millimeters was used to determine the apical root resorption.Though minimal craters were noticed along the root surface area, their measurement was difficult due to hardening of the beam and cupping artefacts (Figure 4).

Cold test using Endo-Frost was done to assess the pulp vitality. Cotton was used for the application of Endo- Frost on the tooth of interest at the beginning of study phase and at the end of 4th month. The sensitivity that was exhibited by the tooth determined the pulp vitality status.

## 3. Results

Study demonstrated an increase in the rate of orthodontic tooth movement in PBM group by 2.03, 1.61 and 1.44 fold in $1^{st}$, $2^{nd}$ and $3^{rd}$ month respectively and all were statistically significant. In the 4th month there was an increased rate of tooth movement by 0.93 fold which was not statistically significant. In overall 4-month period of space closure was increased by 1.4 fold which was again statistically significant. (Table 2 and Figure 5)

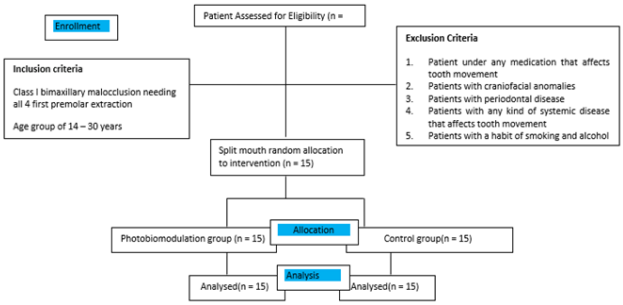


**Figure 1:** Consort flow chart of the study protocol

**Figure 2:** Intraoral photobiomodulator with led lights

Maxillary arch PBM group showed increased rate of orthodontic tooth movement by 1.87,1.61 and 1.34 fold in $1^{st}$, $2^{nd}$ and $3^{rd}$ month respectively and overall 4month period of space closure increased by 1.39 fold which was statistically significant. In the 4th month there was an increase in rate of tooth movement only by 1fold which was not statistically significant.(Table 3 and Figure 6)

Mandibular arch PBM group showed an increase in the rate of tooth movement by 2.24, 1.64 and 1.58 fold in $1^{st}$,

**Figure 3:** Intraoral photobiomodulator connected to usb connection

**Figure 4:** Assessment of root resorption using CBCT

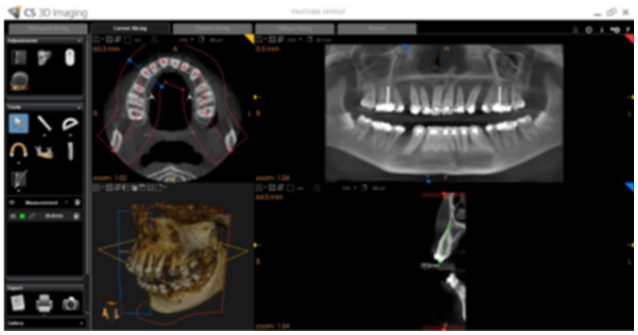

**Figure 5:** Comparison of the mean rate of tooth movement inthe month 1, 2, 3 and 4 between the experimental and control side

**Table 1:** Randomization sequence

| SL. NO | Patients Name | 1ST Quadrant | 2ND Quadrant | 3RD Quadrant | 4TH Quadrant |
|---|---|---|---|---|---|
| 1 | Subject 1 | LLLT | CONTROL | LLLT | CONTROL |
| 2 | Subject 2 | CONTROL | LLLT | CONTROL | LLLT |
| 3 | Subject 3 | LLLT | CONTROL | LLLT | CONTROL |
| 4 | Subject 4 | CONTROL | LLLT | CONTROL | LLLT |
| 5 | Subject 5 | LLLT | CONTROL | LLLT | CONTROL |
| 6 | Subject 6 | CONTROL | LLLT | CONTROL | LLLT |
| 7 | Subject 7 | LLLT | CONTROL | LLLT | CONTROL |
| 8 | Subject 8 | CONTROL | LLLT | CONTROL | LLLT |
| 9 | Subject 9 | LLLT | CONTROL | LLLT | CONTROL |
| 10 | Subject 10 | CONTROL | LLLT | CONTROL | LLLT |
| 11 | Subject 11 | LLLT | CONTROL | LLLT | CONTROL |
| 12 | Subject 12 | CONTROL | LLLT | CONTROL | LLLT |
| 13 | Subject 13 | LLLT | CONTROL | LLLT | CONTROL |
| 14 | Subject 14 | CONTROL | LLLT | CONTROL | LLLT |
| 15 | Subject 15 | LLLT | CONTROL | LLLT | CONTROL |
| | TOTAL | LLLT=8<br>CONTROL=7 | LLLT=7<br>CONTROL=8 | LLLT=8<br>CONTROL=7 | LLLT=7<br>CONTROL=8 |

