Original Article

Comparison of the effectiveness of piezocision-aided canine retraction augmented with micro-osteoperforation: a randomized controlled trial

Seerab Husain[a]; Shantha Sundari[b]

ABSTRACT

Objective: To evaluate the effectiveness of micro-osteoperforation (MOP) on the rate of piezocision-aided canine retraction (CR).

Materials and Methods: The split-mouth study included 25 participants at the stage of commencing CR. The participants received flapless piezocision bilaterally at T_0 (0 months) and MOP only on one side at T_3 (3 months). The quadrant that received MOP at T_3 served as the intervention, whereas the other quadrant served as the control. The primary outcome was the rate of CR, assessed using digital models. The angular change (AC) of the canine and the change in the buccal cortical bone thickness (BCBT) from before to after CR were also assessed using cone beam computed tomography.

Results: The rate of CR was 0.82 $\pm$ 0.39 mm/month in the control quadrant vs 0.75 $\pm$ 0.44 mm/month in the intervention quadrant ($P > .05$). The AC of the canine was 2.00° $\pm$ 0.88° in the control quadrant vs 1.98° $\pm$ 0.86° in the intervention quadrant ($P > .05$). The crestal bone gain was 0.50 mm in the control quadrant vs 0.28 mm of bone loss in the intervention quadrant. The bone thickness at a 3-mm height was increased by 0.11 mm in the control quadrant vs a 0.29-mm decrease in the intervention quadrant. The bone thickness at a 6-mm height was decreased by 0.12 mm in the control quadrant vs a 0.15-mm decrease in the intervention quadrant. However, none of the changes or group differences in bone height or thickness were statistically significant ($P > .05$).

Conclusions: The periodic activation of a piezocision-aided CR site using MOP had no significant positive effect on the rate of CR, angulation of the canine, or changes in BCBT. (*Angle Orthod*. 2024;94:17–24.)

KEY WORDS: Interradicular mini-implant; Canine retraction; Piezocision; Micro-osteoperforation

INTRODUCTION

Orthodontic retraction is a complex procedure that requires a complete understanding of biomechanics to bring about optimal space closure with minimal side effects.[1] It is also the longest stage in orthodontic mechanotherapy, taking as long as 20 months or even longer in certain cases.[2] A longer treatment duration brings the risk of patient fatigue, root resorption, white spot lesions, and pulpal and periodontal changes.[3]

Acceleration of Orthodontic Tooth Movement (OTM) has been achieved through various means such as pharmacological and physical/mechanical stimulation and surgical intervention.[4] Pharmacological agents such as prostaglandin, relaxin, vitamin D_3, platelet-rich fibrin, and platelet-rich plasma have been used in several studies to demonstrate the acceleration of OTM.[5] Physical methods of accelerating OTM involve the use of low-level laser therapy, photobiomodulation, vibrations,

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and magnets. However, these modalities have shown conflicting results, and the available evidence is of low quality.[5,6]

The concept of accelerated orthodontics is based on the regional acceleratory phenomenon (RAP) by which any noxious stimulus or regional injury to a particular site evokes the RAP. The intensity and site of action of this phenomenon, however, are highly variable among different individuals.[7]

In the late 1950s, Kole was the first to introduce the concept of corticotomy in orthodontics to hasten OTM.[8] Although corticotomy has been shown to have good results, it is an invasive surgical procedure that involves elevation of a mucoperiosteal flap.[9] Piezocision is a minimally invasive procedure that utilizes piezoelectric incisions in the cortex to accelerate OTM.[10] Several studies have reported the efficacy of piezocision in the acceleration of OTM and stated that a twofold increase in the rate of OTM was observed.[10,11]

The most recent development in search of a minimally invasive procedure to accelerate OTM has been micro-osteoperforation (MOP).[12] MOPs are monocortical micropunctures placed at various depths in the alveolar process to initiate the expression of inflammatory markers to hasten the process of OTM.[13,14] MOP has shown a 2.3-fold increase in the rate of OTM.[12,14] However, recent human trials have shown conflicting results regarding the effectiveness of MOP in the acceleration of OTM.[13,15]

The acceleratory effect of these surgical and minimally invasive procedures is believed to last for about 4 months, during which the rate of OTM is increased.[16] After this period, there is a need to reactivate the site for further acceleration of OTM. Hence, the aim of this study was to evaluate the effectiveness of MOP-augmented piezocision on the rate of canine retraction (CR).

