Research Article

Effect of Low-Level Laser Therapy (LLLT) after Piezocision on the Rate of Tooth Movement During En-Masse Retraction: A Prospective Clinical Study

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ABSTRACT

Background: With increasing awareness of facial aesthetics and the desire for an appealing smile, patients are demanding faster and better results than ever before in orthodontic treatment. This trend motivates orthodontists to engage in more research in the field of accelerated orthodontics to expedite treatment and satisfy individual preferences for aesthetics.

Aim and Objectives: To evaluate and compare the effects of sequential Piezocision, Piezocision followed by Low-Level Laser Therapy (LLLT), and conventional sliding mechanics during en-masse retraction.

Materials and Method: The study included 30 subjects with skeletal and dental Class I relationship who were treated orthodontically with four first premolar extraction. They were randomly divided into three groups of 10 patients each. Group A was subjected to conventional sliding mechanics, Group B underwent sequential Piezocision, and Group C received Piezocision followed by LLLT for en-masse retraction. Study models were taken every month for three months to measure the distance between the contact points of the canine and second premolar on both sides.

Result: Statistically significant rates of space closure were observed in Group C, followed by Group B. The amount of space closure on right and left sides after 3 months of study period in Group C, Group B and Group A in descending order were 3.27 ± 0.16 mm and 3.29 ± 0.05 mm > 2.91 ± 0.17 mm and 2.91 ± 0.13 mm > 2.24 ± 0.25 mm and 2.29 ± 0.05 mm respectively.

Conclusion: LLLT further enhances the Regional Acceleratory Phenomenon achieved with Piezocision, resulting in faster Orthodontic Tooth Movement.

KEYWORDS: LLLT (Low-Level Laser Therapy), Regional Acceleratory Phenomenon, Orthodontic Tooth Movement.

INTRODUCTION

Orthodontic treatment is based on the principle that if a light, continuous force is applied to a tooth, the tooth will move as the alveolar bone remodels.[1] In today's age of immediate gratification, people demand faster and better results. Unfortunately, a tooth can only move safely through the alveolus at a speed permitted by the surrounding biological factors.

Efforts to accelerate tooth movement have involved using orthodontic force alongside feasible modulation of biological responses without causing irreversible damage to the teeth and periodontal tissues.[2] Many invasive and non-invasive techniques have been developed, including osteotomy, corticotomy, Piezocision, Low-Level Laser Therapy (LLLT), micro-osteoperforation, and local pharmacological agents.

In 1893, L.C. Bryan first described corticotomy-facilitated tooth movement. However, it was first introduced by Kole in 1959 as a means for rapid tooth movement.[3] More recently, a minimally invasive surgical procedure called Piezocision was introduced by Dibart in 2009 to enhance the Regional Acceleratory Phenomenon (RAP).[4]

Increased research on soft-tissue diodes has highlighted their application in the non-invasive acceleration of orthodontic tooth movement.[5] Researchers suggest that LLLT may evoke RAP through bio-stimulation, accelerating bone remodeling and potentially reducing treatment duration by about 30-40%.[6]

Applying Low-Level Laser Therapy after Piezocision may further reduce the need for frequent surgical interventions to the cortical bone, inducing RAP and thus accelerating orthodontic tooth movement while decreasing overall treatment duration. Therefore, the main aim of our study is to evaluate the rate of tooth movement with Piezocision followed by LLLT after a latent period of one month.

METHOD

The present in vivo study was conducted on patients undergoing orthodontic treatment at the Department of Orthodontics and Dentofacial Orthopedics, CKS Theja Institute of Dental Sciences and Research, Tirupati, Andhra Pradesh, India. Ethical approval was obtained from the Institutional Ethical Committee.