**Table 2:** Comparison of the mean rate of tooth movement in the month 1, 2, 3 and 4 between the experimental and control side

| | | | Mean | SD | Z | |
|---|---|---|---|---|---|---|
| T0-T1 | Experimental | 30 | 1.18 | .35 | -5.99 | 0.0001* |
| | Control | 30 | .58 | .23 | | |
| T1-T2 | Experimental | 30 | 1.10 | .10 | -5.74 | 0.0001* |
| | Control | 30 | .68 | .25 | | |
| T2-T3 | Experimental | 30 | 1.23 | .20 | -5.68 | 0.0001* |
| | Control | 30 | .85 | .21 | | |
| T3-T4 | Experimental | 30 | 1.03 | .61 | -0.1 | 0.9 |
| | Control | 30 | 1.10 | .32 | | |
| T0-T4 | Experimental | 30 | 4.56 | .72 | -5.96 | 0.0001* |
| | Control | 30 | 3.22 | .44 | | |

**Table 3:** Comparison of rate of extraction space closure in the maxilla in 4 months

| | | | Mean | SD | Z | |
|---|---|---|---|---|---|---|
| T0-T1 | Experimental | 15 | 1.16 | .17 | -4.62 | 0.0001* |
| | Control | 15 | .62 | .24 | | |
| T1-T2 | Experimental | 15 | 1.13 | .07 | -3.91 | 0.0001* |
| | Control | 15 | .70 | .29 | | |
| T2-T3 | Experimental | 15 | 1.22 | .22 | -3.77 | 0.0001* |
| | Control | 15 | .91 | .19 | | |
| T3-T4 | Experimental | 15 | 1.03 | .31 | -0.5 | 0.6 |
| | Control | 15 | 1.03 | .35 | | |
| T0-T4 | Experimental | 15 | 4.56 | .52 | -4.35 | 0.0001* |
| | Control | 15 | 3.28 | .47 | | |

$2^{nd}$ and $3^{rd}$ month respectively and overall 4month period of rate of tooth movement was increased by 1.43 fold which showed statistically significant results. Whereas the tooth movement in the 4th month decreased by 0.88 fold which was not statistically significant.(Table 4 and Figure 7)

howed no statistically significant difference between maxillary and mandibular arches for bothPBM and control groups.

Tables 6 and 7 mandibular canine showed the maximum amount of root resorption whereas the maxillary and mandibular premolars showed the least (Figures 9 and 10). Similar results showed when pulp vitality was evaluated where all the teeth in experimental and control side showed positive results to cold test.

**Table 4:** Comparison of rate of extraction space closure in the mandible in 4 months

| | | | **Mean** | **SD** | **Z** | |
|---|---|---|---|---|---|---|
| T0-T1 | Experimental | 15 | 1.19 | .48 | -4.0 | 0.0001* |
| | Control | 15 | .53 | .23 | | |
| T1-T2 | Experimental | 15 | 1.07 | .13 | -4.3 | 0.0001* |
| | Control | 15 | .65 | .21 | | |
| T2-T3 | Experimental | 15 | 1.25 | .18 | -4.0 | 0.0001* |
| | Control | 15 | .79 | .21 | | |
| T3-T4 | Experimental | 15 | 1.03 | .82 | -0.1 | 0.6 |
| | Control | 15 | 1.17 | .29 | | |
| T0-T4 | Experimental | 15 | 4.56 | .89 | -4.0 | 0.0001* |
| | Control | 15 | 3.17 | .41 | | |

