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ORIGINAL ARTICLE

EVALUATION OF RAPID ACCELERATED PHENOMENON USING LOW LEVEL LASER THERAPY AND FLAPLESS OSTEOPUNCTURE METHOD DURING ENMASSE RETRACTION USING PREADJUSTED EDGEWISE APPLIANCE: AN IN VIVO COMPARATIVE STUDY

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ABSTRACT

Background: En-masse retraction of maxillary anterior teeth is a critical phase in orthodontics, and optimizing tooth movement is essential. This study evaluates the clinical effects of Low-Level Laser Therapy (LLLT) and flapless osteopuncture on en-masse retraction during orthodontic treatment using the Pre-Adjusted Edgewise Appliance (PEA).

Objectives: To compare the rate of en-masse retraction in the maxillary arch using three methods: 1) LLLT, 2) Flapless Osteopuncture, 3) Conventional Friction Mechanics.

Methods: A total of 24 orthodontic patients undergoing en-masse retraction with PEA were divided into three groups: Group 1: LLLT, Group 2: Flapless Osteopuncture, Group 3: Conventional Friction Mechanics (control). Tooth movement rates were measured and compared using clinical and radiographic assessments at specified intervals. Statistical analysis was conducted with $p < 0.05$.

Results: The rate of en-masse retraction was compared among the three groups. No significant difference was found between the laser and micro-osteoperforation groups, but the micro-osteoperforation group showed a faster rate of tooth movement.

Conclusions: LLLT and flapless osteopuncture methods were effective in accelerating en-masse retraction using the PEA technique, with micro-osteoperforation demonstrating greater effectiveness than LLLT. These adjunctive techniques may provide alternatives to conventional friction mechanics for improving tooth movement.

Keywords: Low-Level Laser Therapy, Flapless Osteopuncture, En-Masse Retraction, Tooth Movement, Friction Mechanics.

INTRODUCTION

According to the World Health Organization (WHO), malocclusion is one of the most significant oral health problems, following dental caries and periodontal diseases.¹ Orthodontic treatment is the primary solution for malocclusion, improving facial aesthetics and mastication

by aligning teeth. However, post-treatment issues such as dental caries, tooth discoloration, and gum hyperplasia have been reported.² With growing demand for aesthetic treatments, particularly among Millennials and Gen Z, the increased prevalence of malocclusion is also linked to the lengthy duration of orthodontic treatment plans.³⁻⁴

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Orthodontic tooth movement relies on the activity of tissues and the remodeling of alveolar bone around the tooth roots. Applying external forces creates areas of tension and pressure in the periodontal ligament and alveolar bone, leading to bone deposition and resorption.⁵ Older patients experience slower bone metabolic activity, resulting in longer treatment durations compared to younger adults, with the average treatment period for adults around two years.⁶ Prolonged treatment can increase the risk of gingival and periodontal inflammation, root resorption, and caries, which may reduce patient cooperation and delay progress.⁷

Various new treatment modalities and research have been introduced to accelerate orthodontic tooth movement and reduce treatment time without compromising outcomes.⁸ The first corticotomy-assisted tooth movement was described by Bryan in 1893, aiming to reduce treatment time by one-third. In the early 1950s, periodontists began using corticotomy to enhance tooth movement rates.⁹⁻¹¹

Osteoperforations and Low-Level Laser Therapy (LLLT) have been shown to effectively accelerate tooth movement compared to conventional treatment methods. LLLT induces a photochemical reaction at the cellular level, where light energy is absorbed by cellular photoreceptors and converted into ATP (Adenosine Tri-phosphate) by mitochondria. This process activates the proliferation of osteoclasts and osteoblasts through gene expression of RANK (Receptor-activator of nuclear factor kappa-B) and RANK-L (Receptor activator of nuclear factor kappa-B ligand), which accelerates bone remodelling and ultimately increases the velocity of orthodontic tooth movement.¹²⁻¹⁸

The present study was designed to compare the effectiveness of Low-Level Laser Therapy (LLLT) and micro-osteoperforation techniques using flapless osteopuncture with the Pre-adjusted Edgewise Appliance (PEA) in accelerating maxillary anterior tooth movement, with the goal of determining their impact on orthodontic treatment duration compared to conventional methods.

