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Influence of Three Distinct Wavelengths of Photobiomodulation on the Rate of Orthodontic Tooth Movement and The Level of Interleukin-6

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Abstract: Aim and Objective: *To assess the impact of an intraoral photobiomodulation device, operating on wavelengths of 740, 850, and 940 nm, on the rate of accelerated orthodontic tooth movement (OTM) and the levels of Interleukin-6 (IL-6).* ***Background:*** *Orthodontic treatment can be time-consuming when it comes to conventional mechanics due to time duration. Photobiomodulation (PBM) can hasten the rate of tooth movement, which uses visible red to near-infrared wavelengths of light.* ***Methods:*** *15 male and 15 female individuals, aged 13 to 28 years, with 10 patients in groups named A, B, and C, including 5 males and 5 females in each one. These groups underwent photobiomodulation therapy, utilizing three distinct wavelengths of 740, 850, and 940 nm, respectively. The split-mouth technique designated the 1st and 3rd quadrants as experimental and the 2nd and 4th quadrants as control, measuring the decrease in crowding both before pretreatment and after three months. The rates of OTM and IL-6 levels were assessed on the first day (D0), 21st day (D21), and 81st day (D81).* ***Results****: All three groups showed statistically significant differences in pretreatment and after three months of photobiomodulation in both mean OTM value and IL-6 levels at different time periods.* ***Conclusions****: The OTM showed a statistically significant difference on comparing pre-treatment levels to those measured after three months across all three groups. The IL-6 levels peaked in patients from Group A on Day 21, followed by Groups B and C on Day 81, respectively. Photobiomodulation led to increased IL-6 levels and accelerated orthodontic tooth movement.* ***Clinical Significance****: Photobiomodulation leads to accelerated tooth movement.*

Keywords: *Accelerated orthodontic tooth movement, Interleukin-6, Light emitting diode therapy, Photobiomodulation therapy*

INTRODUCTION

The prolonged duration of orthodontic treatment, typically lasting 2 to 3 years, often poses the primary obstacle for patients to accept conventional methods.[1] The significant drawback, has led individuals to discontinue orthodontic care early. Expediting tooth movement can reduce the length of orthodontic treatment. Various methods, including surgical interventions (corticotomy, Piezocision, microosteoperforation) and pharmacological approaches (Vitamin D, Prostaglandins, Parathyroid hormone), have been used to expedite orthodontic tooth movement. Nonetheless, these invasive methods often result in patient discomfort, including pain, oedema, and negative effects.[2]

A non-invasive treatment is necessary to expedite tooth movement without adverse consequences, previously encountered. Photobiomodulation (PBM), also known as Low-Level Light Therapy (LLLT) or Light Accelerated Orthodontics (LAO), [3] is an innovative noninvasive method, that has been shown to expedite orthodontic tooth movement. PBM operates through the absorption of specific wavelength of light by chromophores, primarily cytochrome c oxidase in mitochondria. This interaction enhances mitochondrial respiration, increasing ATP production and reactive oxygen species, which stimulate cellular proliferation and differentiation.[3]

It employs light radiation from the visible red to near-infrared spectrum (600-1000 nm) to alter cellular biology, resulting in bone remodeling and expediting orthodontic tooth movement. This innovative methodology aims to optimize the therapy duration and reduce overall treatment time .[4] Photobiomodulation (PBM) on various wavelengths has demonstrated the ability to expedite orthodontic tooth movement (OTM) without causing any harm to the periodontal tissues .[5] A literature review, revealed that a few research has been conducted on PBM to fasten up tooth movement, with fewer studies

including animal subjects.[6-8] Previous methods, documented in the literature for evaluating accelerated orthodontic tooth movement extraorally, include the use of study models, which allow the assessment of decrowding through contact point measurements before and after the tooth movements .[9]
Measurement of increased orthodontic tooth movement intraorally, by using biomarkers such as, interleukin-6 (IL-6) is more precise. In reaction to orthodontic forces, the cells of the periodontium secrete biologically active substances that induce remodeling of connective tissues, promote the release of osteoclasts, facilitate tooth movement, and trigger an inflammatory response that releases cytokines, including lactate dehydrogenase, matrix metalloproteinases, tumor necrosis factor, and osteoprotegrin.[10-11]

Interleukin-6, a proinflammatory mediator, is produced by the cells of periodontal ligaments has a direct stimulatory effect on bone remodeling and osteoclastic activity, which occurs during OTM.[12] Interleukin-6 can be found in the gingival crevicular fluid (GCF) during the bone remodeling process. It reflects the sequence of biological mechanisms in the periodontal tissue, which helps in detecting the level of other biomarkers .[13]
The substantial relation between PBM and accelerated orthodontic tooth movement is less available in the literature, and studies have found correlation between the parameters used, like power output, energy density and frequency, to achieve an effective accelerated OTM .[14]Therefore, the purpose of this study was to determine how the rate of OTM is affected by light-emitting diodes with three distinct wavelengths and various parameters, by utilizing a photobiomodulation appliance.