The inclusion criteria required subjects with skeletal Class I, all first premolars extracted, and sound periodontal support (i.e., no or mild alveolar bone loss observed radiographically) with no history of trauma or previous orthodontic treatment. Similarly, patients with severe skeletal discrepancies, more than 4mm of crowding per arch, or those who were medically compromised with uncontrolled systemic conditions such as diabetes, hypertension, or asthma, as well as those on long-term medications, were excluded.

Thirty subjects aged 15-30 years, diagnosed with skeletal Class I and Angle Class I malocclusion, exhibiting an average growth pattern, and referred for extraction of all first premolars were included. Pre-treatment orthopantomograms, lateral cephalograms, and study models were obtained, and initial periodontal parameters, such as periodontal pocket depth, bleeding on probing, and gingival index, were measured. The sample size was calculated using G*Power Software, considering an effect size of 0.28 and a power of 95%. All patients were treated with pre-adjusted edgewise appliances using a 0.022" slot MBT prescription with maximum anchorage involving the first and second molars along with a transpalatal arch. Archwire sequences included 0.014", 0.018", 0.017×0.025", and 0.019×0.025" NiTi archwires, followed by a 0.019×0.025" SS archwire as a stabilizing archwire. In all subjects, retraction of the mandibular arch was initiated before the maxillary arch to achieve a minimum overjet of 4mm, facilitating required retraction as accelerated tooth movement is expected in the maxillary arch.

Subjects were randomly assigned by lottery method into three groups:

- **Group A:** Patients subjected only to conventional sliding mechanics for en-masse retraction, serving as the control group.
- **Group B:** Patients subjected to conventional sliding mechanics assisted with sequential Piezocision. Piezocision was performed twice in this group: on day zero and at the end of the second month. Retraction force was activated every 15 days during the study period.
- **Group C:** Patients subjected to conventional sliding mechanics assisted with Piezocision followed by LLLT. Piezocision was performed on the day of the start of retraction (day zero). After one month of the initial Piezocision procedure, LLLT irradiation was performed from the distal side of the canine in one quadrant to the distal side of the canine in the opposite quadrant every 15 days for two months.

In all cases, atraumatic therapeutic extractions of first premolars were performed while preserving the interdental papilla and bone before strap-up. After leveling and aligning, retraction was conducted using a 0.019×0.025" SS archwire with soldered hooks distal to the lateral incisor. Type-1 active tie backs were provided from the first molar to the soldered hook with elastic modules and Stainless Steel ligature wire (conventional sliding mechanics), delivering a force of 200 grams measured using a dynamometer (Morelli orthodontic force gauge tension meter, Brazil) on both sides during each appointment. In Groups B and C, the retraction force was applied every 15 days for a three-month duration.

Alginate impressions and photographs were taken every month for three months. At each visit, patients were instructed to maintain good oral hygiene, and periodontal status was assessed. Informed consent was obtained after explaining the entire procedure, along with its pros and cons. Study models were used to measure the amount of extraction space using vernier calipers from the most prominent proximal surfaces of the canine and second premolars in both quadrants of the maxilla.

PROCEDURE FOR PIEZOCISION

(Piezotome™, Satelec Acteon Group, Mérignac, France)

After all records were obtained, the patient was prepared for surgery. Submucosal local anesthesia was administered with 2% lidocaine solution, covering the area distal to the canine from one quadrant to the opposite quadrant. The intraoral region was cleaned with povidone-iodine solution (5% w/v Betadine), and a William's periodontal probe was used to measure the incision height (Figure 1). Vertical interproximal incisions of 6 mm were made on the buccal aspect of the gingiva using a scalpel with a No. 15 BP blade, 3 mm apical to the interdental papilla (Figure 2). A piezoelectric ultrasonic bone surgery unit was set according to the manufacturer's instructions to cut the alveolar bone using insert No. BS1 Split Crest (Figure 3). Piezocision cuts were made through each incision to a depth of 3 mm, measured using a periodontal probe, while ensuring the soft tissues were isolated to prevent burns from piezo knife contact. The surgical area was then irrigated with a Betadine solution (5% w/v), and an immediate force of 200 grams measured with a dynamometer (Figure 4) was applied to take advantage of RAP. Analgesics and antibiotics were prescribed to reduce post-surgical discomfort.

