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Comparative Evaluation of Low-Level Laser Therapy and Piezocision in Accelerating Orthodontic Tooth Movement During Canine Retraction

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Abstract

Introduction: Orthodontic tooth movement is a process that involves shifting teeth into proper alignment for improved aesthetics and functionality. This study was to assess the acceleratory effects of piezocision and LLLT on canine retraction, utilizing conventional orthodontic tooth movement as a baseline for comparison.

Methodology: This prospective, split-mouth, comparative clinical study was carried out at Department of Orthodontics, Foundation University College of Dentistry (FUCD), Foundation University Islamabad (FUI). Eighty patients were divided equally into LLLT and piezocision groups (n=40 each). Using a split-mouth design, one maxillary quadrant in each patient received the intervention while the opposite side served as an untreated control. This allowed for both intra-individual (experimental vs. control) and inter-group (LLLT vs. piezocision) comparisons. The rate of canine retraction was assessed at day T1=21, T2=42, T3=63 and T4=84 and pain levels using the Visual Analog Scale (VAS) at baseline, Day 1, Day 7 in both groups.

Results: Statistically insignificant difference in canine retraction rate was observed at Day 21($p=0.378$). Statistically significantly greater retraction was observed in the LLLT group at Day 42 ($p<0.001$) and Day 63 ($p=0.001$). By Day 84, interestingly the Piezocision group demonstrated significantly greater canine retraction ($p<0.001$). Despite this late increase, cumulative canine movement throughout the study period was greater in the LLLT group (6.32±0.31 mm) than in the Piezocision one (5.78±0.28 mm). Pain scores were comparable at baseline ($p=0.764$), whereas the LLLT group reported significantly lower pain levels on Day 1 (1.13±0.69 vs. 1.60±0.68; $p<0.001$) and Day 7 (0.43±0.50 vs. 1.10±0.55; $p<0.001$).

Conclusions: Both LLLT and Piezocision effectively accelerated orthodontic tooth movement. LLLT, however produced greater cumulative canine retraction and significantly reduced pain. LLLT may therefore represent a less invasive and more patient friendly adjunct for accelerating orthodontic treatment.

Keywords: Canine Retraction, Low-Level Laser Therapy, Orthodontic Tooth Movement, Pain, Piezocision

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Introduction

Orthodontic treatment aims to correct malocclusions and achieve optimal dental alignment, often involving various techniques to enhance tooth movement and manage associated discomfort.[1] Longer treatment duration is associated with greater unwanted side effects including increased pain, discomfort, white spot lesions , caries and greater likelihood of root resorption. In addition, long treatments adversely affect patients' satisfaction and their compliance during treatment. Therefore, accelerated tooth movement not only reduces treatment time,

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but also decreases the risks associated with prolonged duration of treatment.[2,3]

Previously invasive procedures like corticotomy and periodontally accelerated osteogenic orthodontics were used to expedite treatment velocity but in current years there has been tremendous research on less invasive procedures such as piezocision, micro-osteoperforations, low-level laser therapy and piezopuncture all of which have a similar potential to increase tooth movement hence decreasing the orthodontic treatment time. Among the various acceleration techniques currently available, LLLT and piezocision have emerged as promising adjunctive approaches because of their potential to expedite OTM while improving patient comfort.[4,5]

LLLT is a non-disruptive photobiomodulatory approach that utilizes low-energy laser light to enhance cellular function and facilitate tissue repair. In orthodontic practice, this biological stimulation is believed to accelerate bone remodeling and thereby OTM rate, potentially shortening overall treatment duration. Previous investigations have reported that LLLT may enhance the speed of OTM and lessen pain perceived during treatment activation.[6,7]

Piezocision, on the other hand, involves the use of a piezoelectric device to create micro-incisions in the alveolar bone, which is believed to stimulate bone remodeling and facilitate faster tooth movement. This technique, while more invasive than LLLT, is gaining popularity for its potential to shorten orthodontic treatment durations and improve patient comfort. The mechanism behind piezocision involves enhancing bone and surrounding tissues biological response, thereby accelerating the OTM rate.[8,9] The objective of this study was to assess the acceleratory effects of piezocision and LLLT on canine retraction and pain, using the corresponding control sides for comparison.

Methodology

A prospective, parallel group, split design, comparative clinical study was carried out at the Department of Orthodontics, FUCD, FUI after taking written informed consent from each participant. Patients aged 12–40 years, maintaining meticulous oral hygiene, having Class I Bimaxillary Protrusion / Class II div 1, entailing bilateral maxillary 1st premolar extraction and canine distilization as part of orthodontic management were included in the study. All participants possessed a full complement of permanent teeth (excluding 3rd molars) and an unremarkable medical history. Patients had no previous history of orthodontic treatment.