**Table 5:** Comparison of rate of extraction space closure in the experimental side of maxilla and mandible in 4 months

| | | | MEAN | SD | Z | |
|---|---|---|---|---|---|---|
| T0-T1 | Maxilla | 15 | 1.16 | .17 | -0.08 | 0.9 |
| | Mandible | 15 | 1.19 | .48 | | |
| T1-T2 | Maxilla | 15 | 1.13 | .07 | -1.1 | 0.2 |
| | Mandible | 15 | 1.07 | .13 | | |
| T2-T3 | Maxilla | 15 | 1.22 | .22 | -0.6 | 0.5 |
| | Mandible | 15 | 1.25 | .18 | | |
| T3-T4 | Maxilla | 15 | 1.03 | .31 | -0.5 | 0.5 |
| | Mandible | 15 | 1.03 | .82 | | |
| T0-T4 | Maxilla | 15 | 4.56 | .52 | -0.06 | 0.9 |
| | Mandible | 15 | 4.56 | .89 | | |

**Table 6:** Comparison of amount root resorption between the experimental and control side in 4 months in the Maxillary arch

| | | | Mean | **SD** | **Z** | |
|---|---|---|---|---|---|---|
| CENTRAL INCISOR | Experimental | 15 | .71 | .19 | -2.2 | 0.02* |
| | Control | 15 | .95 | .69 | | |
| LATERAL INCISOR | Experimental | 15 | .48 | .19 | -2.3 | 0.01* |
| | Control | 15 | .72 | .23 | | |
| CANINE | Experimental | 15 | .59 | .22 | -0.2 | 0.8 |
| | Control | 15 | .61 | .23 | | |
| PRE-MOLAR | Experimental | 15 | .78 | .37 | -2.98 | 0.003* |
| | Control | 15 | .29 | .39 | | |

**Table 7:** Comparison of amount root resorption between the experimental and control side in 4 months in the Mandibular arch

| | | | **Mean** | **SD** | **Z** | |
|---|---|---|---|---|---|---|
| CENTRAL INCISOR | Experimental | 15 | .62 | .32 | -0.25 | 0.8 |
| | Control | 15 | .60 | .23 | | |
| LATERAL INCISOR | Experimental | 15 | .41 | .13 | -0.56 | 0.5 |
| | Control | 15 | .47 | .25 | | |
| CANINE | Experimental | 15 | .72 | .42 | -1.1 | 0.2 |
| | Control | 15 | .52 | .16 | | |
| PRE-MOLAR | Experimental | 15 | .53 | .26 | -2.07 | 0.03* |
| | Control | 15 | .81 | .50 | | |

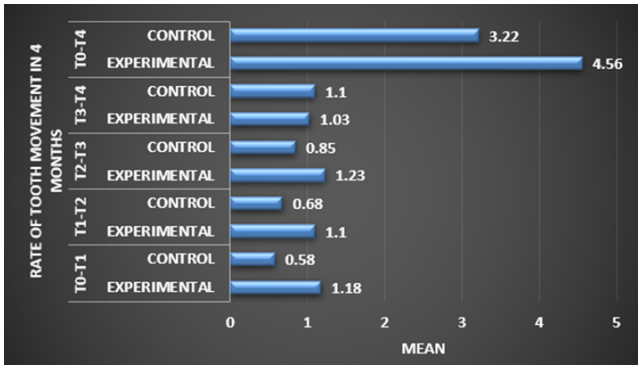


**Figure 6:** Comparison of rate of extraction space closure in the maxilla in 4 months

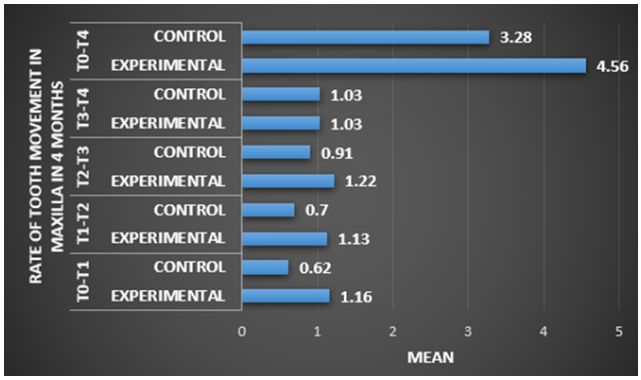


**Figure 7:** Comparison of rate of extraction space closure in the mandible in 4 months

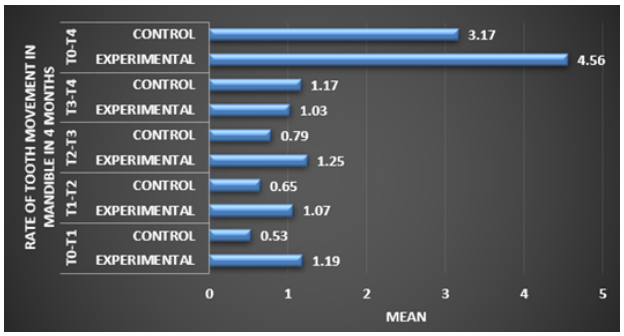


**Figure 8:** Comparison of rate of extraction space closure in the experimental side of maxilla and mandible in 4 months