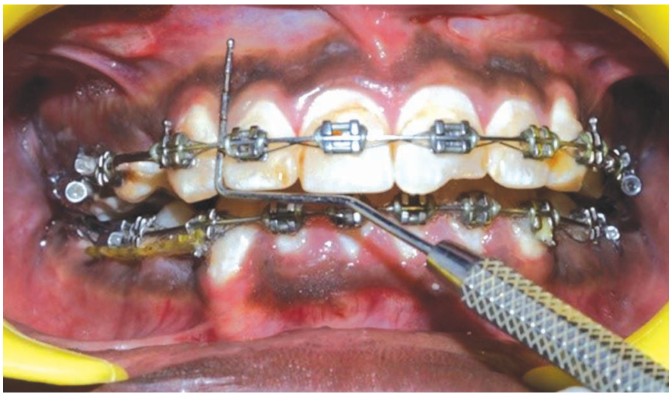

Fig 1. Measuring the length of an incision using William's periodontal probe

Fig 2. Making 6 mm incision over the markings with Bard-Parker blade no. 15

Fig 3. Making corticotomy cuts over the buccal cortical plate using piezoelectric bone surgical unit with insert no.BS 1

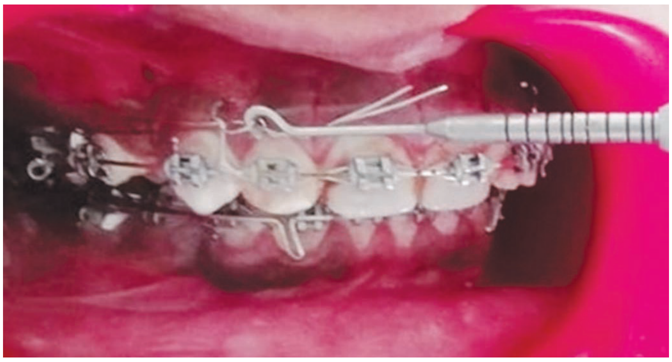

Fig 4. Immediate application of retraction force of 200 gm using Dynamometer.

PROCEDURE FOR LASER APPLICATION

(Figure 5) - Zolar Photon Plus Diode Laser (Ga Al As), Ontario, Canada

Low-Level Laser Therapy was applied after one month of Piezocision. Biostimulation was conducted using a 980 nm wavelength Gallium Aluminium Arsenide (GaAlAs) laser with an output power of 100 mW at one point of irradiation and a power density of 3.97 W/cm² for 10 seconds. A total of 10 irradiations were administered on the buccal and palatal sides (5 each) as follows:

1. Two irradiation doses on the cervical third of each tooth—one on the mesial and the other on the distal.
2. Two on the apical third of each tooth—one on the mesial and the other on the distal.
3. One on the middle third of each tooth—the middle of the root.

This procedure was followed for all subsequent appointments. The laser irradiations were conducted every 15 days for two months following the initial Piezocision procedure. The rate of space closure was measured using digital vernier calipers on the study models over the three-month study period.

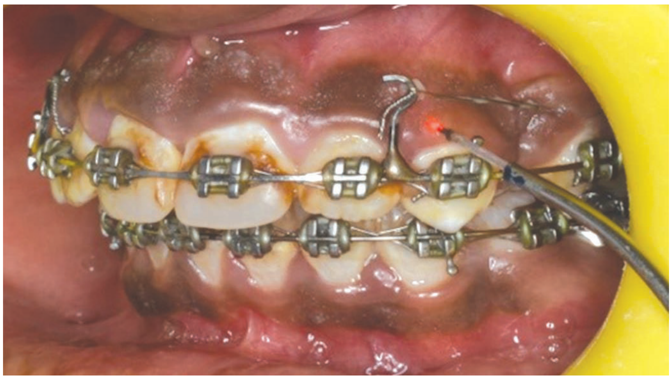

Fig 5. Point of application of Laser on the buccal aspect

Method Used to Evaluate Anchorage Loss:

Anchorage loss was measured using the third palatal rugae and mid-palatal raphe as standard reference landmarks. Perpendiculars were drawn to the mid-palatal raphe from the third palatal rugae (P1), the midpoint of the cingulum of the canine (P2), and the midpoint of the palatal groove of the upper first permanent molar (P3). Vertical linear distances were measured from P2 to P3 (designated as VD1) and from P1 to P3 (designated as VD2). The same measurements were recorded from pre-Piezocision (A1) and post-study period (A2) models. The difference in VD1 and VD2 of both study models was calculated as anchorage loss. Each measurement was taken three times, and the mean value was used for analysis.

STATISTICAL ANALYSIS

Descriptive and comparative statistical analyses were performed. Means, standard deviations, and ranges were calculated. Intragroup comparisons of the rate of space closure on both right and left sides of each group were analyzed using Tukey's HSD test. Intergroup comparisons of the rate of space closure on both right and left sides between groups were analyzed using an independent sample t-test. Anchorage loss was analyzed using a paired t-test.

RESULTS

Results were presented under the following headings:

Table 1: Intergroup comparison of rate of space closure with mean and SD between Group A, Group B, and Group C (in mm).

	TIME PERIOD	GROUP A	GROUP B	GROUP C
		Mean difference ± SD	Mean difference ± SD	Mean difference ± SD
RIGHT	Baseline to 1st month	0.72 ± 0.18	1.05 ± 0.02	1.29 ± 0.00
	Baseline to 2nd month	1.42 ± 0.25	1.78 ± 0.15	2.39 ± 0.06
	Baseline to 3rd month	2.24 ± 0.25	2.91 ± 0.17	3.27 ± 0.16
	1st month to 2nd month	0.70 ± 0.07	0.73 ± 0.17	1.10 ± 0.06
	1st month to 3rd month	1.52 ± 0.07	1.86 ± 0.19	1.98 ± 0.16
	2nd month to 3rd month	0.82 ± 0.00	1.13 ± 0.02	0.88 ± 0.10
LEFT	Baseline to 1st month	0.86 ± 0.00	1.07 ± 0.01	1.23 ± 0.03
	Baseline to 2nd month	1.60 ± 0.09	1.82 ± 0.13	2.33 ± 0.16
	Baseline to 3rd month	2.29 ± 0.05	2.91 ± 0.13	3.29 ± 0.05
	1st month to 2nd month	0.74 ± 0.09	0.75 ± 0.14	1.10 ± 0.13
	1st month to 3rd month	1.43 ± 0.05	1.84 ± 0.14	2.06 ± 0.02
	2nd month to 3rd month	0.69 ± 0.04	1.09 ± 0.00	0.96 ± 0.11

Table 2: Intergroup comparison of rate of space closure between Group A and Group B (in mm) using Independent sample t test.

	TIME INTERVAL	GROUP A	GROUP B	P-value
		Mean difference ± SD	Mean difference ± SD	
RIGHT	Baseline to 1st month	0.72 ± 0.18	1.05 ± 0.02	0.007*
	Baseline to 2nd month	1.42 ± 0.25	1.78 ± 0.15	0.043*
	Baseline to 3rd month	2.24 ± 0.25	2.91 ± 0.17	0.001*
	1st month to 2nd month	0.70 ± 0.07	0.73 ± 0.17	0.795
	1st month to 3rd month	1.52 ± 0.07	1.86 ± 0.19	0.025*
	2nd month to 3rd month	0.82 ± 0.00	1.13 ± 0.02	<0.001
LEFT	Baseline to 1st month	0.86 ± 0.00	1.07 ± 0.01	<0.001
	Baseline to 2nd month	1.60 ± 0.09	1.82 ± 0.13	0.132
	Baseline to 3rd month	2.29 ± 0.05	2.91 ± 0.13	0.011*
	1st month to 2nd month	0.74 ± 0.09	0.75 ± 0.14	0.926
	1st month to 3rd month	1.43 ± 0.05	1.84 ± 0.14	0.069
	2nd month to 3rd month	0.69 ± 0.04	1.09 ± 0.00	0.001*