METHODS

The type of this study is categorized as experimental trial research. After ethical committee approval has been obtained Approval no: TODC/IEC/026-055/2023-24) from the outpatient Department of Orthodontics and Dentofacial Orthopaedics, thirty orthodontic patients—15 male and 15 female—with varying malocclusions and ages ranging from 13 to 28years were chosen. Every participant received an informed signed consent form including the specific goals of the research.
The R analysis software determined a total sample size of 30, achieving a research power of 92% and an error margin of 10% (α=0.10). (Version 4.2, University of Auckland, New Zealand). The study comprised, patients requiring orthodontic treatment characterized by mild to moderate crowding and a non-extraction approach. Inclusion criteria encompassed the absence of prior orthodontic treatment, a healthy gingival index, no periodontal pockets, and no evidence of bone loss. The study excluded patients with prior orthodontic treatment, chronic smokers, individuals with systemic disorders, and those using non-steroidal anti-inflammatory drugs.
Thirty patients enrolled in our trial, resulting in formation of three groups: A, B, and C. Each group comprised of 10 patients. Group A was irradiated on a wavelength of 740 nm, Group B 850 nm, and Group C 940 nm. This research utilized a split-mouth methodology, designating the 1st and 3rd quadrants as experimental, and the 2nd and 4th quadrants, as control groups. Individuals, with a Gingival Index (GI) score of 1were classified as, patients having a satisfactory oral health. They were selected, and GI measurements recorded in each visit.
Though patients were unaware of the specific PBM wavelength applied, Blinding was not feasible due to the visible nature of the LED devices, potentially introducing observer or participant bias, as also reported in prior studies using intraoral PBM devices .[4]
The investigator measuring LII and GCF collection were blinded to group assignments. Laboratory personnel conducting enzyme-linked immunosorbent assay (ELISA) for IL-6 analysis were also blinded to sample origins (experimental vs. control quadrants and group assignments). Blinding was maintained until data analysis was completed to ensure objectivity.

The patients were received orthodontic treatment with a pre-adjusted edgewise appliance (Mini Master Series AO American Orthodontics, Washington Ave, Sheboygan, USA), by using a 0.022 x 0.028-inch slot MBT prescription. To achieve alignment and levelling, a sectional 0.014-inch NiTi wire was placed in both the maxillary and mandibular arches. The decrowding of six anterior teeth, was assessed in both experimental and control quadrants before and after a 3-month period, utilizing Little's Irregularity Index. The evaluation of the GCF biomarker interleukin-6, was conducted on the first day (D0), followed by assessments on days 21 (D21) and 81 (D81) during the therapy.

Photobiomodulation using intraoral Photobiomodulator

The first day of 0.014 niti wire placement, was determined as D0. The selected patients from various groups, received PBM, by using a custom-designed intraoral photobiomodulator appliance, on three distinct LED wavelengths: 740, 850, and 940 nm (Fig.1). Each of these wavelengths were emitted for 3 minutes under varying parameters (Table 1). The study employed a split-mouth technique, designating the 1st and 3rd quadrants as experimental and the 2nd and 4th as control. The device was inverted for irradiation on the contralateral side. The identical procedure was conducted on days D7, D14, D21, D28, D35, D42, D49, D56, D63, D70, D77, D84, and D91, for all the three wavelengths. Patients were instructed to promptly report any discomfort experienced during the procedure.

Measurement of the rate of orthodontic tooth movement

The little irregularity index (LII>3), commonly used to evaluate crowding by considering the anatomical contact points of the anterior six teeth, was employed to assess the rate of orthodontic tooth movement. The method involved measuring the anatomical contact points of six anterior teeth, using a digital vernier calliper on pretreatment models and models after a three-month duration in three groups, to determine the amount of crowding correction. The recorded values were assessed according to the severity of irregularities observed at the outset of treatment and after a duration of three months (Fig. 2).

Gingival crevicular fluid sampling

GCF samples were collected from the mesiobuccal or distobuccal surfaces of all experimental and control quadrant sites on D0, D21, and D81, respectively. The sample collection area was isolated, using sterile cotton gauze to prevent saliva contamination. The GCF was collected by a calibrated and graduated microcapillary pipette, (Fig. 3). The pipette was positioned at the entrance of the gingival sulcus, making gentle contact without causing stimulation (extra crevicular approach). Microcapillary pipettes contaminated with blood and saliva, have been disposed of. A standardized volume of 20 µL of GCF was obtained by 2 mL Eppendorf tubes. Each sample was collected within a 10-minute interval, and centrifuged at 3,000 rpm, then freezed at -21°C, finally analyzed, using enzyme-linked immunosorbent assay (ELISA).

Analysis of Interleukin-6 (IL-6) Biomarker from Gingival Crevicular Fluid Using Enzyme-Linked Immunosorbent Assay

A total of 360 samples were collected from all three groups A, B & C from four quadrants. The GCF samples were defrosted, and ELISA tests were conducted using Krishgen Bio Systems GENLISA Human IL-6 ELISA. The obtained data was sent for statistical analysis.