MATERIAL AND METHODS

A prospective comparative clinical trial was conducted following the search strategy proposed by CONSORT guidelines (Figure 1) after that the ethics approval obtained from the institutional ethics committee (IEC/24/2018). A preliminary clinical and radiographic assessment was performed among the included subjects reporting to the department of Orthodontics using a random sampling method.

Inclusion criteria: Individuals aged 17-35 years, requiring bilateral extraction of upper 1st premolars for

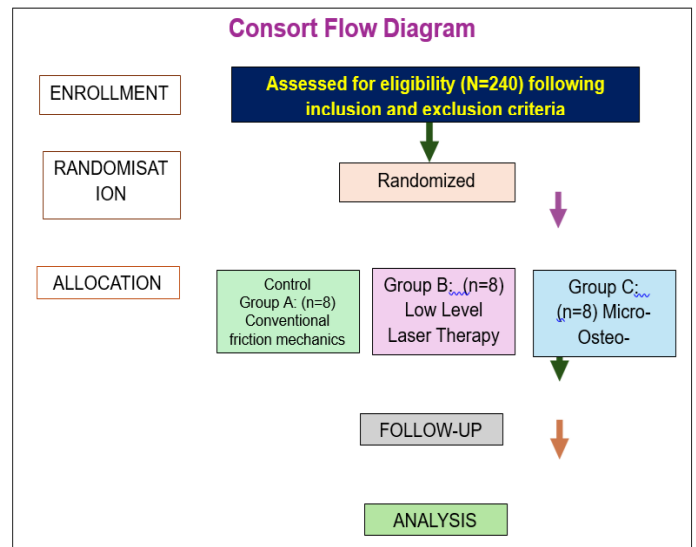


Figure1. Study flow chart

maxillary anterior proclination correction with maximum anchorage, and no systemic illnesses, who provided written consent.

Exclusion criteria: Individuals with medication use, pregnancy, unilateral chewing or parafunctional habits, skeletal crossbite, occlusal interferences, periodontal/prosthetic issues, or impactions/dilacerated canines.

Study procedure: A pre-assessment of oral hygiene was conducted, and only individuals with good oral hygiene were included. Twenty-four subjects undergoing fixed orthodontic treatment with Pre Adjusted Edgewise Appliances (PEA) were divided into three equal groups (n=24) to compare tooth movement rates using Low-Level Laser Therapy (LLLT), Micro-Osteoperforations (MOP)

GROUP – A: retraction carried out with conventional friction mechanics.

GROUP –B: with friction mechanics receiving Low-Level Laser Therapy(LLLT).

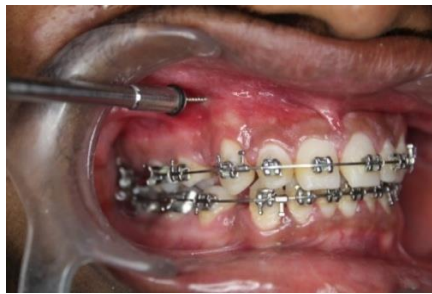
GROUP– C: with friction mechanics receiving Micro-Osteoperforation (MOP).

The orthodontic treatment was initiated seven days after the extraction of premolars using Pre Adjusted Edgewise McLaughlin Bennet Trevesi bracket system with 0.022”x0.028” slot with MBT prescription (3M UNITEK KITS) for bonding.

Materials used were listed below:

1. PAE with MBT prescription - 0.022" × 0.028" Slot. (3M Unitek)
2. Trans palatal arch for anchorage.
3. 0.019" × 0.025" Stainless steel (SS) as working arch wire.
4. Alginate impression material.
5. Type III dental stone.
6. Nickel Titanium closed coil springs with 150 grams of constant force, 6mm length. (NiTi Arch wire, DIA: 0.010 inch).
7. A diode laser Gallium-Aluminium-Arsenide (Ga-Al-As) of 940nm, 100mw.
8. Mini implant driver.
9. Mini screws (diameter 1.5 x 8 mm)
10. Force measuring gauge.
11. Digital vernier callipers.