*Statistically significant (P<0.05)

Table 3: Intergroup comparison of rate of space closures between Group A and Group C (in mm) using Independent sample t test.

	TIME INTERVAL	GROUP A	GROUP C	P-value
		Mean difference ± SD	Mean difference ± SD	
RIGHT	Baseline to 1st month	0.72 ± 0.18	1.29 ± 0.00	0.002*
	Baseline to 2nd month	1.42 ± 0.25	2.39 ± 0.06	0.000*
	Baseline to 3rd month	2.24 ± 0.25	3.27 ± 0.16	0.002*
	1st month to 2nd month	0.70 ± 0.07	1.10 ± 0.06	0.010*
	1st month to 3rd month	1.52 ± 0.07	1.98 ± 0.16	0.043*
	2nd month to 3rd month	0.82 ± 0.00	0.88 ± 0.10	0.606
LEFT	Baseline to 1st month	0.86 ± 0.00	1.23 ± 0.03	0.005*
	Baseline to 2nd month	1.60 ± 0.09	2.33 ± 0.16	0.002*
	Baseline to 3rd month	2.29 ± 0.05	3.29 ± 0.05	0.014*
	1st month to 2nd month	0.74 ± 0.09	1.10 ± 0.13	0.023*
	1st month to 3rd month	1.43 ± 0.05	2.06 ± 0.02	0.069
	2nd month to 3rd month	0.69 ± 0.04	0.96 ± 0.11	0.217

*Statistically significant (P<0.05)

Table 4: Intergroup comparison of rate of space closures between Group B and Group C (in mm) using Independent sample t test.

	TIME INTERVAL	GROUP B	GROUP C	P-value
		Mean difference ± SD	Mean difference ± SD	
RIGHT	Baseline to 1st month	1.05 ± 0.02	1.29 ± 0.00	0.062
	Baseline to 2nd month	1.78 ± 0.15	2.39 ± 0.06	0.006*
	Baseline to 3rd month	2.91 ± 0.17	3.27 ± 0.16	0.193
	1st month to 2nd month	0.73 ± 0.17	1.10 ± 0.06	0.018*
	1st month to 3rd month	1.86 ± 0.19	1.98 ± 0.16	0.572
	2nd month to 3rd month	1.13 ± 0.02	0.88 ± 0.10	0.020*
LEFT	Baseline to 1st month	1.07 ± 0.01	1.23 ± 0.03	0.187
	Baseline to 2nd month	1.82 ± 0.13	2.33 ± 0.16	0.017*
	Baseline to 3rd month	2.91 ± 0.13	3.29 ± 0.05	0.263
	1st month to 2nd month	0.75 ± 0.14	1.10 ± 0.13	0.026*
	1st month to 3rd month	1.84 ± 0.14	2.06 ± 0.02	0.456
	2nd month to 3rd month	1.09 ± 0.00	0.96 ± 0.11	0.485

*Statistically significant (P<0.05)

Table 5: Amount of anchorage loss before and after study period on maxillary right and left sides in Group A, Group B and Group C (in mm) using paired t- test

		GROUP A			p-value	GROUP B			p-value	GROUP C			p-value
		MEAN	SD	Mean difference		MEAN	SD	Mean difference		MEAN	SD	Mean difference	
RIGHT	A1	15.60	3.34	0.22±0.09	0.06	19.55	1.79	0.20±0.46	0.08	18.52	2.99	0.19±0.02	0.08
	A2	15.38	3.43			19.35	2.25			18.33	3.01		
LEFT	A1	15.14	2.95	0.21±0.20	0.07	19.65	2.61	0.22±0.05	0.06	18.34	2.78	0.21±0.04	0.07
	A2	14.93	3.15			19.43	2.66			18.13	2.74		

*Statistically significant (P<0.05)

A1- before study period
A2- after study period

Table 1 shows the intergroup comparison of the rate of extraction space closure with means and standard deviations during each month between Groups A, B, and C.

