Original Article

pISSN, eISSN 0125-5614
M Dent J 2022; 42 (2) : 175-190

Effect of piezocision using double incisions at the maxillary first bicuspid extraction site on the rate of canine tooth movement: A randomized controlled trial

Paranee Leehathorn[1], **Peerapong Santiwong**[2], Rochaya Chintavalakorn[2]

[1] *Residency Training Program in Orthodontics, Faculty of Dentistry, Mahidol University, Bangkok, Thailand*
[2] *Department of Orthodontics, Faculty of Dentistry, Mahidol University, Bangkok, Thailand*

Objective: To evaluate the effect of piezocision at the maxillary first bicuspid extraction site on the rate of canine tooth movement, pain, and the amount of root resorption.
Materials and Methods: A split-mouth randomized controlled trial was conducted on 15 patients who required maxillary first bicuspid extractions. On the intervention side, piezocision was performed on the buccal alveolar bone mesial and distal of the extraction space. Mini-screws were placed between the maxillary second premolar and first permanent molar on each side. The rate of canine tooth movement was calculated using the distance between the canine cusp tip and the mini-screw head immediately after piezocision and then every 4 weeks for 6 months thereafter. The amount of canine root resorption was measured before piezocision and 6 months after using cone-beam computed tomography (CBCT). Pain and discomfort were evaluated using a visual analog scale at immediate, 1 day, 3 days, 5 days, and 7 days post-piezocision. Paired t-tests or Wilcoxon matched-pairs signed-rank tests were used for statistical analysis.
Results: 13 females and 2 males (mean age 18.6 ± 3.56 years) were recruited. The rate of canine tooth movement on the piezocision side (0.91±0.23 mm/month) was higher than the control side (0.85±0.21 mm/month) but not statistically significant. The amount of canine root resorption was statistically greater on the coronal plane of the piezocision side. Most participants reported no to mild pain post-piezocision.
Conclusion: Piezocision at the extraction site did not significantly accelerate maxillary canine tooth movement but led to a greater amount of canine root resorption.

Keywords: accelerated tooth movement, canine retraction, orthodontics, piezocision

How to cite: Leehathorn P, Santiwong P, Chintavalakorn R. Effect of piezocision using double incisions at the maxillary first bicuspid extraction site on the rate of canine tooth movement: A randomized controlled trial. M Dent J 2022; 42: 175-190.

Introduction

With the purpose of enhancing the rate of tooth movement and reducing the adverse side effects which may occur during orthodontic treatment, the regional accelerated phenomenon (RAP) was introduced by Frost in 1983. According to this theory, the recruitment of osteoclasts and osteoblasts during the wound healing process would lead to localized demineralization and remineralization in the alveolar bone and therefore expedite orthodontic tooth movement [1]

Piezocision is a minimally invasive surgical alternative to conventional corticotomies [2]. It is performed by insertion of a piezoelectric knife through a small vertical incision without elevation of a mucoperiosteal flap. The decortication creates a three to four months window of opportunity to

Correspondence author: Peerapong Santiwong
Department of Orthodontics Faculty of Dentistry, Mahidol University
6 Yothi Road, Ratchathewi, Bangkok 10400, Thailand
Tel. +669 2265 9256
E-mail: peerapong.san@mahidol.ac.th
Received: 26 April 2022 Revised: 7 June 2022 Accepted: 9 June 2022

move teeth rapidly through the demineralized bone matrix and can be re-activated by repeated piezocision [3].

Piezocision has been shown to enhance bone healing without causing osteonecrotic damage while preserving root integrity and sparing the soft tissue with its blood supply [4]. Hard tissue or soft tissue grafting can be combined with piezocision via selective tunneling, which allows for the correction of gingival recession and bone deficiencies [5].

Accelerated maxillary canine tooth movement has been observed by several authors who performed piezocision mesial and distal to the canine [5-8]. We hypothesized that the effect of RAP should be more effective if bone injury occurs directly at the alveolar bone of the extraction site.

Therefore, our study chose to evaluate the effect of double piezocision at the maxillary first bicuspid extraction site on the rate of canine retraction. The secondary outcomes assessed in this study included anchorage loss, canine root resorption, as well as pain and discomfort associated with the piezocision procedure. With the advancement of digital images and CBCT, these methods are highly reliable, have fewer distortions, provide precise measurements, and were used to evaluate results to avoid the shortcomings of data collection methods from previous studies.