## 4. Discussion

Photo biomodulation is a system which uses light emitting diodes (LED) with different parameters (wavelength, output power, continuous wave or pulsed operation modes, pulse parameters) to stimulate natural biological processes to reduce the duration of orthodontic treatment . Light in near infrared has a wavelength around 630-1000 nm and is found to possess the best penetration into tissues and activates intra-cellular signaling mechanisms.[8]

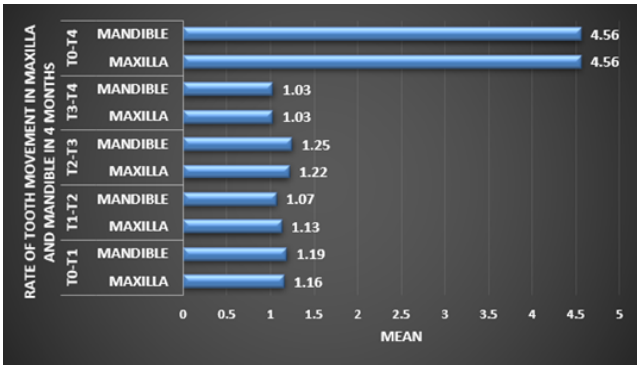


**Figure 9:** Comparison of amount root resorption between the experimental and control side in 4 months in the maxillary arch

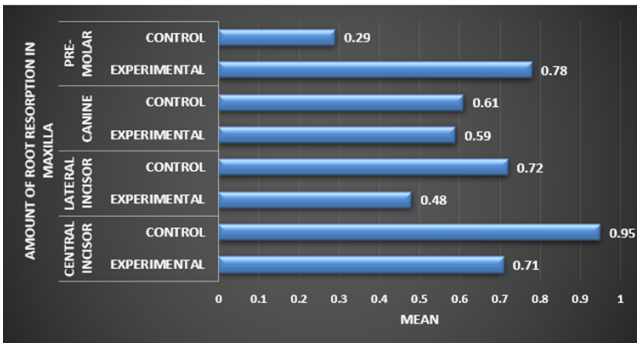


**Figure 10:** Comparison of amount root resorption between the experimental and control side in 4 months in the mandibular arch

The application of Photobiomodulation to increase the rate of orthodontic tooth movement has gained a lot of popularity in the recent years. Effects related to improvements in cellular function have been reported in the past. However, there is inconsistency in the results that have been reported regarding responses to PBM in orthodontic treatment.[3]

Kau et al. and Shaugnessy et al. reported that photobiomodulation therapy with a LED device, with 850-nm wavelength clinically increased the rates of OTM in the alignment phase of orthodontic treatment.[3,5,9] Chung et al reported no significant results for accelerating OTM during retraction phase with extraoral device and the LED arrays were penetrating through the skin.[6]Chulaluk et al also agreed with the same but this could be due to the use of lesser wavelength of 460-480nm.[7,10,11]

In the previous literature, split mouth design was used in 2 studies where both of the studies showed no significant changes compared to the control group. This could be because in one of the study an extraoral device was used to accelerate the OTM whereas in the other a low wavelength of 460-480nm and split mouth design was used only in the maxillary arch, both may not be effective.[6,7]

In our study we have used a customized intraoral photobiomodulator and a split mouth design to eliminate inter-individual variations to accelerate the rate of OTM. Also, hardly any study in literature evaluated the side effects related to it. Thus, our study aimed to evaluate the efficiency of photobiomodulation therapy in accelerating orthodontic tooth movement with a customized device using LED and related side effects.