Fig. 1: Intra oral photobiomodulator appliance.

Fig.2: Measurement of crowding using Digital vernier caliper.

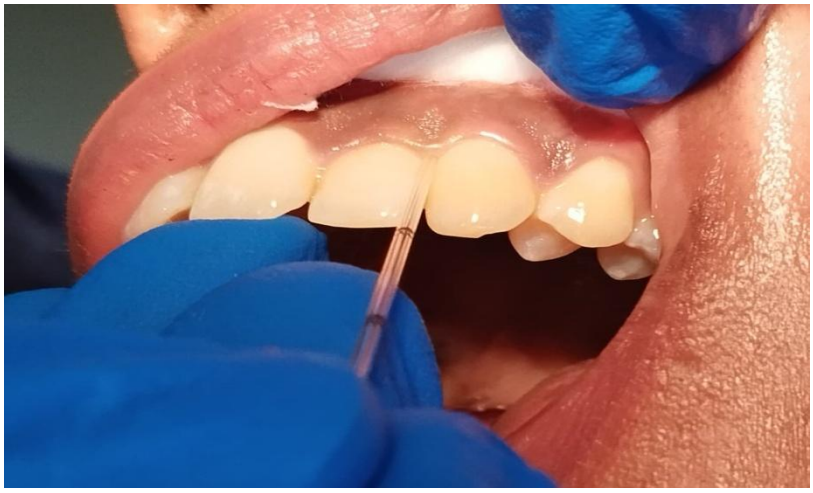

Fig. 3: Collection of Gingival crevicular fluid. Sample using graduated micro capillary pippete.

RESULTS

The study revealed statistically significant differences in the mean values of the maxilla and mandible, when comparing pre-treatment measurements to those taken three months post-decrowding (Table 2-6). The greatest difference has been observed in Group A compared to Groups B and C. The average decrowding rates were recorded as 0.440 mm per month in the maxillary arch and 0.237 mm per month in the mandibular arch for group A; 0.213 mm vs 0.234 mm for group B; and 0.259 mm vs 0.161 mm for group C, respectively (Table 7). On comparison, with wavelength, the average pretreatment crowding with 740 nm, which was measured 7.82 mm, decreased to 2.31 mm, yielding an average reduction of 5.51 mm. On 850nm; 6.51mm to 2.71mm, with a reduction of 3.84mm. On 940 nm; 6.37 mm to 2.87 mm, resulting in an average reduction of 3.45 mm. The acceleration percentages of OTM were found to be 70.5% on 740nm, 58.4% 850nm, and 54.6% 940nm (Table 8).

In the GCF evaluation, our analysis of D0 indicated that the experimental quadrants exhibited higher mean and median values compared to the control quadrants on those wavelengths, with a modest difference observed on 740 nm (2.358 versus 1.836). This finding correlates with the results obtained, regarding decrowding after a 3-month period (Fig. 4-5). Experimental quadrant values exhibited a significant increase relative to control quadrants on D21 and D81, recorded 3.740 versus 1.497. The experimental quadrants on D81 exhibited the greatest disparity on 850 nm, indicating possible treatment effects D81 ,3.5459 versus 1.685. An intermediate difference was observed on wavelength of 940 nm, which remained statistically significant on D81 (4.354 vs 1.670) (Table 9). Comparison of mean Interleukin IL-6 (in pg/mL) between 3 groups at different time intervals is shown in (Table10).

This study's statistical analysis was conducted by using the 2013-released Statistical Package for the Social Sciences (SPSS) for Windows, Version 22.0. (IBM Corporation in Armonk, New York, employing paired t-tests and independent samples). Descriptive Statistics: Summarized data using means, medians, standard deviations, and ranges to describe central tendencies and variability. Independent Samples T-Test: Compared means between two groups (e.g., genders or quadrants) to identify significant differences, with p-values <0.05 considered statistically significant.

One-Way ANOVA: Assessed differences across multiple groups (e.g., wavelengths) for variables like optical density (OD) and RESULTS, followed by post-hoc tests where applicable.

Table1: Wavelengths and Parameters Used in Photobiomodulation.