Specific Objectives and Hypotheses

The primary outcome of this study was to assess the rate of CR using digital models. The secondary outcome was to assess the buccal cortical bone thickness (BCBT) and the angular changes (ACs) of the canine as observed with cone beam computed tomography (CBCT). The null hypothesis was that there would be no difference between the rates of CR assisted by piezocision with and without MOP.

MATERIALS AND METHODS

Trial Design and Settings

This was a prospective, split-mouth, single-center, single-blind, randomized controlled trial with a 1:1 allocation ratio according to the CONSORT statement reporting guidelines (Figure 1). The study was approved by the Institutional Review Board and Human Ethical Committee of the Saveetha Institute of Medical and Technical Sciences (SIMATS) (SRB/SDC/ORTHO-1805/20/TH-01). The trial was registered with the CTRI (identifier CTRI/2022/01/039275). Informed consent was obtained from the participants before the commencement of the study.

Eligibility Criteria and Participant Preparation

Inclusion criteria:

1. Permanent dentition and age group of 18–35 years.
2. Required fixed orthodontic treatment.
3. Maximum anchorage requirement in the maxilla.
4. Bimaxillary protrusion and Class I malocclusion for whom first premolars were extracted in both arches.
5. Class II malocclusion for whom maxillary first premolars were extracted for camouflage treatment.

Exclusion criteria:

1. Mixed dentition and under 18 years of age for whom adequate bone density would not have been established.
2. Missing teeth or abnormal tooth morphology.
3. History of orthodontic treatment.
4. Systemic problem or bone pathology.

All of the participants were treated with a preadjusted edgewise appliance system: 3M Unitek Gemini metal brackets (3M, Monrovia, Calif, USA), with a slot size of 0.022×0.028 inches. The participants were recruited after leveling and aligning to 0.019×0.025-inch stainless steel archwires. All participants had a stainless steel self-drilling interradicular implant of 1.5×8 mm in diameter placed between the upper second premolar and the first molar bilaterally. CBCT images of the maxillary arch for each subject in natural head position, without archwires, were taken 6 months apart at T_0 (0 months) and T_6 (6 months) (Carestream 9600, Kodak CS imaging 8.0.18, Atlanta, Ga). The CBCT was standardized with a field of view of 8/5 mm, a tube current of 4 mA, a peak voltage of 120 kVp, and an exposure time of 15 seconds.

Piezocision at T_0

All participants received flapless piezocision, administered at T_0, in the buccal cortical plate of the maxillary first premolar extraction space bilaterally, using Piezotome Solo (Satelec, Acteon Group, Merignac, France). A Piezotome 2 BS1 slim bone surgery tip was used to place a single vertical piezocision, of 5 mm in length and 5 mm in depth, starting 2 mm above the alveolar crest (Figure 2). Postpiezocision, CR was initiated on the same day using a 6-mm NiTi closed