In this study, an intraoral photobiomodulator consisting of LED light was used with a wavelength of 860nm for 3mins per side at 38.49mW,6.9J/cm2 on 30 days of every month. Our study demonstrated that there was statistically significant increase in the rate of tooth movement in the first three months and in the 4th month there was an increase which was not statistically significant. It could be because in some of the patients some amount of the extraction space was utilized to relieve the crowding, hence only minimum amount of space was left when retraction was started and also because of the rapid acceleratory phenomenon the rate of tooth movement could be faster as the tooth were retracted within 3months of extraction. Thus, in this study we have increased the wavelength of the LED, duration of exposure time which resulted in faster rate of tooth movement than the previous study.[11]

Nahas et al reported a statistically significant increase in the rate of tooth movement in the $1^{st}$, $2^{nd}$ and $3^{rd}$ month with a wavelength of 618nm for a duration of 20mins once daily for 21 days.[12]

In this study, when maxillary arch was evaluated alone, there was statistically significant increase in the rate of orthodontic tooth movement in the 1st three months and overall 4 month period in experimental side compared to control group. In a study done by Ekizer et al when evaluated upper canine distalization in maxilla alone, the exposed side to LED irradiation had increased tooth movement with respect to the control side during the 1st three months.[13]Mandibular arch also showed similar results.

Nahas et al exhibited an increase in space closure velocity by 0.265 mm/month in maxillary arches compared to mandibular arches. The increase could be due to structural differences such as geometry and mass of different types of bone that have been described between the mandible and the maxilla.[12]Whereas in this study, the maxillary and mandibular arches behaved much similar way with no statistical significance between them.

Three studies in literature evaluated the root resorption in patients receiving PBM to accelerate the OTM compared to the control group in which all the studies showed no significant differences in root resorption in both the groups.[7,14,15]

In this study, the mean root resorption was lesser in experimental group compared to control group except in maxillary premolar and mandibular canine. The mean difference was statistically significant in the case of maxillary central incisor and lateral incisor, maxillary and mandibular premolar. Among the four teeth assessed for root resorption mandibular canine showed the maximum amount of root resorption whereas the maxillary and mandibular premolars showed the least it could be because of elongated and pointed roots of the canines which lead to stress accumulation in the apex of the root of the canine making it highly susceptible to apical root resorption. Nimeri et al showed no correlation between the root resorption and LLLT though in their study root resorption was more in the lateral incisor followed by central in both maxilla and mandible which could be because of abnormal root shapes and the erupting canines can resorb the lateral incisor.[14]

Chulaluk et al evaluated pulp vitality for all the teeth before the LED photobiomodulation and after where the results were positive to electric pulp test (EPT). Using this test to evaluate pulp vitality might give false positive results as the brackets were placed on the center of the teeth, hence, in our study we used an Endo-Frost cold test in order to overcome these shortcomings.

This study also showed similar results where all the teeth in experimental and control side showed positive results to cold test. A study done by Chulaluk et al evaluated for tooth vitality before and after treatment also showed that all teeth were vital (positive to EPT test).

## 5. Limitations of the study

As most of the subjects in our study were females, there was an unequal gender distribution. All the subjects were given a check list to assess the appliance wear on a daily basis for 4 months but this method was not reliable to check accurately whether the patient is wearing the appliance or not. Split mouth design can lead to systemic effects from LED phototherapy and photoleakage to the contralateral side of the dental arch. Electric pulp testing was not possible as the brackets were present on the teeth which would have been more accurate compared to cold test.

## 6. Conclusion

PBM showed an increased rate of orthodontic tooth movement compared to the control group. Both in the maxillary and mandibular arches PBM group showed an increase in the rate of OTM compared to control side.There was no increase in the rate of tooth movement on the experimental side of maxillary and mandibular arches. Mandibular canine showed the maximum amount of root resorption whereas the maxillary and mandibular premolars showed the least. Pulp vitality test showed positive results to cold test both on the experimental and control side. Therefore, PBM is a better method compared to control group as it has shown increased rate of orthodontic tooth

movement.

## 7. Author Contributions

The contributory roles of co-authors are as follows:

Dr. Prashantha G.S was incharge of conceptualization , Dr.Sharanya Sabrish formed the methodology, Dr Silju Mathew was the project administrator , Dr Sauni Ashfaq and Dr.Sathyashree Krishnamurthy contributed towards the investigation and formal analysis respectively.

## 8. Source of Funding

None.

## 9. Conflicts of Interest

No conflict of interest was declared by the authors

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**Cite this article:** Manoghna Subramanya H, Prashantha GS, Sabrish S, Mathew S, Ashfaq S, Krishnamurthy S. Effectiveness of a customized intraoral photobiomodulator for accelerating orthodontic tooth movement . *J Contemp Orthod* 2024;8(4):512-519.