Materials and Methods

This study was designed as a split-mouth randomized controlled trial. Participants were recruited from patients attending the Orthodontic Clinic at the Faculty of Dentistry, Mahidol University. Sample size calculation, using the paired t-test dependent sample formula, at a level of significance of 5%, a power of 80%, a mean difference of 1.1, and a standard deviation of 1.3 according to a previous study [9], resulted in n=14.

Participants were selected according to the following criteria: 1) Permanent dentition, age range from 12-25 years; 2) Patients presenting with Class II division 1 malocclusion or bimaxillary protrusion who require extraction of the maxillary first bicuspids; 3) Bilateral residual extraction space ≥ 7 mm; 4) Healthy, no systemic disease or prolonged medication; 5) Absence of craniofacial deformities or previous dentofacial trauma; 6) Good oral hygiene and healthy periodontium; 7) No previous orthodontic treatment; and (8) Non-smoker. All subjects signed consent forms before the study.

Orthodontic treatment was performed by the same operator throughout the study. The 0.022” slot self-ligating brackets with Roth’s prescription (Clippy, Tomy®, Tokyo, Japan) were used. The upper dental arches were leveled and aligned by straight wire technique using the sequence of archwires as follows: 0.014” nickel-titanium (NiTi), 0.016” NiTi, and 0.018 stainless steel archwires. Cone-beam computed tomography (CBCT) images were taken prior to canine retraction to be used as a baseline for evaluation of canine root resorption as well as to determine inter-radicular bone density at the maxillary second premolar (U5) and first permanent molar (U6) regions to assure the primary stability of mini-screws [10].

For the split-mouth study design, randomization was done using opaque, sealed envelopes containing cards with the word ‘left’ or ‘right’ to allocate the experimental side. All participants underwent a level and align phase to ensure symmetrical arch form and equal canine to miniscrew distance before maxillary first premolar extraction, thus, simple randomization was used to allocate the experimental side. Although blinding the participants was not possible, blinding the operator during outcome measurement was done.

Four weeks before piezocision, extraction of the maxillary first bicuspids (U4) was done together with the placement of mini-screws of 1.4 mm diameter and 8 mm length (Osstem©, Seoul, Korea) between the U5s and U6s on each side.

The piezocision procedure was done by first making two vertical incision lines, 5 to 8 mm long, on the buccal gingiva of the U4 extraction site, distal to the canine, and mesial to the U5, 2-3 mm below the alveolar crest to allow insertion of the piezocision tip. A piezosurgery knife (PZ1, Piezotome, SATELEC®, Acteon, France) set to program D1 was inserted (frequency modulation 60 Hz, normal saline irrigation 60 ml/min) through the gingival opening to a depth of 3 mm, identified by a millimetric marker on the knife, and 5 mm in length (Figure 1).

Canine retraction on both sides was started immediately after the piezocision procedure on 0.018” SS archwire using NiTi closed-coil springs attached from the miniscrew to the hook of the canine bracket (Figure 2). The length of the spring corresponded with a force of 150 grams measured with a strain gauge (Dentaurum, Federwaage, dial-type, Ispringen, Germany). Participants were only allowed to take paracetamol for any post-operative pain relief.

The participants were scheduled for follow-up every 4 weeks for 6 months or until the canines were in Class I occlusion. At each appointment, the retraction force was calibrated and adjusted to maintain the 150 g force levels. After 6 months, another CBCT was taken.

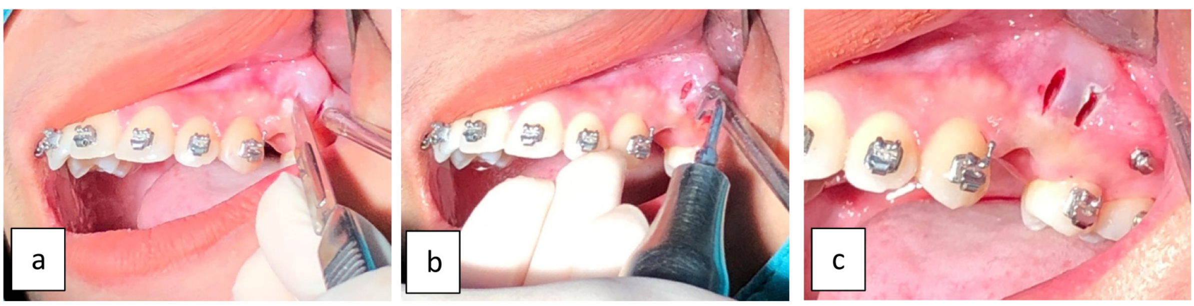

Figure 1 Piezocision procedure at the maxillary first premolar extraction site. Double-incision lines were made on the buccal gingiva of U4 extraction site (a). Piezocision was performed with piezosurgery knife (b). No suture was applied (c).