Wavelength	Energy Density	Power Output
740nm	8J/sq cm	51mw
850nm	4J/sq cm	26mw
940nm	15J/sq cm	93mw

Table 2: Mean Maxillary Values of Decrowding Recorded in the Groups – Pre Treatment/3 Months

Duration of Treatment

Group	n	Mean	Std Dev	SE of Mean	95% CI for Mean		Min	Max	P Value
					Lower bound	Upper bound			
740 nm	10	8.87	4.78	1.51	5.45	12.29	1.97	16.60	0.098
850 nm	10	5.82	2.01	0.64	4.39	7.26	2.79	9.35	
940 nm	10	6.47	1.90	0.60	5.11	7.83	3.25	10.34	
Group	**n**	**Mean**	**Std Dev**	**SE of Mean**	**95% CI for Mean**		**Min**	**Max**	
					Lower Bound	**Upper Bound**			
740 nm	10	2.27	1.34	0.42	1.45	3.09	0.59	3.77	0.782
850 nm	10	2.62	1.65	0.52	1.44	3.80	0.96	6.83	
940 nm	10	2.68	1.34	0.36	1.72	3.64	0.00	4.71	

Table 3: Mean Mandibular Values of Decrowding Recorded in the Groups – Pre Treatment/3 Months Duration of Treatment

Group	n	Mean	Std Dev	SE of Mean	95% CI for Mean		Min	Max	P Value
					Lower bound	Upper bound			
740 nm	10	4.86	2.19	0.69	3.29	6.42	2.36	9.35	0.623
850 nm	10	4.95	1.44	0.45	3.92	5.98	2.18	6.27	
940 nm	10	4.10	2.58	0.82	2.25	5.94	0.44	8.99	
Group	**n**	**Mean**	**Std Dev**	**SE of Mean**	**95% CI for Mean**		**Min**	**Max**	
					Lower Bound	**Upper Bound**			
740 nm	10	1.40	0.72	0.23	0.89	1.92	0.32	2.58	0.817
850 nm	10	1.54	0.78	0.25	0.98	2.10	0.69	3.18	
940 nm	10	1.68	1.29	0.41	0.75	2.61	0.39	4.89	

Table 4:Comparison of pre-treatment and 3 months after treatment mean maxillary/Mandibular values of Decrowding in 740 nm group: (Paired t-test)

Maxillary	n	Mean	Std Dev	SE Mean	Mean Difference	t	P-Value
Pre-Treatment	10	8.87	4.78	1.51	6.600	4.488	0.002*
3 Months	10	2.27	1.15	0.36			
Mandibular							
Pre-Treatment	10	4.86	2.19	0.69	3.451	4.973	0.001*
3 Months	10	1.70	1.30	0.23			

*Denotes significant difference

The reduction in mean maxillary value from pre-treatment to 3 months after treatment in 740 nm group was found to be statistically significant (P<0.001).

Table 5:Comparison of Pre-treatment and 3 Months after Treatment Mean Maxillary/Mandibular Values of Decrowding in 850 nm Group: (Paired T-test)

Maxillary	**n**	**Mean**	**Std Dev**	**SE Mean**	**Mean Difference**	**t**	**P-Value**
Pre-Treatment	10	5.82	2.01	0.64	3.205	6.167	<0.001*
3 Months	10	2.62	1.65	0.52			
Mandibular							
Pre-Treatment	10	4.95	1.44	0.45	3.410	8.309	<0.001*
3 Months	10	1.54	0.78	0.25			

*Denotes significant difference

The reduction in mean maxillary values of decrowding from pre-treatment to 3 months after treatment in 850 nm group was found to be statistically significant (P<0.001).

Table 6:Comparison of Pre-treatment and 3 months after Treatment Mean Maxillary/Mandibular Values in 940 nm Group: (Paired T-test)

Maxillary	**n**	**Mean**	**Std Dev**	**SE Mean**	**Mean Difference**	**t**	**P-Value**
Pre-Treatment	10	6.47	1.90	0.60	6.600	3.792	<0.001*
3 Months	10	2.68	1.34	0.42			
Mandibular							
Pre-Treatment	10	4.10	2.58	0.82	2.419	3.097	0.013*
3 Months	10	1.68	1.29	0.41			

*Denotes significant difference

The reduction in mean maxillary value of decrowding from pre-treatment to 3 months after treatment in 940 nm group was found to be statistically significant (P<0.001).

Table 7: Average reduction Maxillary and Mandibular crowding with mean and standard deviation values

Wave length	**Quadrant**	**Pre-Treatment (mm)**	**Mid-Treatment (mm)**	**Reduction (mm)**	**Rate (mm/month)**	**Difference (Max vs. Mand)**	**p-value**
740 nm	Mandibular	0.971 ± 0.048	0.261 ± 0.012	0.710 ± 0.036	0.237 ± 0.011	Maxillary 46% faster	**0.038***
	Maxillary	1.774 ± 0.086	0.454 ± 0.022	1.320 ± 0.064	0.440 ± 0.021		
850 nm	Mandibular	1.010 ± 0.042	0.308 ± 0.015	0.702 ± 0.027	0.234 ± 0.010	Maxillary 24% slower	**0.210**
	Maxillary	1.164 ± 0.050	0.524 ± 0.025	0.640 ± 0.025	0.213 ± 0.009		
940 nm	Mandibular	0.820 ± 0.037	0.336 ± 0.016	0.484 ± 0.021	0.161 ± 0.007	Maxillary 20% faster	**0.045***
	Maxillary	1.293 ± 0.055	0.515 ± 0.024	0.778 ± 0.031	0.259 ± 0.012		

Table 8: Comparison of reduction of crowding by wavelength (Pre-Treatment vs. Mid-Treatment)

Frequency	**Pre-Treatment (mm)**	**Mid-Treatment (mm)**	**Reduction (mm)**	**% Improvement**	**p-value**
740 nm	7.82 ± 0.86	2.31 ± 0.23	5.51 ± 0.63	70.5%	**<0.001***
850 nm	6.51 ± 0.72	2.71 ± 0.27	3.80 ± 0.45	58.4%	**0.015***
940 nm	6.32 ± 0.70	2.87 ± 0.29	3.45 ± 0.41	54.6%	**0.020***

Table 9:Comparison of wavelength specific difference at different time interval.