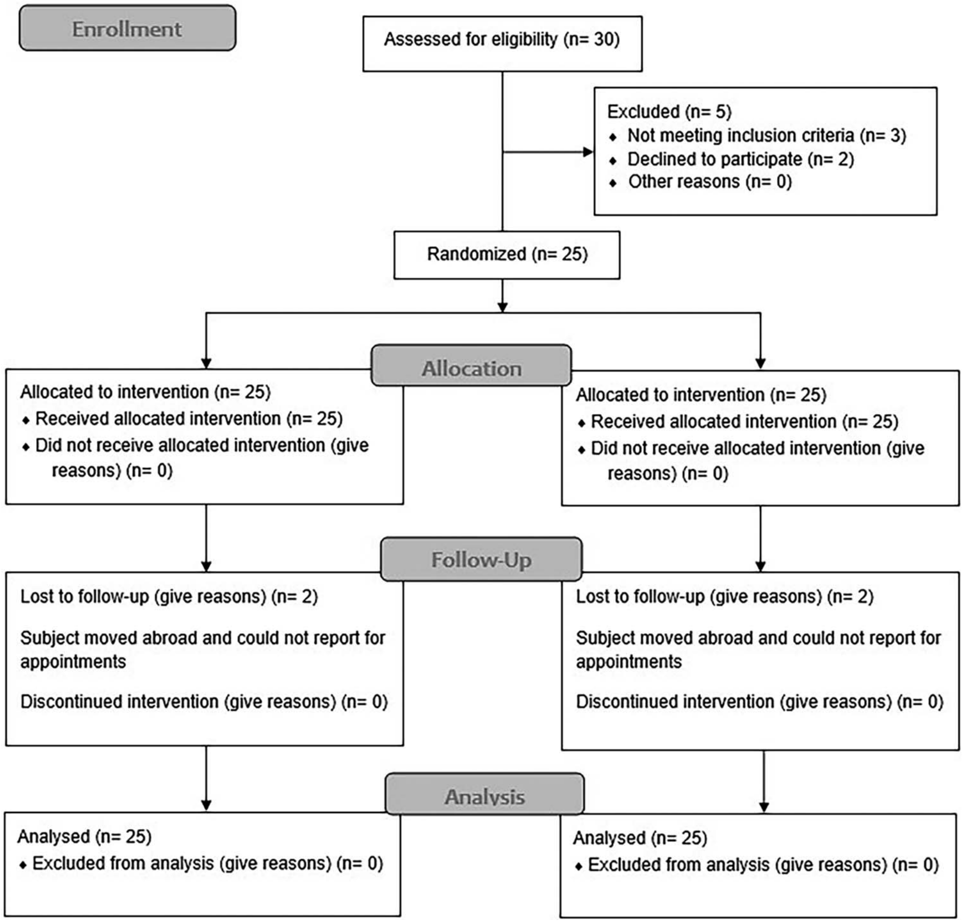

Figure 1. CONSORT flowchart.

coil spring. The magnitude of force was 150 g per side as measured by a Dontrix tension gauge (Ortho Care, West Yorkshire, UK) (Figure 3).

Intervention at T_3

At T_3 (3 months), participants received the intervention (MOP) in the quadrant selected based on the side determined by the blinded opaque envelopes. MOP was administered using a sterile stainless steel mini-implant of 1.5 × 8 mm in diameter. A periodontal probe was used to measure the gingival thickness, and a rubber stopper was used to demarcate the amount of mini-implant depth that had to be penetrated transmucosally to achieve a 5-mm bone puncture. Under local anesthesia, 3 MOPs were placed in

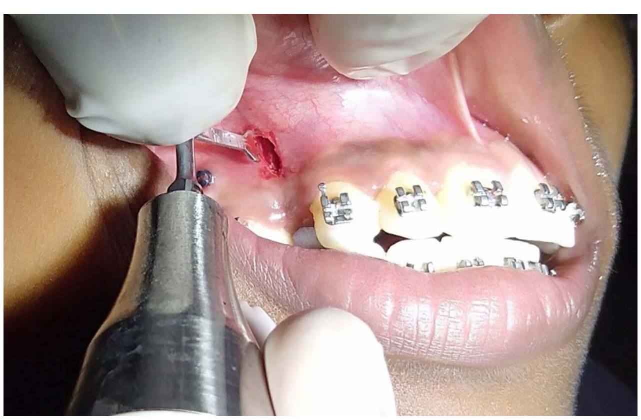

Figure 2. Piezocision in the buccal cortical plate of the maxillary first-premolar extraction space.

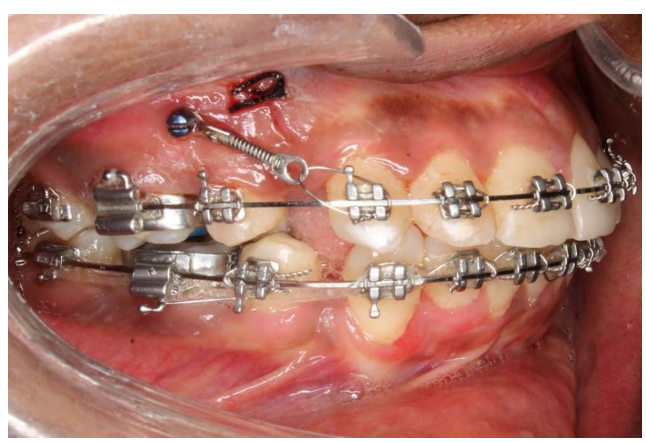

Figure 3. CR using 6-mm NiTi coil springs.