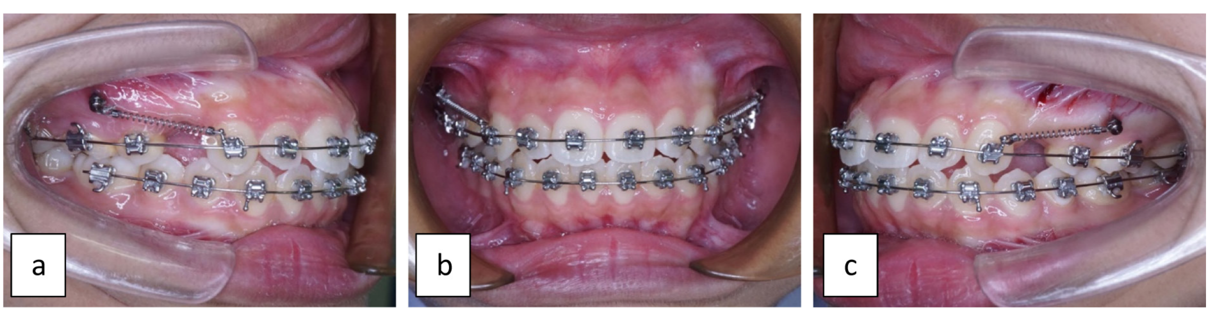

Figure 2 Maxillary canine retraction immediately after piezocision by using NiTi closed-coil springs (150g per side) attached from the mini-screws to the hook of the canine bracket on control side (a) and piezocision side (c). Frontal view at immediate canine retraction (a).

Predictor and outcome variables

The primary outcome variable was the rate of canine tooth movement, while the secondary outcome variables were canine root resorption, anchorage loss, canine distal bone thickness, and levels of post-operative pain and discomfort.

Outcomes measurement

Intraoral scans (3Shape Intraoral scanner, Trios®, Copenhagen, Denmark) were used for data collection. With the OrthoAnalyzer™ software, the distance from the canine cusp tip to the middle of the mini-screw head was measured every 4 weeks after canine retraction for 6 months to calculate the rate of canine tooth movement. (Figure 3). If tooth wear presented at any cusp tip the center of the wear facet was measured in triplicate and averaged to be used as the reference point.

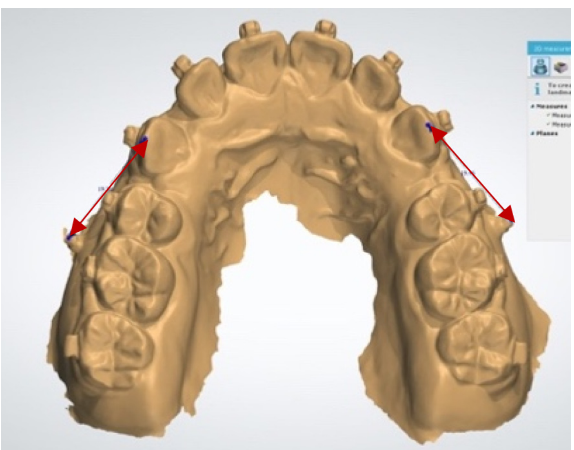

Figure 3 Measurement of canine movement (red arrows): Distance from middle of mini-screw head to canine cusp tip.

Canine root resorption evaluation was done using OneVolume viewer software of the CBCT scans (CBCT, 3D Accuimoto 170, FOV: 6 cm x 6 cm, Voxel size: 0.125 mm) taken at T0 and T6. Canine tipping was evaluated from CBCT, using the angle between the long axis of the canine to the palatal plane.

Anchorage loss was determined in terms of U6 rotation and tipping. Rotation of the U6s was assessed from intraoral scans, using the angle formed by a line drawn from the mesial to distal surfaces through the central groove of the U6s to the median palatine raphe. U6 tipping was measured from CBCT images, using the angle between the long axis of the U6 to the palatal plane.

The distance of canine movement was measured twice at a 2-week interval, and the average value was used for the rate of tooth movement calculation. The amount of distal interseptal bone thickness, canine root resorption, canine tipping, and anchorage loss was measured twice, and average values were used. Intra-rater reliability was calculated for data reliability evaluation.

The assessment of pain and discomfort was done immediately after the piezocision procedure, then on days 1, 3, 5, and 7 post-operatively by using a visual analog scale (VAS).