Patients with conditions that could alter bone metabolism, wound healing, or OTM, such as diabetes mellitus, osteoporosis, or endocrine disorders, were excluded. Individuals receiving medications known to influence bone remodeling, including corticosteroids, bisphosphonates, long-term non-steroidal anti-inflammatory drugs, or hormonal therapy, were also excluded.

Additional exclusion criteria included craniofacial anomalies, cleft lip and palate, congenital dentofacial deformities, smoking or tobacco use, pregnancy or lactation, impacted, missing, or malformed maxillary canines, and the requirement for additional surgical procedures other than the intervention under investigation. Patients who were unable or unwilling to comply with the study protocol and follow-up schedule were likewise excluded. Participant flow throughout the study was documented according to the (CONSORT) guidelines and is presented in Figure I.

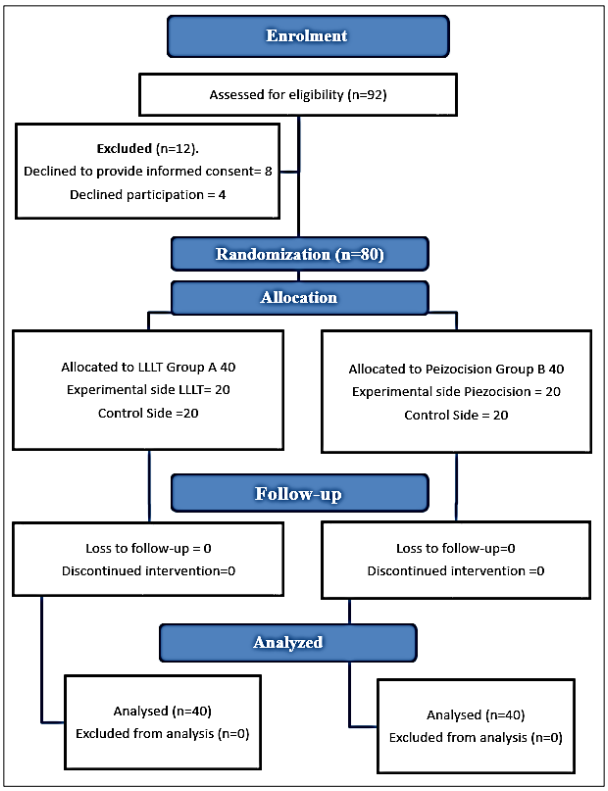

Fig. I: CONSORT flow diagram demonstrating participant recruitment, Two-arm Parallel-group randomized controlled trial with split-mouth allocation within each treatment group, follow-up and analysis. No participants were lost to follow-up.

Utilizing Open Epi (Version 3.01), a sample size of 36 participants per group was calculated based on published canine retraction data (α=0.05, power = 80%, effect size =0.5).To compensate for likely attrition, 40 participants were recruited in each group.[10,11] An independent investigator used block randomization (block size = 4) and sequentially numbered, opaque, sealed envelopes to ensure allocation concealment. A second computer-generated sequence randomly assigned each subjects right or left maxillary quadrant into the experimental side and the control. Study casts were made for both groups at baseline (T0) and at four subsequent three-week intervals: Day 21 (T1), Day 42 (T2), Day 63 (T3), and Day 84 (T4) after commencement of canine retraction. Pain perception was assessed using a Visual Analog Scale (VAS) at baseline and on Days 01 and 07 following the initial treatment.

Canines were retracted into the extraction space using Nickel Titanium close coil spring (delivering a force of 150g over the entire phase of canine retraction), Maxillary incisors were figure-eight ligated using 0.010-inch stainless steel wire. Pain perception was gauged utilizing a 10-cm VAS (0 - no pain and 10 - "worst imaginable pain") at baseline (before intervention), Day 1 and Day 7 for better outcome after the first application of LLLT or Piezocision. Because of the nature of the interventions, complete blinding was not possible. Nevertheless, the investigator responsible for outcome measurements and data analysis was blinded to treatment allocation and side assignment throughout the study period.

In Group A LLLT Group:

On the intervention side, irradiation was performed using a 635-nm diode laser (Lasotronix, Poland) with an output power of 100 mW operating in pulsed mode. Each irradiation point received laser exposure for 10 seconds, corresponding to an energy delivery of 1 J per point. Ten points (five buccal and five palatal) were irradiated around each canine, resulting in a total energy dose of 10 J per tooth per session as shown in figure II.