Wavelength specific differences

740nm	3.820 vs. 1.377	Largest absolute differences between groups
850nm	3.5459vs 1.685	Highest variability in EXPERIMENTAL group
940nm	4.354 vs. 1.670	Intermediate differences but still significant

Table 10: Comparison of Mean Interleukin- 6 (in pg/mL) between 3Groups at Different Time Intervals.

Time	Measurement	Wave length	Group	Mean	Median	SD	Min	Max	p-value
D0	OD	740 nm	CONTROL	0.164	0.146	0.0428	0.1130	0.234	0.312
			EXPERIMENTAL	0.170	0.148	0.0510	0.1120	0.282	
		850 nm	CONTROL	0.156	0.134	0.0446	0.1120	0.251	0.198
			EXPERIMENTAL	0.167	0.139	0.0677	0.1150	0.407	
		940 nm	CONTROL	0.158	0.141	0.0467	0.1110	0.226	0.754
			EXPERIMENTAL	0.160	0.134	0.0543	0.1070	0.244	
	RESULTS	740 nm	CONTROL	1.836	1.772	1.3048	0.0409	5.788	0.021*
			EXPERIMENTAL	2.358	2.040	1.3172	1.0200	6.500	
		850 nm	CONTROL	1.420	1.475	1.0872	0.0983	3.829	0.003*
			EXPERIMENTAL	2.561	2.072	1.2501	1.0983	5.500	
		940 nm	CONTROL	1.079	0.975	0.6055	0.1200	2.744	<0.001*
			EXPERIMENTAL	1.876	1.699	0.7175	1.0983	3.477	
D21	OD	740 nm	CONTROL	0.187	0.204	0.0479	0.1080	0.264	0.587
			EXPERIMENTAL	0.182	0.203	0.0487	0.1120	0.236	
		850 nm	CONTROL	0.179	0.195	0.0491	0.1130	0.232	0.901
			EXPERIMENTAL	0.180	0.207	0.0525	0.1110	0.242	
		940 nm	CONTROL	0.178	0.197	0.0501	0.1010	0.242	0.225
			EXPERIMENTAL	0.190	0.211	0.0545	0.1160	0.316	
	RESULTS	740 nm	CONTROL	1.497	1.423	0.8821	0.1785	3.955	<0.001*
			EXPERIMENTAL	3.740	3.669	1.5898	1.4810	8.784	
		850 nm	CONTROL	1.587	1.679	0.4821	0.4810	2.226	<0.001*
			EXPERIMENTAL	3.239	3.044	0.8366	2.1230	4.817	
		940 nm	CONTROL	1.711	1.662	0.4821	1.1228	2.754	<0.001*
			EXPERIMENTAL	3.224	3.094	0.7093	2.2829	4.578	
D81	OD	740 nm	CONTROL	0.184	0.198	0.0395	0.1160	0.244	0.422
			EXPERIMENTAL	0.188	0.206	0.0376	0.1250	0.244	
		850 nm	CONTROL	0.181	0.195	0.0404	0.1250	0.237	0.048*

			EXPERIMENTAL	0.192	0.212	0.0434	0.1220	0.242	
		940 nm	CONTROL	0.203	0.204	0.0303	0.1420	0.269	0.673
			EXPERIMENTAL	0.201	0.208	0.0358	0.1230	0.260	
	RESULTS	740 nm	CONTROL	1.377	1.354	0.7232	0.1982	2.921	<0.001*
			EXPERIMENTAL	3.820	3.521	1.2494	2.0925	6.921	
		850 nm	CONTROL	1.685	1.580	0.6825	0.6771	3.299	0.002*
			EXPERIMENTAL	4.834	3.778	3.5459	2.3078	15.568	
		940 nm	CONTROL	1.670	1.656	0.7696	0.3648	3.655	<0.001*
			EXPERIMENTAL	4.354	3.976	1.5251	2.7082	8.055	