Statistical analysis

The rate of canine movement, distal interseptal bone thickness, canine root resorption, canine tipping, and anchorage loss was analyzed using the Kolmogorov-Smirnov test for normality test and paired t-tests or Wilcoxon matched-pairs signed-rank tests were used for outcomes comparison between groups. Pain and discomfort from VAS scores were subjected to repeated-measures ANOVA. Intra-rater reliability was determined using Cronbach's Alpha. The level of significance was set as $p<0.05$.

Results

A total of 15 participants were recruited for this study (13 females, 2 males) with a mean age of 18.6 ± 3.56 years.

Primary outcome: Rate of canine tooth movement

Mean rates of canine movement are presented in Tables 1 and 2. As the raw data were not normally distributed, non-parametric statistical analyses were used. Wilcoxon matched-pairs signed-rank tests were used to compare the rate of canine movement between the control and experimental side at each time interval.

The results show that the rate of canine movement on the piezocision side was higher during T2 to T4 but was not statistically significant (p>0.05). During T5 to T6, the rate decreased to be equal to the control side. No significant statistical differences were found between the control and experimental sides at any time point (T1 – T6) (Figure 4, Table 3). Intra-rater reliability from Cronbach's Alpha was 0.984-0.999 which indicated high reliability.

Table 1 Distance from miniscrew to canine cusp tip at baseline (T0) between left and right side.

	Distance from miniscrew to canine cusp tip at baseline (T0) (mean ± SD)
Left side	23.17 ± 1.31
Right side	23.44 ± 1.36

Table 2 Comparison of rate of canine tooth movement between control and piezocision sides as measured from the middle of mini-screw head to the canine cusp tip.

	Rate of canine tooth movement (mm/month)						
	T0-T1 (mean ± SD)	T1-T2 (mean ± SD)	T2-T3 (mean ± SD)	T3-T4 (mean ± SD)	T4-T5 (mean ± SD)	T5-T6 (mean ± SD)	T0-T6 (mean ± SD)
Control side	0.89 ± 0.62	1.14 ± 0.61	1.06 ± 0.51	0.78 ± 0.34	0.69 ± 0.33	0.56 ± 0.40	0.85 ± 0.21
Piezocision side	0.84 ± 0.35	1.24 ± 0.42	1.17 ± 0.45	0.79 ± 0.44	0.66 ± 0.36	0.77 ± 0.48	0.91 ± 0.23
Wilcoxon signed ranks test	0.776 NS	0.650 NS	0.691 NS	0.629 NS	0.955 NS	0.112 NS	0.185 NS

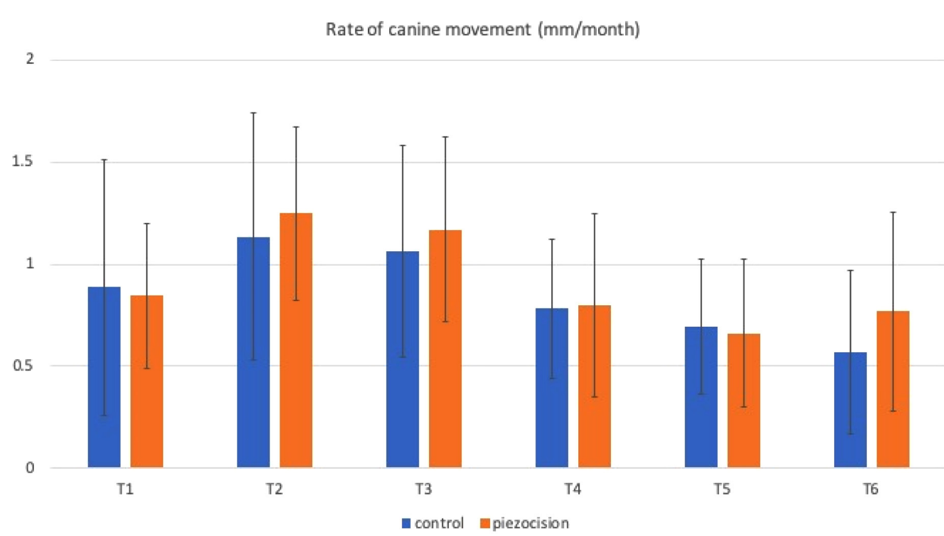

Figure 4 Mean rates of canine tooth movement as measured from middle of mini-screw head to canine cusp tip.