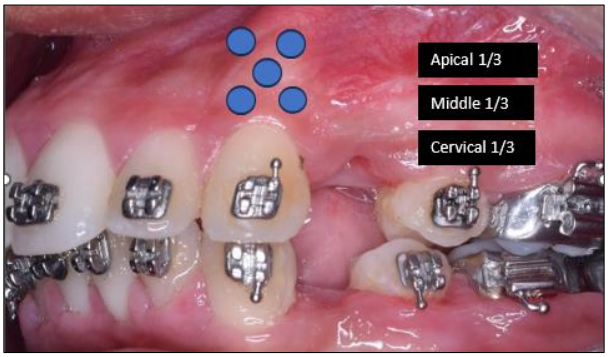

Fig. II: Laser Application points on root of canine in the buccal vestibule

- 2X irradiations on apical 1/3rd one mesial one distal
- 1X irradiations on middle 1/3rd

- 2X irradiations on coronal 1/3rd one mesial one distal

In order to maintain blindness and eliminate bias in subjects' response, a sham laser procedure was performed on the control side without emission of laser energy. The laser regimen was applied at 3-week intervals. Low-level laser irradiation was administered immediately after the initiation of canine retraction using a nickel–titanium (NiTi) closed-coil spring and then at day 21, 42, 63 and 84 over the three months study period.

In Group B Piezocision Group:

In Group B (Piezocision group), Piezocision was carried out only on the experimental side, while the contralateral side designated as the control. Piezocision was performed under local infiltration anesthesia using 2% lignocaine with 1:100,000 epinephrine by a technique shown in figure III (a, b & c). The incisions were sutured with non-resorbable 4-0 black silk with the interrupted suture technique and removed after 1 week.

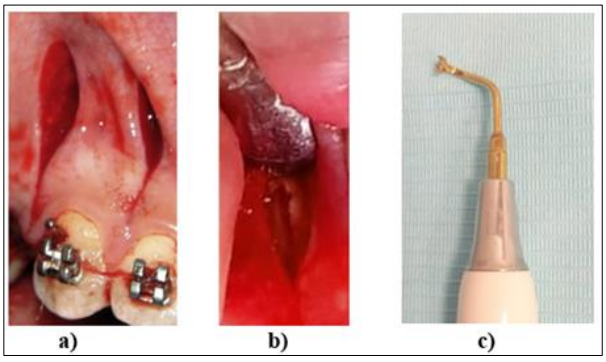

Fig. III: a) Piezocision intraoperative pictures showing flapless incision mesial and distal to canine b) At least 3mm deep incisions made in cortical bone, c) Piezo tip used for bone cutting

Mean retraction was measured at four-time intervals day 21,42, 63 and 84 on dental casts through Ziegler and Ingervall method as shown in figure IV. To assess intra-examiner reliability, 20 randomly selected study models were measured twice at a two-week interval. Reliability was evaluated using the intraclass correlation coefficient (ICC). The ICC value was 0.86 ($P < 0.001$), indicating good repeatability and measurement reliability.

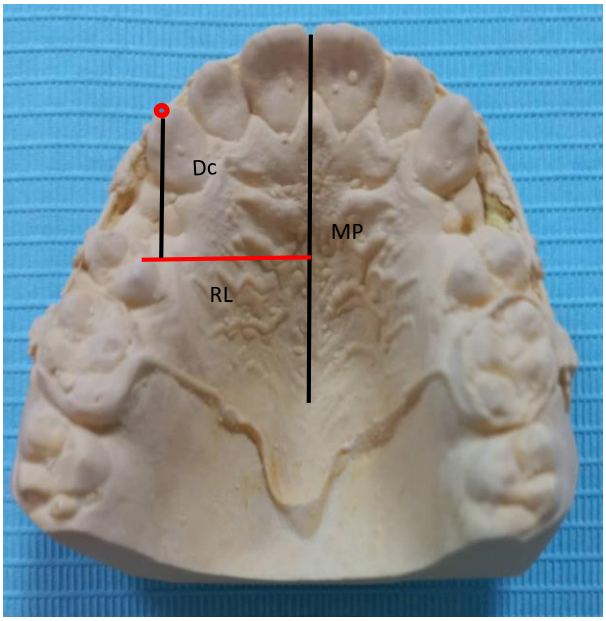

Fig. IV: Dental cast showing the reference lines used to measure the anteroposterior canine movement