A Trans palatal Arch (TPA) was placed in the molar band's palatal sheath and secured with ligature wire or elastic modules for anchorage reinforcement. Levelling and alignment were initiated with sequential Ni-Ti wires for space closure, completed in 8 weeks. Maxillary impressions were taken after alignment, followed by the placement of a 19 x 25 SS final arch wire for 21 days. En-masse retraction was performed using NiTi closed coil springs with a continuous 150-gram force, measured with a Dontrix gauge, from the first molar hook to a crimpable hook between the canine and lateral incisor, as shown in Picture 1. A fixed-length coil spring was used to maintain this force, adjusted with ligature wire and reactivated every 28 days. Measurements were taken with a digital vernier caliper on the first day, 4th week, and 8th week, recording the distance from the canine's distal contact to the mesial contact of the second premolar.



Picture 1. En-masse retraction using NiTi closed coil springs from first molar hook to crimpable hook between canine and lateral incisor.

Group A – Control Group (n=8): Underwent en-masse retraction using conventional friction mechanics without accelerated orthodontic procedures.

Group B – Laser Group (n=8): Exposed to a 940nm Gallium-Aluminium-Arsenide diode low-intensity laser (100mW) in continuous wave mode. Laser application involved 10 sessions (5 on the buccal side and 5 on the palatal side) covering the periodontium and alveolar process around the six anterior teeth. Sessions were scheduled at T0, T1 (4 weeks), and T2 (8 weeks), with total energy density of 10J per application. Closed Ni-Ti coil springs with 150g force were applied and activated at each visit.

Group C – Micro-Osteoperforation (MOP) Group (n=8): Pre-assessment included evaluating gingival thickness, periodontium health, and frenum proximity, along with panoramic and intra-oral radiographs. MOPs were performed using a mini-implant driver with a 1.5 x 8mm miniscrew under anaesthesia, creating three Osteoperforations to a depth of 3mm on the labial surface of each tooth. MOPs were performed on days 1 and 28, with evaluations at week 8. Closed Ni-Ti coil springs (150g) were used for force delivery, as shown in Picture 2.



Picture 2. Closed Ni-Ti coil springs for force delivery

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Measurement of space closure: En-masse space closure using Rapid Accelerated Phenomenon (RAP) was assessed by taking alginate impressions at three time points: T0 (on the day of laser and micro-osteoperforation application), T1 (1 week later), and T2 (2 weeks later). A 150-gram force was applied continuously. Distance from the distal contact of canine to the mesial contact of the second premolar was measured. Anchorage loss was evaluated by measuring the horizontal distance from the Pterygoid Vertical (PtV) to the distal surface of the maxillary first molar at T0 and T2.

Statistical analyses: Data was collected and entered into MS Excel, then analyzed using SPSS Version 25. Descriptive statistics were presented as mean and standard deviation (SD). The Shapiro-Wilk test was used to assess normality. Repeated measures ANOVA, independent t-test, and Dunnett’s and Tukey’s post hoc analyses were performed. A p-value of <0.05 was considered statistically significant.

RESULTS

When the inter group comparisons were done between three groups, a statistically significant difference was found at T2 on right side (Table 1; Figures 2 & 3).