Table 3 Differences and mean differences between different time intervals for the amount of canine tooth movement as measured from the middle of the mini-screw head to the canine cusp tip.

Time Interval	Piezocision Side (mm) (mean ± SD)	Control Side (mm) (mean ± SD)	Mean Difference (mm) (mean ± SE)
T0-T1	0.84 ± 0.35	0.89 ± 0.62	0.04 ± 0.15
T1-T2	1.24 ± 0.42	1.14 ± 0.61	0.11 ± 0.19
T2-T3	1.17 ± 0.45	1.06 ± 0.51	0.10 ± 0.17
T3-T4	0.79 ± 0.44	0.78 ± 0.34	0.02 ± 0.3
T4-T5	0.66 ± 0.36	0.69 ± 0.33	0.03 ± 0.13
T5-T6	0.77 ± 0.48	0.56 ± 0.40	0.2 ± 0.11
T0-T3	3.26 ± 0.01	3.08 ± 0.22	1.15 ± 0.18
T0-T6	5.49 ± 0.09	5.13 ± 0.05	1.10 ± 0.23

Secondary outcomes

Distal interseptal bone thickness

The distal interseptal bone thickness of the maxillary canines was measured from the CBCT before canine retraction to determine if it would affect the rate of canine tooth movement. Measurement was done on the axial plane at the cementoenamel junction level. No statistically significant differences between the control and experimental sides were found ($p>0.05$) (Figure 5, Table 4).

Table 4 Comparison of distal interseptal bone thickness of maxillary canines between control and piezocision side.

	Distal bone thickness (mm)
Control side	0.54 ± 0.10
Piezocision side	0.58 ± 0.10
Wilcoxon signed ranks test	0.073

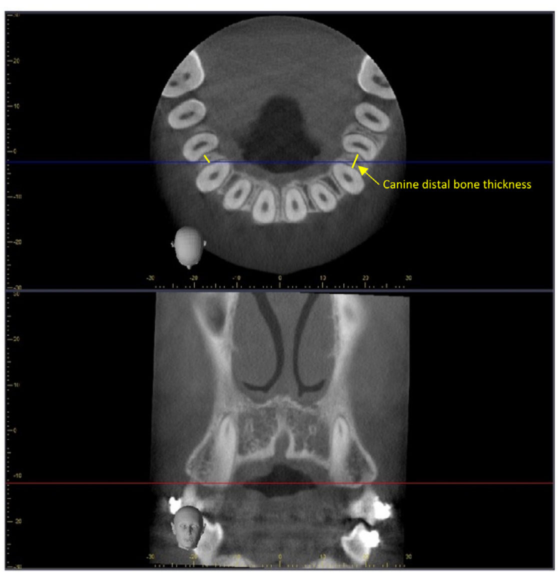

Figure 5 CBCT images for evaluation of distal interseptal bone thickness. Measurement was done on axial plane, at cementoenamel junction level.

Canine root resorption

CBCT scans used to evaluate canine root resorption are shown in Figure 6. The canine length was measured on both coronal and sagittal planes and compared with paired t-tests (Table 5). On the control side, the mean amount of canine root resorption was 0.68 ± 0.33 mm and 0.67 ± 0.49 mm on the coronal and sagittal planes, respectively, while the piezocision side was 0.95 ± 0.54 mm and 0.74 ± 0.55 mm, confirming that both sides showed decreased tooth length. The amount of canine root resorption on the piezocision side was significantly greater only on the coronal plane (p<0.05) but not statistically significant on the sagittal plane (p>0.05).

Table 5 Comparison of amount of canine tooth length changes between control and piezocision sides on coronal and sagittal planes.

Canine root resorption	Coronal plane (mm) (mean ± SD)	Sagittal plane (mm) (mean ± SD)
Control side	0.68 ± 0.33	0.67 ± 0.49
Piezocision side	0.95 ± 0.54	0.74 ± 0.55
Paired t-test	0.044*	0.646