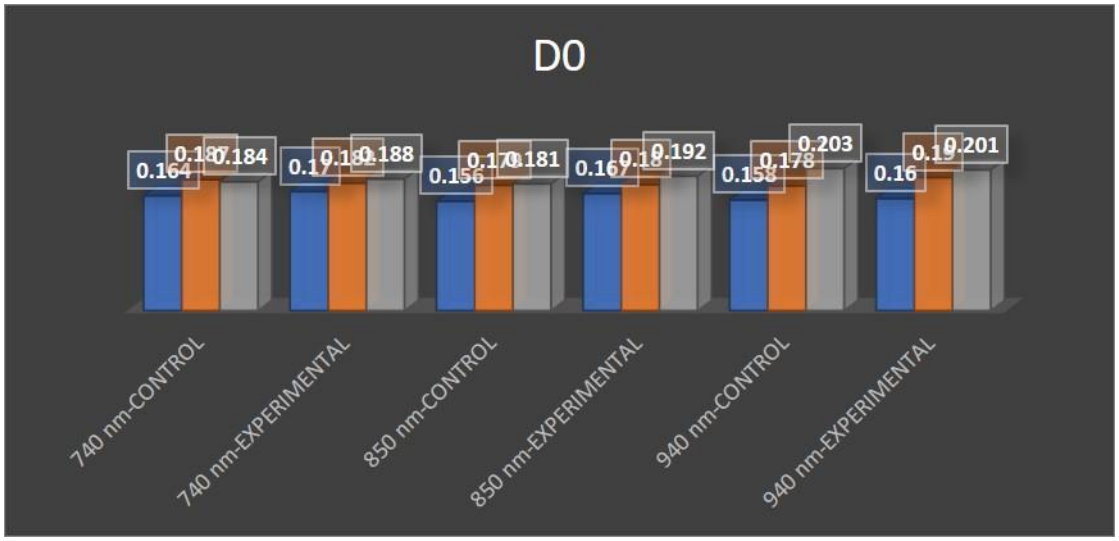

Fig. 4: Representation of GCF Values Before photobiomodulation.

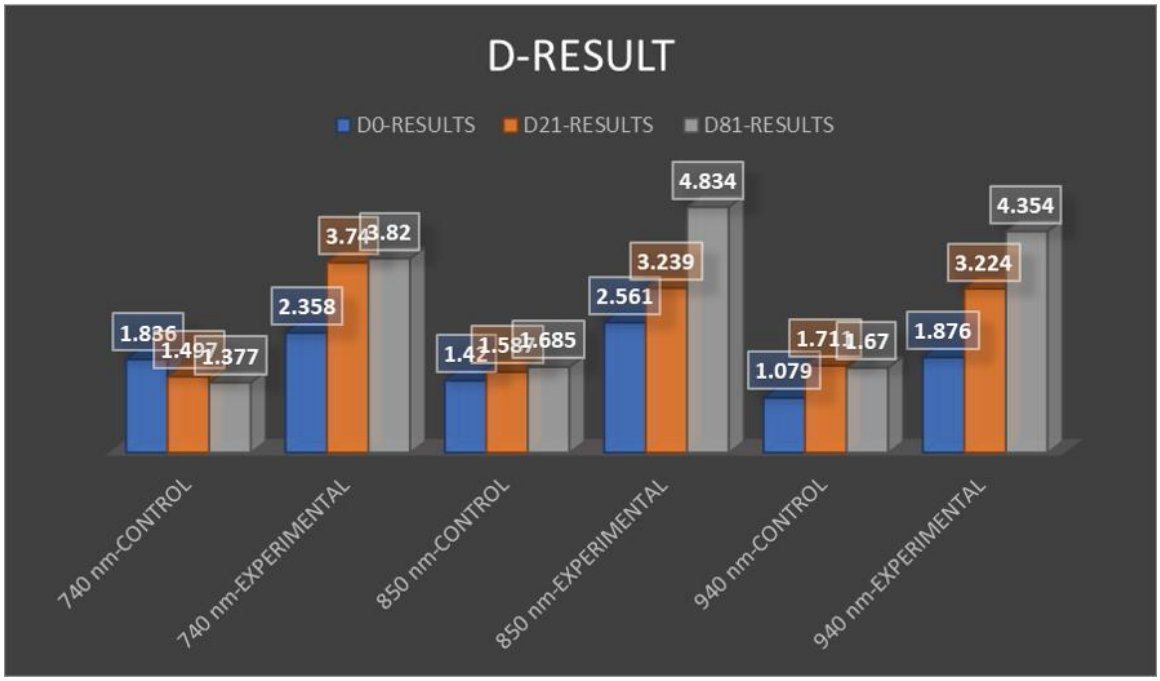

Fig. 5: Representation of GCF Values at 3 months duration.