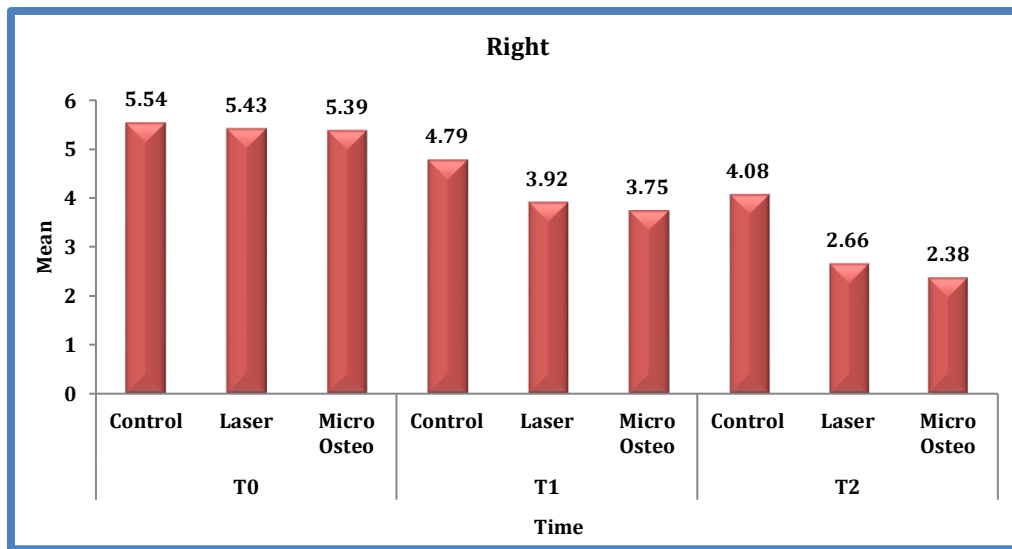


Figure 2. Comparison between amount of space remaining in control, laser and micro-osteoperforation group on right side at T0, T1 and T2

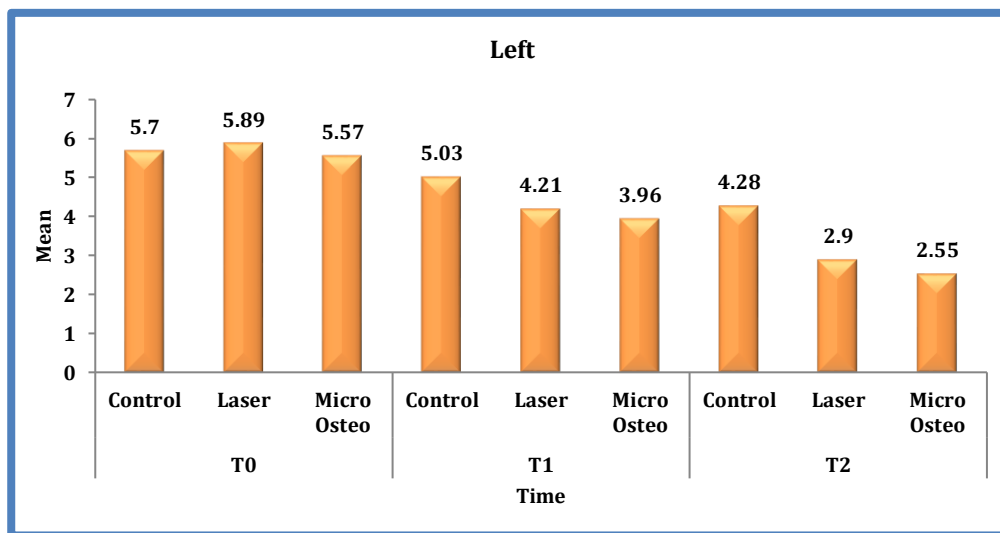


Figure 3. Comparison between amount of space remaining in control, laser and micro-osteoperforation group on left side at T0, T1 and T2

Table 1. Comparison between the amount of space remaining in control, laser and micro-osteo perforation group on right side and left side at T0, T1 and T2

Right side	Group	Minimum	Maximum	Mean	SD	P-value	Post hoc	
T0	Control	4.28	6.70	5.54	0.81	0.932	-	
	Laser	4.60	7.05	5.43	0.86			
	Micro Osteo	4.28	6.70	5.39	0.78			
T1	Control	3.28	5.92	4.79	0.90	0.091	-	
	Laser	2.28	6.01	3.92	1.15			
	Micro Osteo	2.52	5.12	3.75	0.81			
T2	Control	2.01	5.09	4.08	1.02	0.004*	Control vs Laser	0.013*
	Laser	1.20	4.72	2.66	1.09		Control vs Micro Osteo	0.003*
	Micro Osteo	1.25	3.30	2.38	0.70		Laser vs Micro Osteo	0.830
Left Side								
T0	Control	4.00	6.70	5.70	0.94	0.823	-	
	Laser	4.43	7.47	5.89	1.14			
	Micro Osteo	4.10	7.00	5.57	0.97			
T1	Control	3.12	5.91	5.03	1.01	0.186	-	
	Laser	2.00	6.12	4.21	1.46			
	Micro Osteo	2.30	5.43	3.96	0.99			
T2	Control	2.22	5.13	4.28	1.07	0.026*	Control vs Laser	0.07*
	Laser	0.50	4.83	2.90	1.47		Control vs Micro-osteo	0.003*
	Micro Osteo	0.50	4.12	2.55	1.15		Laser vs Micro-osteo	0.83