*Significant difference p <0.05

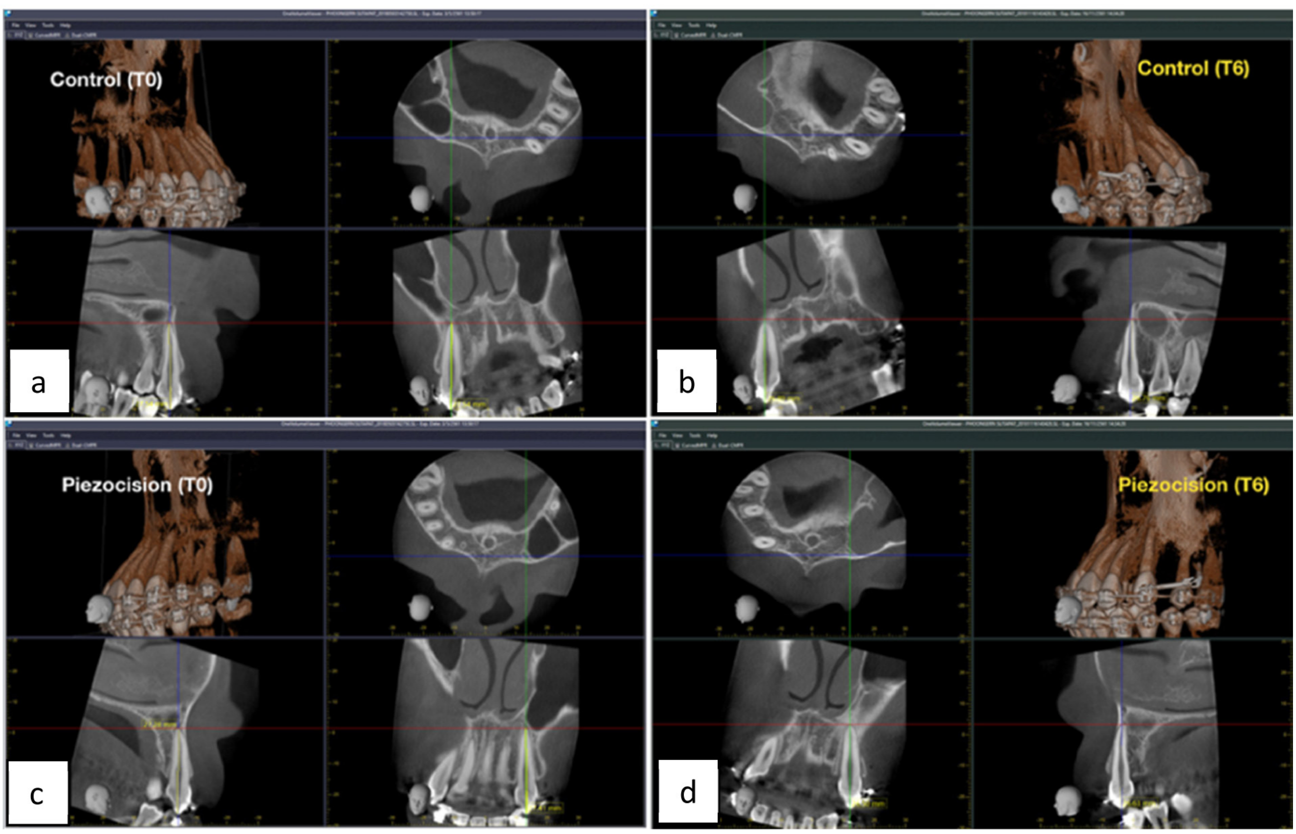

Figure 6 CBCT images for measurement of canine tooth length: At baseline, T0 (a, c) and T6 (b, d).

Canine tipping

From CBCT images, the degree of canine tipping was measured as the angle between the long axis of the upper canines to the palatal plane and compared between T0 and T6. The canine on the control side showed a greater degree of distal tipping but without statistical significance (*p*>0.05). (Figure 7, Table 6)

Anchorage loss

Regarding anchorage loss, both U6 movement and mini-screw displacement were evaluated. Alveolar bone density was assessed from CBCT images and classified according to Lekholm and Zarb [11]. Most of the participants had D2 bone type, and only two participants showed D3 bone type, both of which would contribute to the high clinical stability of the mini-screws (Figure 8).

Table 6 Comparison of canine tipping between the control and piezocision sides. No statistical significance was found (*p*>.05).

	Canine tipping (°) (mean ± SD)
Control side	13.06 ± 8.25
Piezocision side	12.33 ± 5.57
Wilcoxon Signed Ranks test	0.569

Although the piezocision side showed a greater amount of mesial molar tipping and mesio-palatal rotation when compared between T0 and T6, no statistical significance was found. (Figures 9 and 10, Table 7)