- MPR - Midpalatine raphe signifies the ridge formed by the fusion of the two plates of the skull that form the hard palate
- RL - Rugae line formed by a projection from the most medial point on the third right rugae.
- Dc - Distance between the cusp tip of the canine and the rugae line

Statistical Analysis:

Data were analyzed using IBM SPSS Statistics version 22, with normality confirmed via the Shapiro–Wilk test ($p > 0.05$). Continuous variables (expressed as mean + SD) and categorical data were evaluated using independent t-tests, Chi-square tests, and ANOVA with Bonferroni post hoc adjustments. For the split-mouth comparisons across time points (T1–T4), paired-t-tests were applied. Inter-group canine retraction and VAS pain scores (at baseline, Day 1, and Day 7) were compared using independent samples t-tests with significance set at $p < 0.05$.

Result

Calculated descriptive statistics have been shown in Table-I.

Characteristics	Group A Low-Level Laser Therapy (n=40)	Group B Piezocision (n=40)	P value
Age (years)			
Mean Age	15.6±2.9	17.2±4.2	0.051[1]
<16 years	22 (55.0%)	24 (60%)	0.0821[2]
≥16 years	18 (45.0%)	16 (40%)	
Gender			
Male	13 (32.5%)	21 (52.5%)	0.113[2]
Female	27 (67.5%)	19 (47.5%)	

Table-I: Demographic Characteristics of Patients

At Day 21 (T1), no statistically significant difference was observed between the LLLT and Piezocision experimental sides (1.42±0.06 mm vs. 1.37±0.02 mm; p=0.378). At Day 42 (T2), the LLLT group demonstrated significantly greater canine retraction than the Piezocision group (1.68±0.04 mm vs. 1.12±0.05 mm; p<0.001). Similarly, at Day 63 (T3), canine retraction remained significantly higher in the LLLT group (1.58±0.05 mm) compared with the Piezocision group (1.33±0.04 mm; p=0.001). However, at Day 84 (T4), the Piezocision group exhibited significantly greater canine retraction than the LLLT group (1.96±0.06 mm vs. 1.64±0.04 mm; p<0.001).

The cumulative canine movement from T1 to T4 was significantly greater in the LLLT group (6.32±0.31 mm) than in the Piezocision group (5.78±0.28 mm; p<0.001), indicating a greater overall acceleration of orthodontic tooth movement with LLLT (Table-II).

Time Stamp	Mean Distance (mm)				P-value
	Low Level Laser Therapy side		Piezocision		
	Experimental	Control	Experimental	Control	
Day 21 (T1)	1.42±0.06	0.76±0.04	1.37±0.02	0.69±0.05	0.378
Day 42 (T2)	1.68±0.04	0.85±0.05	1.12±0.05	0.81±0.03	<0.001*
Day 63 (T3)	1.58±0.05	1.01±0.06	1.33±0.04	0.93±0.06	0.001*
Day 84 (T4)	1.64±0.04	1.06±0.05	1.96±0.06	1.00±0.04	<0.001*

Table-II: Comparison of canine retraction between experimental and control sides in the LLLT and Piezocision groups at different time intervals (n=80)

At baseline (T0), mean VAS pain scores were comparable between the LLLT group (2.60±0.59) and the Piezocision group (2.55±0.62), with no statistically significant difference (p=0.764). On Day 1, the LLLT group reported significantly lower pain scores than the Piezocision group (1.13±0.69 vs. 1.60±0.68; p<0.001). This difference persisted on Day 7, with the LLLT group continuing to demonstrate significantly lower pain scores (0.43±0.50 vs. 1.10±0.55; p<0.001), indicating superior pain control associated with low-level laser therapy (Table-III). Within both treatment groups, pain scores were higher on the control side than on the corresponding experimental side following canine retraction. Pain intensity peaked on Day 1 and decreased by Day 7; however, the experimental sides continued to demonstrate lower VAS scores, indicating a significant analgesic effect of both interventions ($p < 0.05$). Pain intensity following orthodontic force application is known to peak within the first 24–48 hours and gradually decline over the subsequent days. Therefore, pain assessment was performed at predefined intervals: baseline, Day 1 and Day 7 allowing evaluation of both early peak pain and later pain reduction. No additional pain assessments were performed outside these predefined time points. All pain scores were

recorded by the participants using a Visual Analogue Scale (VAS) at baseline (before canine retraction) and subsequently on Day 1 and Day 7.