*P<0.05 is considered statistically significant

At T1 and T2, the rate of space closure in each group was 0.75mm, 0.71mm in control group, 1.51mm, 1.26mm in laser group and 1.64mm, 1.37mm in micro-osteoperforation group. On left side (Table 2), at T1 and T2, the rate of space closure observed was 0.67mm, 0.75mm in control group, 1.68mm, 1.31mm in laser group and 1.61mm, 1.41mm in micro-osteoperforation group. Further post- hoc tests were done to know which comparison groups were significant. When mean values were compared between study groups, micro-osteoperforation (3.01mm, 3.02mm) was found to accelerate tooth movement faster than laser group (2.77 mm, 2.99). (Table 1 & 2; Figures 2, 3 & 4)

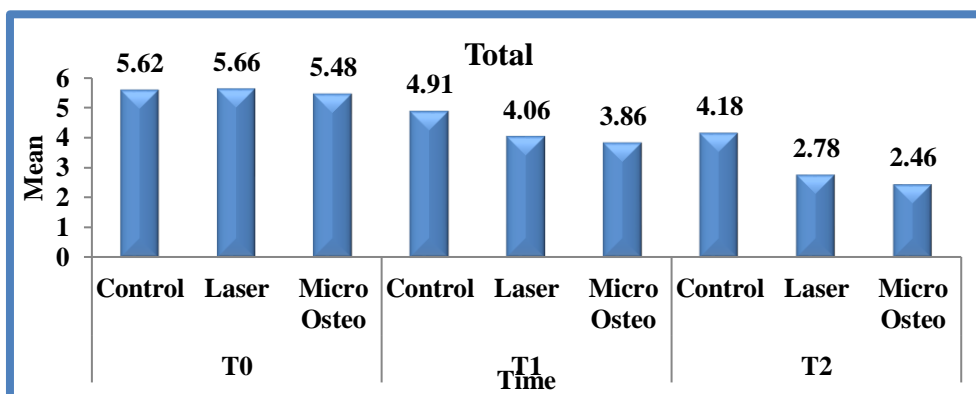


Figure 4. Comparison between the amount of space remaining in control, laser and micro-osteoperforation group combined at T0, T1, T2.

Table 2. Intra-group comparison in the control group and laser group on right, left side separately and total at T0, T1, and T2

Group	Side	Minimum	Maximum	Mean	SD	% change	P-Value		
Control	Rt at T0	4.28	6.70	5.54	0.81	-	<0.001*		
	Rt at T1	3.28	5.92	4.79	0.90	13.5			
	Rt at T2	2.01	5.09	4.08	1.02	26.4			
	Control	Lt at T0	4.00	6.70	5.70	0.94	-	<0.001*	
		Lt at T1	3.12	5.91	5.03	1.01	11.8		
		Lt at T2	2.22	5.13	4.28	1.07	24.9		
		Control	Total at T0	4.00	6.70	5.62	0.85	-	<0.001*
			Total at T1	3.12	5.92	4.91	0.93	12.6	
			Total at T2	2.01	5.13	4.18	1.02	25.6	
Laser	Rt at T0	4.60	7.05	5.43	0.86	-	<0.001*		
	Rt at T1	2.28	6.01	3.92	1.15	27.8			
	Rt at T2	1.20	4.72	2.66	1.09	51.0			
	Laser	Lt at T0	4.43	7.47	5.89	1.14	-	<0.001*	
		Lt at T1	2.00	6.12	4.21	1.46	28.5		
		Lt at T2	0.50	4.83	2.90	1.47	50.8		
	Laser	Total at T0	4.43	7.47	5.66	1.01	-	<0.001*	
		Total at T1	2.00	6.12	4.06	1.27	28.3		
		Total at T2	0.50	4.83	2.78	1.26	50.9		