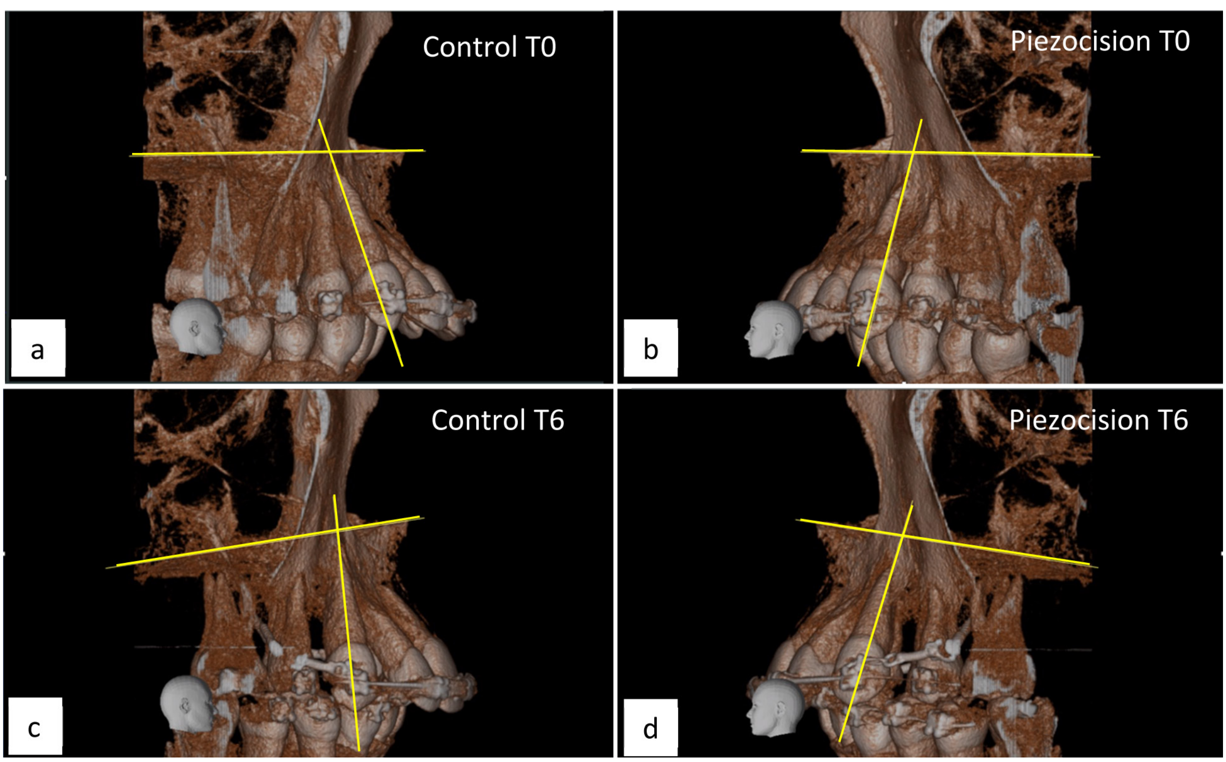

Figure 7 Canine tipping was measured as the angle between the long axis of upper canines to the palatal plane in CBCT images, control side at T0 and T6 (a,c) and piezocision side at T0 and T6 (b,d).