DISCUSSION

The length of therapy plays a vital role in achieving patient's satisfaction in orthodontics. Fixed orthodontic treatment generally lasts for an extended period, often up to two years, which may lead to negative effects on the surrounding tissues. As a result, many researchers aimed to discover enhanced methods that could shorten the length of orthodontic treatment, and reducing the negative effects .[15-16] A variety of procedures have been utilized, including corticotomy, Piezocision, microosteoperforation, pulsed electromagnetic fields, and pharmacological agents. Nevertheless, these invasive methods often result in patient's discomfort, including pain, swelling, and negative outcomes .[2] Extended orthodontic treatment, especially in adults, presents various issues, including root resorption and discomfort. The investigation of solutions to increase the rate of OTM is currently gaining interest. The tooth shifts because of the alveolar bone remodeling, which it occurs as a consequence of inflammation, and the response of bone cells induced by the stresses applied during orthodontic therapy.[15,17-18] A non-invasive treatment is crucial to accelerate tooth movement without any previously encountered adverse effects. PBM, commonly known as LLLT or Light Accelerated Orthodontics (LAO), is a novel noninvasive technique in this field that has demonstrated the ability to accelerate orthodontic tooth movement. This method employs LED light frequencies ranging from red to near-infrared (600-1000 nm) with varying parameters such as, power density and output to facilitate PBS, thereby inducing bone remodeling through a series of biomechanical reactions.

Photobiomodulation has gained popularity in orthodontics as a method to enhance the acceleration of tooth movement. Previous reports have indicated effects linked to improved cellular function .[4]

The effects of PBM remain a subject of controversy regarding OTM. Many studies in the literature discuss the potential role of parameters in PBM therapy. Baxter et al. identified wavelength and energy density as the primary factors affecting the tissue response .[19] The variability in light parameters and the efficacy of photobiomodulation (PBM) has led to numerous studies, primarily focusing on single frequencies, with fewer investigations utilizing multiple frequencies in animal models to assess the impact of PBM .[20]Hence, our clinical trial study conducted in vivo, to evaluate accelerated orthodontic tooth movement using three different wavelengths of 740nm, 850nm and 940nm and a customized photobiomodulator appliance with different parameters, and also assessed the usage of IL-6 at their levels.

The three wavelengths with distinct parameters incorporated in the photobiomodulator device were derived from the Finite Element Method (FEM) study conducted in 2023 which investigated, the effect of three Light Emitting Diode (LED) wavelengths of 740,850 and 940 nm and their heat generation on soft tissues in accelerating tooth movement which has shown to have faster tooth movement .[21] Responses to orthodontic treatment involving PBM have been documented; however, the outcomes are not consistently uniform .[4,22] Ubolviroj C. A study was conducted with a range of 430-480 nm, revealed no significant results regarding accelerated tooth movement. This may result from the utilization of shorter wavelengths and parameters associated with the blue spectrum wavelength .[23] Chung et al. found no evidence supporting accelerated OTM with the application of an extraoral device to the cheek region during the retraction phase .[24]

This study utilized a split-mouth design, enabling intra-patient comparisons. The split-mouth design utilized in previous research did not demonstrate significant difference when compared to the control group. Ajit Pilla et al.,[25] conducted a study utilizing a split-mouth technique, with a frequency range of 460-480 nm, which yielded no significant results. Furthermore, the study's design was restricted to the upper arch only. The infrequent occurrence and the singular arch may lack efficacy. A comparable study by Chung et al., utilizing a split-mouth design, yielded insignificant results, potentially attributable to the large extraoral device employed to expedite tooth movement .[24] Numerous studies in the literature have reported varying results concerning different wavelengths and parameters, with some indicating positive effects while others demonstrate no significant effects. This study aimed to compare and evaluate three distinct wavelengths with varying parameters to determine the optimal wavelength of irradiation for accelerating tooth movement, given the complexity and diversity of PBM.

We applied a split-mouth design and a customized intraoral photobiomodulator appliance to reduce inter-individual variations and accelerate the rate of orthodontic tooth movement (OTM). The device features three specific LED light wavelengths: 740 nm with an energy density (ED) of 8 J/cm² and a power density (PD) of 51 mW; 850 nm with an ED of 4 J/cm² and a PD of 21 mW; and 940 nm with an ED of 15 J/cm² and a PD of 93 mW, maintained over a duration of three months. This study assessed pretreatment crowding and the resolution of crowding after three months, measured by using the Little Irregularity

Index (LI > 3 mm). When compared the experimental quadrants to control over three months, our study showed a statistically significant increase in the rate of tooth movement (P<0.001).

This investigation evaluated multiple LED wavelengths with different exposure times and characteristics, resulting in a more rapid rate of tooth movement compared to the previous study.

In our experimental clinical study, wavelength of 740 nm demonstrated superior performance, which likely was attributed to the selected parameters, specifically a power density of 8 J/sq cm and a power output of 51 mW. In contrast to 740 nm wavelength, 850 nm was utilized with less favorable parameters. Research indicated that, parameters significantly were influenced by the efficacy of LED lights in literature. A study by Zein R.et al.,[26] has demonstrated that various parameters significantly influenced the efficacy of LED photobiomodulation. The selection of fewer parameters on 850 nm wavelength yielded superior results compared to 740 nm in our study.