*P<0.05 is considered statistically significant

When both right and left sides were combined and total was compared, significant difference was found at T1 and T2 with p- values of 0.02, 0.001 and further post hoc test showed significant difference between the laser, micro-osteoperforation at T1 & T2. Laser vs micro-osteoperforation groups showed no significant difference but in micro-osteoperforation group space closed by 0.2mm faster than laser group at T1 and by 0.32mm at T2. On an average space closure in laser group was 2.88 mm and micro-osteoperforation group was 3.02 mm during the total 8 weeks study. In intra-group comparison of control group (Table 3), 13.5%, 26.4% of space closed on right side and 11.8%, 24.9% respectively on left side at T1 and T2. On an average the combined right and left showed 12.6%, 25.6% at T1 and T2. Laser group (Table. 2, Figure 5) also showed a change of 27.8% and 51% on right and 28.5% and 50.8% on left sides respectively at T1 and T2. The total shows the 28.3% and 50.9% at T1 and T2. Micro-osteoperforation group showed 30.4% and 55.8% on right side and 28.9% and 54.2% on left side at T1 and T2. The total shows 29.6% and 55.1% at T1 and T2. (Figure 6)

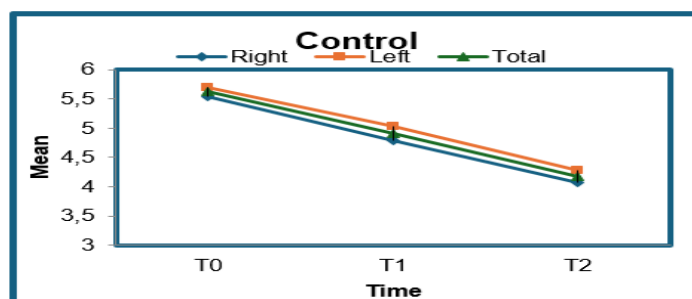


Figure 5. Graph showing the intra-group showing amount of space left at T1 and T2 in control group on right side, left side and total

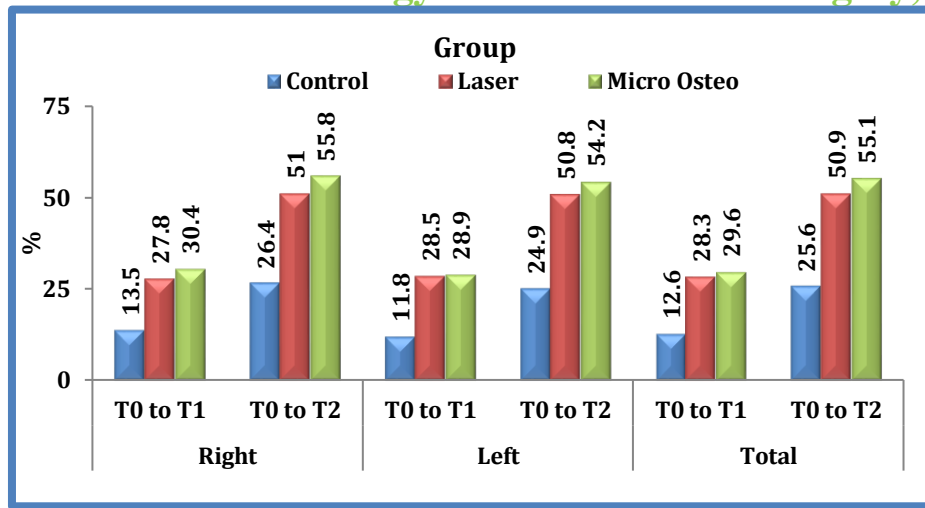


Figure 6. Graph showing the percentages of space closed in control, laser and micro-osteoperforation groups