Figure 4. MOP placed using a mini-implant.

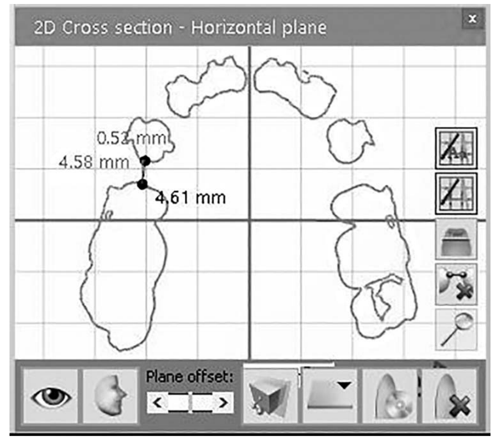

Figure 6. Linear measurement derived from a constructed horizontal plane bisecting the most convex portion of the canine.

the buccal cortical plate of the maxillary first premolar extraction space. Each MOP was 5 mm deep and with an interval of 3 mm between each other (Figure 4).

Measurements

Digital models were scanned using Trios 3Shape software (3shape A/S, Copenhagen, Denmark) at every appointment. Three-point surface superimpositions of the digital models were done at T_0, T_3, and T_6 using the third rugae as a reliable landmark (Figure 5). The horizontal cross-sectional view was used for linear measurement of the rate of CR, derived from a constructed horizontal plane bisecting at the level of the most convex portions of the canine and the second premolar (Figure 6).

The AC of the canine was measured from the CBCT images using Dolphin Imaging software version 11 (Dolphin Imaging & Management Solutions, Chatsworth, Calif, USA) (Figure 7). The angular measurements were made using the long axis of the canine and palatal plane as references. The BCBTs at T_0 and T_6 were measured using RadiAnt Dicom Viewer software (Medixant, Poznan, Poland). The canine was oriented by constructing a vertical plane along the long axis of the canine and a Constructed Horizontal Plane (CHP) extending across the buccal and palatal Cementoenamel Junction (CEJ). The BCBT was measured at 3- and 6-mm heights from the CHP (Figure 8).

Sample Size Calculation

Sample size calculation was done using G*Power Software Version 3.0.10 (Franz Faul, Universität Kiel, Germany) software with a power of 90%. A sample size of 23 participants (n = 23/group) was obtained. An additional 2 participants (n = 2/group) were added to compensate for any attrition.

Random Sequence Generation and Blinding

Randomization was done with computer-generated random numbers by using Random Allocation software 2.0 (Informer Technologies Inc, https://www.informer.com). Allocation concealment was done using opaque envelopes. Blinding of the patients and the operator was not possible because of the nature of the study. Blinding of the outcome assessor was done through data concealment during the assessment.

Interim Analyses

An intent-to-treat analysis was done, so all of the data for the participants regardless of the treatment outcome were included in the analysis. This consisted of the analysis of all of the participants who were entered into the trial for whom baseline data and final records were available.

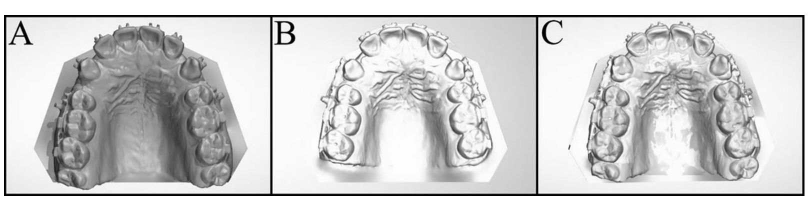

Figure 5. Three-point surface superimposition of the digital models at the third rugae. (A) At T_3. (B) At T_6. (C) Superimposition of the T_3 and T_6 digital models.