Studies in literature, confirmed that low frequencies and high parameters can lead to increase orthodontic tooth movements. Our study correlates with a similar study conducted by Nahas AZ., Samara SA., Ta RL et al, that has shown more decrowding of lower anterior segment by using 618nm wavelength with increased energy density and power output .[27]

In contradictorily note when in comparison with 940 nm wavelength with the lowest efficacy in this study due to higher parameters like energy density and power output. Hyalinization-like effects can be observed within the tissues. When forces are applied to the teeth, movements occur due to optimal orthodontic forces within biological limits. However, even if the selected parameters are high, tooth movement may be impeded due to a hyalinization-like effect, resulting in a lag phase. During this phase, tooth movement may cease or slow down, leading to a prolonged resolution of crowding when using a 940 nm wavelength. Friedrichsdorfa SP et al., described the hylanization effect associated with root resorption under conditions of elevated parameters, particularly power output and energy density. The study utilized an Olympus BX 60 light microscope to measure hyalinization. This effect was observed in the pressure areas of both groups .[28]

According to the Arndt-Schulz rule., sometimes known as Schulz's law, tiny dosages of any irradiation would stimulate the biological processes, moderate levels inhibit the effect, and excessive doses would kill[26],which correlates, while using different doses of wavelengths with parameters.

When orthodontic force is applied, periodontal cells generate biologically active molecules that promote the remodeling of connective tissues and the formation of osteoclasts, leading to tooth movement .[6] The movement of teeth during orthodontic treatment induces an inflammatory response associated with the release of several cytokines, osteoprotegerin, matrix metalloproteinases, tumor necrosis factor (TNF), and lactate dehydrogenase, .[7] Periodontal ligament cells release proinflammatory mediators such as Interleukin-6 (IL-6) during the initial stages of tooth movement .[8] This biochemical mediator (IL6) promotes osteoclastic processes during OTM. IL6 serves as a potent stimulator of bone resorption. Research indicates that IL-6, in conjunction with other pro-inflammatory cytokines such as, IL-1β, plays a crucial role in modulating the biological response to mechanical forces during orthodontic treatment .[8]

Molecules involved in bone modeling and remodeling processes can be detected in gingival crevicular fluid (GCF), an exudate that reflects biological activities in periodontal tissues and facilitates the identification of specific biomarkers .[9-12] Hence, our study also evaluated the role of biomarker IL-6 to find the inflammatory response with three different wavelengths.

In our study, experimental quadrants on D0 exhibited higher mean and median values of GCF compared to control quadrants across all wavelengths, with a modest difference observed on 740 nm: 2.358 versus 1.836. The outcomes of decrowding after three months indicated a more rapid OTM on 740 nm, succeeded by 850 nm and 940 nm, respectively. The most significant difference in decrowding was observed at 850 nm on D81, while intermediate differences were noted at 940 nm. This observation indicated that LLLT initiated a self-propagating sequence of events. The therapeutic efficacy of LLLT is substantially influenced by these essential parameters .[29] A noninvasive technique that may assist in assessing the extent of periodontal remodeling during orthodontic treatment is the evaluation of specific inflammatory markers .[30] This information may assist the clinician in identifying the optimal timing for orthodontic intervention .[25] Fernandes et al., demonstrated that photobiomodulation accelerated tooth movement during molar intrusion by regulating IL-6, IL-8, and IL-1β during bone remodeling, which presented significant advantages .[31] Reitan indicated that elevated biomarker levels during OTM significantly influenced the cellular response .[32]

This study examined the impact of photobiomodulation on three distinct wavelengths and varying

parameters on the acceleration of orthodontic tooth movement, as well as assessment of the mechanism by which these wavelengths influenced IL-6 levels. The GCF is vulnerable to contamination by plaque and saliva, and this bias must be considered. The multitude of confounding variables and biological responses in both GCF and periodontal ligament maybe due to inadequate sample's size of this study.

CONCLUSION

The research indicates that the rate of orthodontic tooth movement (OTM) with accelerated decrowding was more shown on 740 nm wavelength, compared to 850 nm and 940 nm. IL-6 levels were elevated across all wavelengths, with the highest levels observed on 740 nm from D0 to D81, followed by high levels on 850 nm, and intermediate levels on 940 nm, on D21 and D81, respectively.

As a result, photobiomodulation led to accelerated decrowding and increased interleukin 6 concentrations in gingival crevicular fluid.

Limitation of the study.

This study employed a split-mouth design with the 1st and 3rd quadrants designated as the experimental group and the 2nd and 4th as the control group. However, quadrant assignment was not randomized, which may introduce a potential for anatomical bias—a limitation acknowledged in the study design.

The sample size was relatively small, which may have reduced the statistical power and generalizability of the results. The study duration was also limited, and longer-term outcomes such as post-treatment stability or relapse could not be evaluated.

Future Scope

Future research should incorporate larger sample sizes, multicentric designs, and extended follow-up periods to better understand the long-term impact of PBM. Standardizing PBM dosimetry across all wavelengths is essential for isolating wavelength-specific effects.

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