Table 3. Intra-group comparison in the micro-osteoperforation group on right, left side separately and total at T0, T1 and T2

Group	Side	Minimum	Maximum	Mean	SD	% change	P-value
Micro Osteo-perforation	Rt at T0	4.28	6.70	5.39	0.78	-	<0.001*
	Rt at T1	2.52	5.12	3.75	0.81	30.4	
	Rt at T2	1.25	3.30	2.38	0.70	55.8	
	Lt at T0	4.10	7.00	5.57	0.97	-	<0.001*
	Lt at T1	2.30	5.43	3.96	0.99	28.9	
	Lt at T2	0.50	4.12	2.55	1.15	54.2	
	Total at T0	4.10	7.00	5.48	0.85	-	<0.001*
	Total at T1	2.30	5.43	3.86	0.88	29.6	
	Total at T2	0.50	4.12	2.46	0.92	55.1	

*P<0.05 is considered statistically significant

The rate of space closure was higher in the laser group (51%) compared to the control group (26.4%), and higher in the micro-osteoperforation (MOP) group (55.8%) on the right side. On the left side, the results were similar, with the control group at 24.9%, laser group at 50.8%, and MOP group at 54.2%. Overall, the right side showed faster tooth movement than the left side in all groups. In total, the laser (50.9%) and MOP (55.1%) groups showed about twice the tooth movement rate of the conventional group (25.6%). The MOP group demonstrated a 4.2% higher increase in tooth movement compared to the laser group at T2. (Figure 6)

This study concluded that there was no significant difference between laser and micro-osteoperforation group but overall micro-osteoperforation group can accelerate the rate of tooth movement than laser group.

DISCUSSION

Orthodontic tooth movement involves complex biological processes, where mechanical forces applied to teeth generate stress on the alveolar bone and periodontal ligament (PDL). The compression on one side and tension on the opposite side of the PDL trigger bone remodeling and modeling.¹⁹⁻²⁰ Bone modelling is an inflammatory

process, while bone remodeling involves resorption and formation, controlled by osteoclasts, osteoblasts, and osteocytes. The rate of tooth movement is influenced by bone resorption at the PDL-bone interface. Proper force application is essential to prevent negative effects like bone necrosis or root resorption.²¹⁻²³

Orthodontic tooth movement (OTM) is influenced by systemic factors like nutrition, age, metabolic bone diseases, drug history, and internal factors such as cytokines, interleukin-1 β , and prostaglandins (PGE2).¹³ While careful planning can reduce treatment duration, biological factors remain the primary limitation. Accelerating OTM has been explored through various methods and studies, including increased force, drug applications, vibratory forces, lasers, and surgical techniques like corticotomy. These approaches aim to shorten treatment time, reduce side effects (e.g., root resorption), improve tooth movement precision, and enhance post-treatment stability.²⁴⁻²⁵

Certain methods to accelerate orthodontic tooth movement (OTM), like prostaglandin injections and osteocalcin, can cause discomfort and side effects, limiting their clinical use. Over the past decade, the regional acceleratory phenomenon (RAP) induced by surgical trauma has gained attention for reducing treatment time.²⁶ Minimally invasive procedures like Micro-osteoperforations (MOP) and low-level laser therapy (LLL) are explored for their effectiveness and reduced pain. Lasers are increasingly used in orthodontics, offering advantages in diagnostics, bonding, and minor surgeries, such as frenectomy and exposure of impacted teeth, making them valuable alternatives to traditional methods.²⁷⁻³⁰

Lasers used in dental practice vary in wavelength (488 nm to 10,600 nm) and are classified by emission type, output power, active medium, target tissue, and potential biological damage.

Dental lasers are classified³¹ in terms of the following characteristics:

- Emission type: Spontaneous emission or stimulated emission
- Output power: High powered, mid powered, or low powered

- Active medium: Liquid, gas, or solid-state

- Target tissue: Hard or soft tissue

- Potential biological damage: Class I, Class II, Class III, or Class IV.