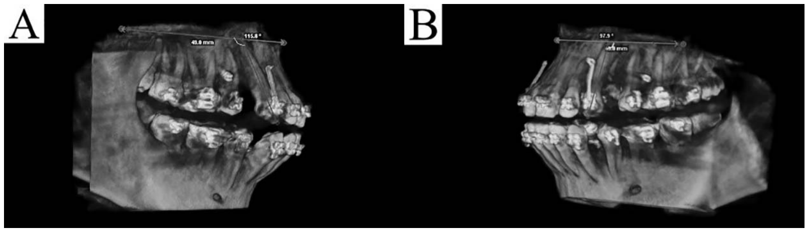

Figure 7. AC in the canine from T_0–T_6 measured using the palatal plane Anterior Nasal Spine (ANS) - Posterior Nasal Spine (PNS) as the reference plane and the long axis of the canine. (A) Right side. (B) Left side.

Statistical Analysis and Data Presentation

All of the statistical analyses were performed using IBM SPSS software version 23 (IBM Corp, Armonk, NY). The mean and standard deviation for each digital model and radiographic variables were determined. For parametric statistical tests, independent or unpaired Student's *t* tests were used for the rate of CR, AC, and BCBT. A confidence level larger than 5% was considered statistically not significant. The intraclass correlation test was used to assess intra- and interobserver agreement.

RESULTS

Participant Flow

Thirty patients (17 men and 13 women) with a mean age of 24.6 $\pm$ 5.7 years were assessed for eligibility, among whom 5 were excluded. The intraoral quadrants of these 25 patients were randomized in a 1:1 ratio to either the MOP activation quadrant (intervention quadrant) or the non-MOP activation quadrant (control quadrant). Two patients were lost to follow-up. Inter- and intraobserver reliability showed excellent correlation (intraclass correlation $>$ 0.98).