Time Stamp	LLLT Experimental	LLLT Control	Piezocision Experimental	Piezocision Control	P-value
`At Baseline	2.60±0.59	2.65 ± 0.61	2.55±0.62	2.62 ± 0.60	0.764
Day 1	1.13±0.69	1.85 ± 0.71	1.60±0.68	1.90 ± 0.72	<0.001*
Day 7	0.43±0.50	0.92 ± 0.56	1.10±0.55	0.96 ± 0.58	<0.001*

Table-III: Comparison of Visual Analog Scale (VAS) pain scores between the LLLT and Piezocision groups at different time intervals

Discussion

OTM is a pivotal aspect of orthodontic management aimed at correcting dental malocclusion and malaligned teeth thus improving the overall aesthetics and functionality of the teeth. The need to reduce orthodontic treatment time has led to the development of accelerated orthodontic techniques. Various surgically facilitated and noninvasive approaches have been widely studied and discussed, however, the onset and duration of effectiveness of Regional acceleratory phenomena (RAP) has limited evidence. LLLT has been explored as a potential adjunctive treatment in orthodontics, specifically in the context of canine retraction and pain management.[12] Despite encouraging findings in the literature, the evidence remains insufficient, particularly within the local population, highlighting the need for the present investigation.

Our observation is in agreement with a similar previous study where Abbas et al. experienced an increase in canine retraction with piezocision at 4 weeks (0.50±0.07 vs. 0.30±0.08; p-value<0.005), 8 weeks (0.70±0.12 vs. 0.45±0.09mm; p-value<0.001) and 12 weeks (0.99±0.10 vs. 0.60±0.04mm; p- value<0.001) similar to the results produced in this study. We also found that the mean canine retraction was significantly higher in piezocision the group at day 42 (1.12±0.05 vs. 0.69±0.03mm; p-value<0.001), day 63 (1.33±0.04 vs. 0.68±0.06mm; p-value<0.001), and day 84 (1.30±0.04 vs. 1.06±0.05mm; p-value<0.001) depicting accelerated orthodontic tooth movement in patients undergoing piezocision as compared to controls.[11] Our study has shown similar results to a study of Alfawal et al where the author reported similar significantly greater mean canine retraction with the use of piezocision as compared at 8 weeks follow-up (0.66±0.25 vs. 0.53±0.24; p-value<0.05) which is comparable to results obtained in our study at day 42 (1.12±0.05 vs. 0.69±0.03mm; p-value<0.001).[13]

Study results of Alqadasi et al were similar to our study showing increased tooth movement in both groups, when compared against the intra-individual control side.[14] Hawkins et al, compared the canine distalization rate with and without piezocision and the results were contradictory to our results.[15] In the control group, pain scores also increased following canine retraction and subsequently decreased over time. However, the mean pain scores in the control group remained higher than those observed in the experimental group at all assessment intervals. Intergroup comparison demonstrated a statistically significant reduction in pain in the experimental group ($p < 0.05$).

Several studies have explored the effects of LLLT in orthodontics,[10,12] specifically in canine retraction. This study aligns with previous research by Eslamian et al., which found that 810-nm low-level laser therapy (LLLT) significantly reduces orthodontic pain during canine retraction.[16] Qamruddin et al. simultaneously evaluated the efficacy of low-

level laser therapy (LLLT) in accelerating orthodontic tooth movement and reducing treatment-related pain. The authors reported similar role of LLLT in alleviating procedural pain (1.8±0.4 vs. 3.6±0.9; p- value<0.001) and in accelerating OTM (4.67±0.25 vs. 2.87±0.24mm; p-value<0.001) in accordance with the present study. These findings are comparable to those of the present study, in which significant differences in VAS pain scores were observed initially, whereas no significant differences were noted during the later observation periods.[17]

Both LLLT and piezocision demonstrated clinical efficacy in speeding up canine retraction relative to conventional methods. Additional research is required to evaluate the potential benefits of combining these modalities. While both modalities independently stimulate biological processes favorable to OTM, piezocision through localized bone injury activating the Regional Acceleratory Phenomenon (RAP), and LLLT through photobiomodulation of cellular activity, their combined use may provide a synergistic effect, resulting in greater and more sustained acceleration. Recent clinical trials have reported promising results when combining both techniques. Simhadri et al. observed significantly faster en-masse retraction in patients who received both piezocision and LLLT compared to those treated with either modality alone or conventional mechanics, with the combined group achieving 3.27 mm of retraction over three months versus 2.91 mm (piezocision only) and 2.24 mm (controls).[18] The findings of their study are comparable with those of the present study.