In Group A, the amount of space closure after 3 months on right and left side was 2.24 ± 0.25 mm and 2.29 ± 0.05 mm respectively. In Group B, the amount of space closure after 3 months on right and left side was 2.91 ± 0.17 mm and 2.91 ± 0.13 mm respectively. Whereas in Group C, the amount of space closure after 3 months on right and left side was 3.27 ± 0.16 mm and 3.29 ± 0.05 mm respectively.

Table 2 represents the intergroup comparison of the rate of space closure between Groups A and B (in mm) using an independent sample t-test. There was a statistically significant difference found between baseline to 1st month, 2nd month, and 3rd month, between 1st month to 3rd month and 2nd month to 3rd month on the right side of maxillary arch ($p<0.05$).

There was a statistically significant difference found between baseline to 1st month & 3rd month, and 2nd month to 3rd month on left side of maxillary arch ($p<0.05$).

Table 3 presents the intergroup comparison of the rate of space closures between Groups A and C (in mm) using an independent sample t-test, which also showed statistically significant differences.

There was a statistically significant difference found between baseline to 1st month, 2nd month, and 3rd month, between 1st month to 2nd month and 1st month to 3rd month on right side of maxillary arch ($p<0.05$).

There was a statistically significant difference found between baseline to 1st month, 2nd month, and 3rd month and between 1st month to 2nd month on left side of maxillary arch ($p<0.05$).

Table 4 shows the intergroup comparison of the rate of space closure between Groups B and C (in mm) using an independent sample t-test.

There was a statistically significant difference found between baseline to 2nd month, between 1st month to 2nd month and 2nd month to 3rd month on the right side of maxillary arch ($p<0.05$).

There was a statistically significant difference found between baseline to 2nd month, and between 1st month to 2nd month on the left side of maxillary arch ($p<0.05$).

Table 5 indicates that there was no statistically significant anchorage loss observed before and after the study period in all three groups.

DISCUSSION

Orthodontic treatment is a time-consuming procedure, often making patients reluctant to undergo treatment. Therefore, various methods to accelerate tooth movement have been studied, including drug injections, electric stimulation, pulsed electromagnetic fields, corticotomy, Piezocision, and LLLT. Piezocision has been proven effective in accelerating tooth movement.[8] To date, no studies have evaluated the rate of tooth movement during en-masse retraction with Piezocision followed by LLLT. Thus, our aim was to evaluate this aspect.

In our study, the rate of space closure was assessed at monthly intervals over three months. No statistically significant difference was found in the rates of space closure during the monthly intervals in Group B; however, the mean rate of space closure during the first and third months was greater than that of the second month. The difference in the rate of space closure could be attributed to the duration and magnitude of RAP produced by the sequential Piezocision procedure performed at the study's beginning and the end of the second month.

The findings of our study were consistent with those of Mehr et al.[9], who utilized Piezocision for alleviating mandibular crowding. Conversely, Tuncer Ni et al.[10] reported no significant difference in space closure in a Piezocision-assisted mini-implant-supported group compared to a control group.

In Group C, the highest space closure was observed during the first month following Piezocision. This increased space closure was attributed to the persisting RAP from Piezocision rather than LLLT in the second month. However, LLLT alone did not show significant acceleration in the rate of space closure during the third month.