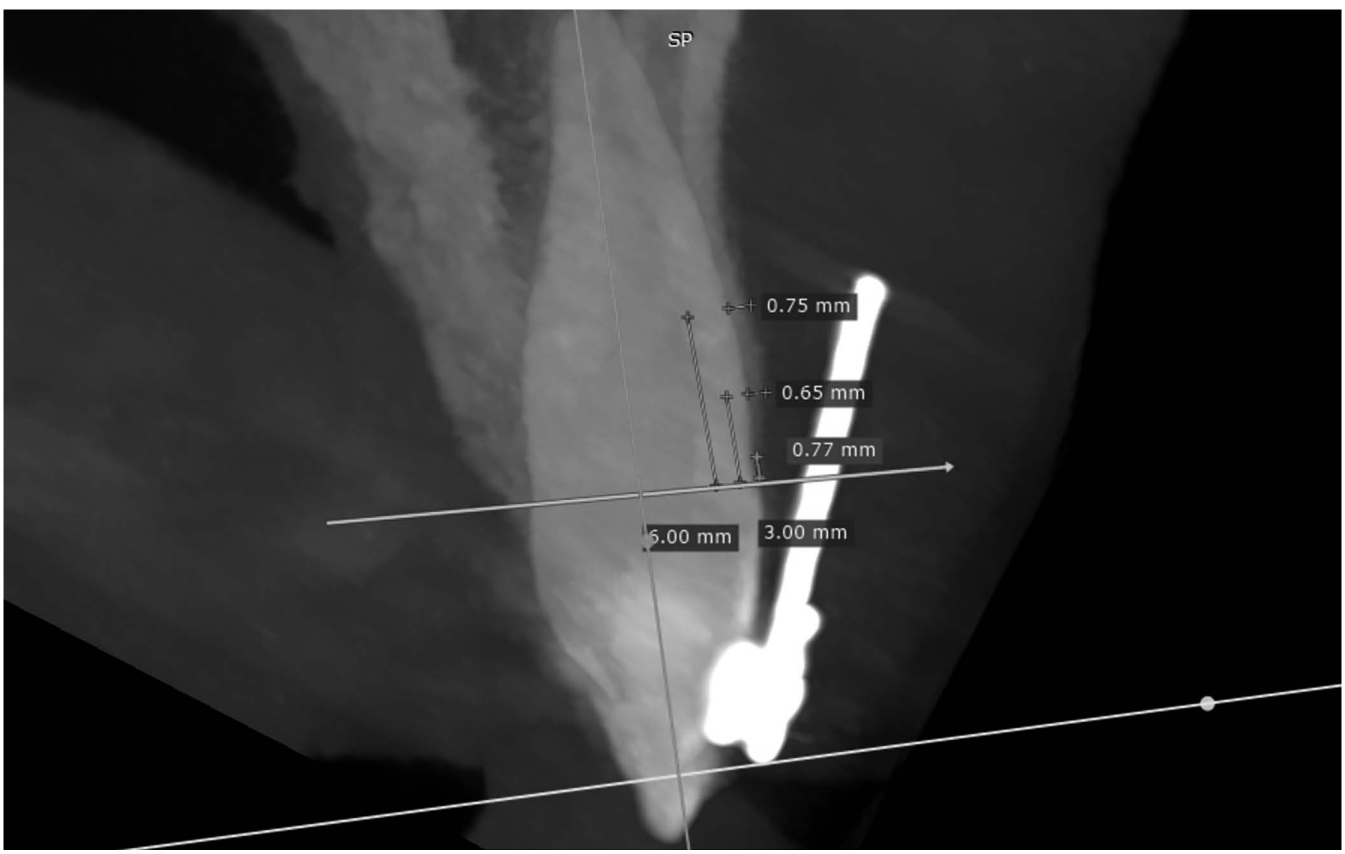

Figure 8. BCBT measured at 3-mm and 6-mm heights using the long axis of the canine and buccolingual CEJ points used as the vertical and horizontal reference planes.

Table 1. Comparison of the Rates of Canine Retraction From T_3 to T_6 Between the Groups Treated Using Piezocision With and Without MOP

Group	Number of Samples	Mean Rate, mm/Month	Standard Deviation	*P* Value
Control—without MOP	25	0.82275	0.3965	.496
Intervention—with MOP	25	0.746	0.4485	

Numbers Analyzed for Each Outcome

The control quadrant showed a mean CR rate of 0.82 ± 0.39 mm per month. The intervention quadrant showed a mean CR rate of 0.75 ± 0.44 mm per month. The difference between the control and intervention groups, however, was not statistically significant ($P = .496$) (Table 1).

The control quadrant showed a mean AC of 2.00° ± 0.88°. The intervention quadrant showed a mean AC of 1.98° ± 0.86°. The difference between the groups, however, was not statistically significant ($P = .644$) (Table 2).

The control quadrant showed a mean increase in the crestal bone height of 0.50 mm, which was not statistically significant ($P = .810$). The bone thickness at a 3-mm height from the CEJ was increased by 0.11 mm, which was not statistically significant ($P = .245$). The bone thickness at a 6-mm height from the CEJ was decreased by 0.12 mm, which was also not statistically significant ($P = .875$).

The intervention quadrant showed a mean decrease in the crestal bone of 0.28 mm, which was not statistically significant ($P = .163$). The bone thickness at a 3-mm height from the CEJ was decreased by 0.29 mm, which was not statistically significant ($P = .964$). The bone thickness at a 6-mm height from the CEJ was decreased by 0.15 mm, which was also not statistically significant ($P = .664$) (Table 3).

Harms

No serious harms were observed. Some gingival overgrowth and inflammation occurred, mainly due to irritation from the NiTi coil springs during individual CR.

DISCUSSION

Corticotomy has been considered to be the gold standard in increasing the rate of OTM. Several studies have consistently reported its effectiveness in hastening OTM.[17,18] However, it is still considered to be an invasive procedure. As an alternative, piezocision has shown promising results in increasing the rate of OTM.[10,11] Although minimally invasive, the effect of piezocision has been reported to be short-lived and requires periodic reactivation.[7] Therefore, a minimally invasive procedure such as MOP could potentially be used to augment the RAP in the piezocision site and further increase the rate of OTM for a longer duration.

Evidence on the rate of CR with MOP has been controversial. Several authors have conducted human trials on MOP and reported a two- to threefold increase in the rate of CR.[12,19] Other authors using split-mouth study designs reported that MOP did not increase the rate of CR.[13,20] A systematic review of MOP reported that there was no significant increase in the rate of OTM during short-term observation.[15] The reason for such diverse results, however, has not been adequately documented in any of these studies.