Another split-mouth randomized controlled trial demonstrated that the group receiving both LLLT and piezocision achieved significantly more canine retraction than either monotherapy group.[19] Furthermore, Qamruddin et al. found that LLLT contributed not only to canine movement acceleration but also to significant reduction in pain, particularly in the initial days post-activation.[17] These analgesic benefits may enhance patient compliance, especially when combined with the surgical benefits of piezocision. Studies by Alqadasi et al. and Eid et al. have further corroborated that LLLT and piezocision each contribute to enhanced OTM, but when administered in combination, the biostimulatory effects of LLLT may extend the peak biological response initiated by piezocision, providing both early and sustained enhancement in tooth movement.[14,20] However, clinical evidence on the long-term safety and optimal protocol for combining these interventions remains sparse. While pain and treatment time improvements are well-documented, future trials should focus on root resorption, alveolar bone integrity, and long-term treatment stability.

In our study, both groups showed similar levels of canine retraction in the early stages (Day 21). However, the LLLT group exhibited significantly greater retraction on Days 42 and 63, suggesting a sustained and gradually increasing effect due to repeated laser application. This aligns with findings by Eid et al.20 and Isola et al.[21] Interestingly, by Day 84, the Piezocision group surpassed the LLLT group in mean retraction distance, indicating a delayed secondary peak effect of RAP or continued bone remodeling.[22] Nevertheless, the cumulative canine movement over the entire observation period remained greater in the LLLT group, indicating a superior overall acceleration effect.

These time-dependent differences reflect that LLLT may offer earlier acceleration, while Piezocision may sustain acceleration later in the treatment phase. Notably, the LLLT experimental group demonstrated more total canine retraction (6.32 mm) than the Piezocision group (5.78 mm) over the full treatment period (Day 21 to 84), indicating that LLLT not only initiates early movement but also sustains a higher cumulative retraction,

consistent with findings by Zheng et al.[22] and Qamruddin et al.[17] The LLLT group exhibited significantly lower pain scores on both Day 1 and Day 7, consistent with evidence from multiple clinical trials reporting the pain-relieving effects of low-level laser therapy.[21,23] This is of high clinical relevance as patient discomfort is a key limiting factor in orthodontic treatment. Piezocision, despite its minimally invasive nature, still involves surgical manipulation, contributing to higher postoperative discomfort, as also noted by Qamruddin et al.[17]

Both interventions demonstrated efficacy in accelerating OTM, but they cater to different clinical scenarios:
LLLT may be preferable in younger patients or those with a low tolerance for surgical procedures, offering a non-invasive, comfortable, and repeatable option. Piezocision may be better suited for adult patients with denser bone or when a stronger, longer-lasting RAP is required. Combined, the modalities may produce synergistic effects. Simhadri et al.[18] and Bashir et al.[24] demonstrated that the dual application of LLLT and piezocision resulted in significantly higher rates of tooth movement than either intervention alone. Thus, in selected cases, combining both modalities may provide optimal results.

To the best of our knowledge, this is the first prospective clinical trial from Pakistan comparing LLLT and piezocision for accelerated canine retraction using a split-mouth design. The strengths of the present study include its randomized controlled design, split-mouth allocation, and strict eligibility criteria. The present single center study is limited by relatively small sample size and short follow-up period Also, complications such as root resorption or long-term periodontal changes were not assessed. Future studies should include larger, samples, long-term follow-ups, and bone density analysis to evaluate the stability and safety of both techniques.

Conclusion

Both LLLT and piezocision significantly accelerated orthodontic tooth movement during canine retraction. However, LLLT demonstrated superior efficacy and was associated with lower pain levels, indicating better patient comfort. Therefore, LLLT may serve as a non-invasive and patient-friendly adjunctive modality for accelerating orthodontic treatment, while piezocision remains a useful alternative in selected cases.

Ethical Approval

The study was approved by the Ethical Review Committee of Foundation University School of Health Sciences (FUSH) (No. FF/FUMC/215-724/Phy/25)

Funding Declaration

This study received no grant from any funding agency, commercial, or not-for-profit sectors.

Conflict of Interest

It is declared that the authors don't have any conflict of interest.

Authors' Contribution

AM: Conceptualization of the study, study design, clinical procedures, data collection, statistical interpretation, and manuscript writing
RN: Supervision of the research project, validation of results, and final review and approval of the manuscript
SK: Assistance in methodology development, data analysis, literature review, and critical revision of the manuscript.

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