All medical and dental lasers are typically classified as Class IV due to their high power and potential to cause harm to skin and eyes, including through reflected beams, making safety precautions essential. Lasers can be classified as high and low-intensity lasers based on their potency and mechanism of action. High-intensity lasers, such as CO₂ and argon lasers, are destructive and used in surgical procedures. In contrast, low-intensity lasers (soft lasers) do not have destructive potential. Their photo biomodulation action stimulates cellular metabolism, bone remodeling, and tooth movement, making them particularly useful in orthodontics.³²⁻³⁵

Common dental lasers include Nd: YAG, CO₂, diode, and Erbium lasers, with the Ga-Al-As diode laser being most effective for orthodontics due to its deep tissue penetration. Low-Level Laser Therapy (LLL), or "soft laser," stimulates cells without significantly raising tissue temperature.³⁶ LLL accelerates tooth movement, promotes wound healing, induces vasodilation, and improves local blood flow, making it useful for treating joint inflammation, including temporomandibular joint disorders.³⁷

The study used a 940 nm wavelength laser with a low energy dose of 1 J/cm² for deeper tissue penetration and bone cell stimulation. Due to facial structure variability, measuring light exposure in the dentoalveolar complex is challenging. Previous studies suggest low doses (e.g., 2.25 J/cm²) can accelerate tooth movement, though results vary. Sousa et al. recommend doses between 0.2 J and 2.2 J per point for effective acceleration. While LLL is non-invasive, improper settings may cause negative effects. The 4-week laser application interval in this study aligns with conventional orthodontic schedules, making it clinically adaptable.³⁸⁻⁴⁰

Several studies have explored the effect of lasers on accelerating orthodontic tooth movement. Curz et al. (2004)¹⁴ used a Ga-Al-Ar diode laser with a 780 nm wavelength for 10 seconds at 20 mW, 5 J/cm², showing accelerated movement. Doshi Mehta

(2012)⁴¹ found a 30% increase in canine retraction using an 800 nm, 250 mW laser. However, Limpanichkul W et al. (2006)¹⁵ and Herav et al. (2014)⁴² found no significant results with different wavelengths and dosages, attributing the lack of effect to low energy input, different dosages, or application methods. Sousa et al. (2011)⁴³ observed a twofold acceleration using a 780 nm laser at 20 mW.

Micro-osteoperforations (MOPs) accelerate tooth movement by triggering cytokine release, which recruits osteoclasts and enhances bone resorption.⁴⁴ Some studies report a 2–3 fold increase in tooth movement rate. The key proinflammatory cytokines released during orthodontic movement are IL-1 (a and b), TNF- α , and IL-6, which promote osteoclastic activation and faster tooth movement.⁴⁵

Age and type of tooth movement can influence the rate of orthodontic tooth movement. Younger patients typically experience faster movement due to higher osteoclastic activity and bone density. To control for age, only patients older than 15 were included, ensuring equal average ages in both groups. Additionally, while tipping movements in MOP studies were suggested to cause false-positive results, no significant difference in tipping was observed between groups, ruling it out as a factor in accelerated tooth movement.⁴⁶

The study had certain limitations, including the inability to evaluate root resorption due to the short duration, as various factors could contribute to it. A longer study period would make it harder to control these variables. No evidence of root resorption was found in the panoramic radiographs taken as final records.

Both LLLT and MOP procedures were effective, comfortable, and safe in significantly accelerating tooth movement, potentially leading to shorter orthodontic treatment durations. Future research should examine factors such as the number and wavelengths of LLLT, frequency of MOPs, and variables like pulp vitality and root resorption, with a longer observation period.

CONCLUSIONS

The study concludes that both Micro-Osteoperforations (MOPs) and Low-Level Laser Therapy (LLLT) accelerate en-masse retraction

during orthodontic treatment, with MOPs showing greater effectiveness compared to conventional methods. Key findings include significant tooth movement differences in the MOP and LLLT groups versus the conventional group at the 4th and 8th weeks. However, no significant differences were observed between the LLLT and MOP groups. Additionally, no changes in anchorage were noted in either treatment group.

DECLARATIONS

Conflict of Interest

There are no conflicts of interest.

Financial support

None

Competing Interests

The authors have no competing interests to declare.

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