The results of this study showed that the overall treatment changes in relation to the linear and angular measurements as well as the BCBT changes were similar in both groups. Special attention was given to the rate of individual CR from T_3 to T_6 since this was the time when the participants received the MOP. From T_3 to T_6, there was no significant difference in the rate of CR. Similar results were reported previously by Aboalnaga et al., who stated that the mean rate of CR was 0.99 ± 0.3 mm/month in both groups.[13] Alkebsi et al. also reported no significant difference in the rate of CR in subjects receiving three MOPs.[20] Fattori et al. showed that there was no significant difference in the rate of OTM in participants receiving MOP and also reported a negative impact on the oral health–related quality of life.[21] Alqadasi et al. reported no significant difference in the rate of OTM with MOPs at a 3-month interval.[22] In their systematic review, Sivarajan et al. reported on the inability of a single application of MOP to accelerate OTM.[15] However, it was also suggested that multiple applications of MOP could be effective in accelerating OTM over a longer observation period.[15,19]

This study also showed no significant difference in the AC of the canine in both groups. This was in

Table 2. Comparison of the Angular Changes of the Canine From T_0 to T_6 Between the Groups Treated Using Piezocision With and Without MOP

Group	Number of Samples	Mean Degree	Standard Deviation	*P* Value
Control—without MOP	25	2.0040	0.83690	.644
Intervention—with MOP	25	1.9840	0.86152	

Table 3. Comparison of the Changes in Buccal Cortical Bone Thickness in the Groups Treated Using Piezocision With and Without MOP Between T_0 and T_6

Parameter	Group	Number of samples	Mean	Standard Deviation	*P* Value
Control—Without MOP					
Crestal bone height	Pretreatment	25	1.9760	2.59898	.810
	Posttreatment	25	1.4740	3.01905	
Bone thickness at 3 mm from CEJ	Pretreatment	25	0.7510	0.42270	.245
	Posttreatment	25	0.8620	0.58021	
Bone thickness at 6 mm from CEJ	Pretreatment	25	0.6730	0.39536	.875
	Posttreatment	25	0.5560	0.40330	
Intervention—With MOP					
Crestal bone height	Pretreatment	25	2.37	2.552	.163
	Posttreatment	25	2.65	3.205	
Bone thickness at 3 mm from CEJ	Pretreatment	25	0.7490	0.51492	.964
	Posttreatment	25	0.4600	0.43742	
Bone thickness at 6 mm from CEJ	Pretreatment	25	0.6540	0.48275	.664
	Posttreatment	25	0.5060	0.34284	

agreement with the results of other studies comparing MOP to a control group, which also showed no significant difference in the AC of the canine postretraction.[20,22] This could also be attributed to the fact that CR was carried out on a rigid 0.019 × 0.025-inch stainless steel (SS) wire using a 0.022-inch slot McLaughlin, Bennett, Trevisi (MBT) prescription brackets, which offered minimal allowance for tipping under controlled gradual forces.

In terms of changes in BCBT, there was no significant difference observed between the groups, indicating that the changes in BCBT and crestal height were minimal. Agrawal et al., however, showed that there was a significant increase in BCBT in the corticotomy as well as the MOP groups.[23] However, their study involved the placement of a demineralized freeze-dried bone allograft in the corticotomy site.[23] Another study showed no significant change in vertical bone height in the piezocision as well as the MOP groups.[24] These results indicate that these minimally invasive procedures for accelerating OTM do not have any deleterious effects on the periodontium over a 6-month follow-up period.

Limitations

The subjects recruited for this study were standardized based on skeletal and dental malocclusion. However, it would have been more accurate if the participants were matched for the density and quality of bone. Additionally, since the study had a split-mouth design, the crossover effect of the intervention from one side to the other also could not be ruled out with absolute certainty.[20] The effect of such interventions on the acceleration of OTM in terms of anterior tooth retraction would be of more clinical significance as canine retraction is used in daily orthodontic practice less often than it was in the past.[1]

CONCLUSIONS

- There is no significant difference in the rate of piezocision-aided CR with or without MOP.
- There is no significant difference in the AC of the canine postretraction.
- There are no significant changes seen in the BCBT.

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