Intergroup comparisons of Groups A and B at the first month indicated a greater effect of RAP achieved with the increased rate of space closure in Group B. In the second month, both groups exhibited a similar rate of space closure, implying that the RAP induced by Piezocision lasted approximately four weeks. An increased rate of space closure in Group B was again observed in the third month, indicating that the Piezocision performed at the end of the second month accelerated tooth movement in the third month.

When comparing Groups A and C, the rate of space closure was greater in Group C during the first and second months due to Piezocision. However, it was less in the second month than in the first, indicating that the residual RAP from Piezocision was maintained with LLLT. The increased space closure seen in Group C during the third month was insignificant, which is consistent with the results of a split-mouth study conducted by Arumughan S et al.[11], which used a diode laser every three weeks for 84 days.

A statistically significant difference was found in the rate of space closure between Groups A and B, as well as between Groups A and C, on both the right and left sides. This indicates that the difference in the rate of space closure was due to the RAP achieved with the Piezocision procedure in the maxillary anterior segment for both Groups B and C.

The mean difference in anchorage loss on the right and left sides between the groups after the study period was not statistically significant, indicating that in both Groups B and C, the interventions with Piezocision and LLLT only showed localized RAP, which did not extend into the posterior segment of the maxillary arch.

Kim et al. conducted a study demonstrating reduced tooth movement with the use of corticision and LLLT in male beagles, postulating that immediate LLLT application after corticision primarily concentrated on accelerating alveolar defect healing at the corticision site, rather than enhancing the osteoporotic activity induced by RAP.[6] This contrasts with our study, where LLLT was applied after a latency period of one month, showing accelerated tooth movement.

Any surgical insult to the bone typically stimulates an inflammatory process, which in turn triggers accelerated remodeling at the tooth-alveolar bone interface and induces a state of osteopenia in the bone. During this state, the application of orthodontic force could potentially accelerate tooth movement. The extent of invasiveness also plays a role in influencing the magnitude of the inflammatory and bone remodeling process. Therefore, the duration of RAP may vary with different surgical techniques based on the degree of invasiveness. Studies have reported that the Piezocision technique effectively alleviated crowding, where the type of tooth movement was primarily tipping and the distance each tooth moved was minimal. Consequently, the duration required for the alveolar bone to maintain a state of osteopenia was also shorter.[4,12]

Thus, the magnitude of RAP generated by the Piezocision technique was sufficient to enhance the rate of tooth movement for en-masse retraction; however, the duration of RAP was not adequate to sustain accelerated tooth movement throughout the entire space closure.[13]

As for the effects of LLLT on expedited tooth movement, varied results have been reported by Cruz et al.[14], Doshi-Mehta and Bhad-Patil[15], Long et al.[16], Yamaguchi et al.[17], Yousef et al.[18], Limpanichkul et al.[19], and Heravi et al.[20] in individual canine retraction studies. While LLLT demonstrated acceleration of tooth movement in some studies, they did not adequately explain the relationship between dose dependency and the biostimulation effects of the laser.

The findings of the present study strongly suggest that the RAP produced by the Piezocision technique lasted only for one month in the case of en-masse retraction with conventional sliding mechanics. Although minimally invasive, the feasibility of performing the Piezocision procedure every month to maintain the same level of RAP for complete space closure is questionable. Instead, LLLT could be employed to maintain the residual RAP generated by the Piezocision procedure. However, no studies to date have reported the ideal parameters for biostimulation with LLLT. The parameters utilized in this study contributed to the maintenance of RAP produced by Piezocision; however, LLLT alone did not yield any clinically significant biostimulation for space closure. We can infer that Piezocision followed by LLLT is more beneficial than sequential Piezocision alone in accelerating OTM during en-masse retraction.

CONCLUSIONS

1. The rate of space closure was greater with Piezocision followed by LLLT than with sequential Piezocision and conventional sliding mechanics alone.
2. No anchorage loss was observed in any of the three groups during the three-month study period.
3. LLLT maintained the RAP achieved with Piezocision but did not induce acceleration of tooth movement on its own.

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