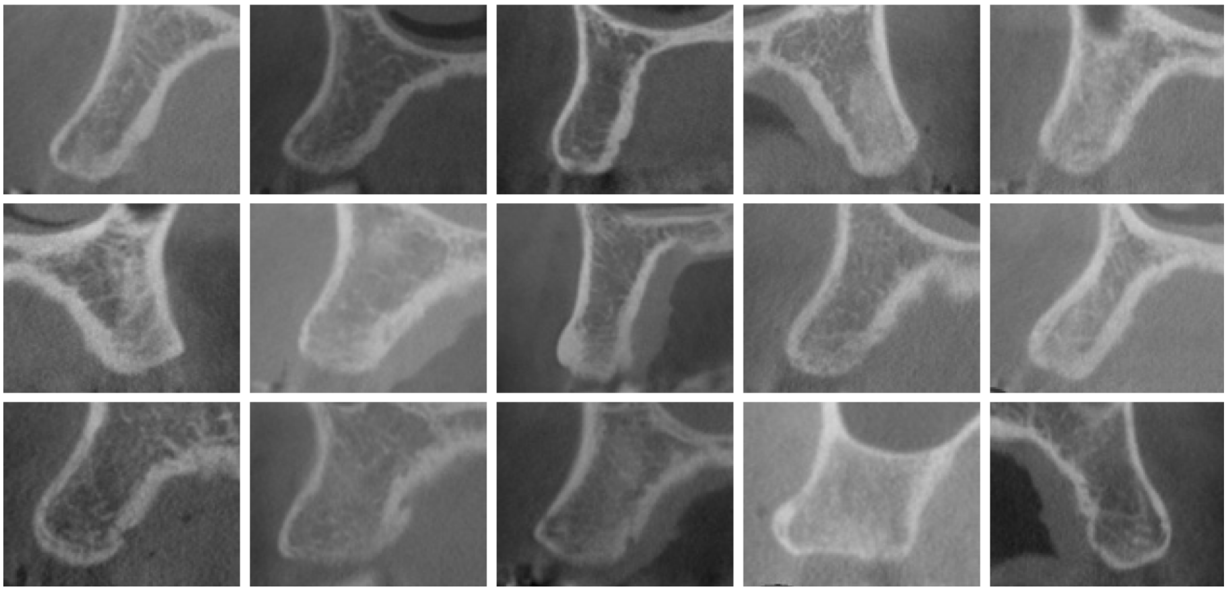

Figure 8 CBCT images for evaluation of alveolar bone density between maxillary second premolar and first molar from each participant.

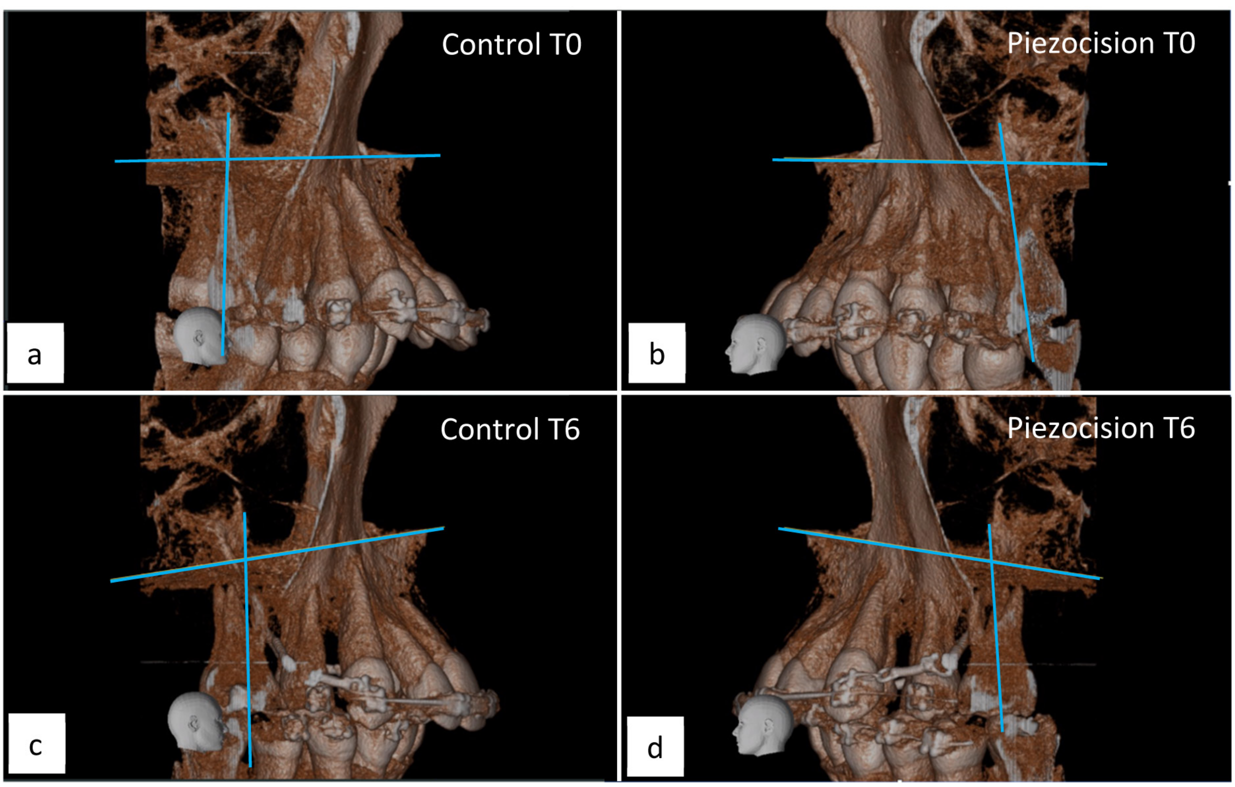

Figure 9 Measurement of molar tipping from CBCT images, using the angle between the long axis of the U6 to the palatal plane, control side at T0 and T6 (a,c) and piezocision side at T0 and T6 (b,d).

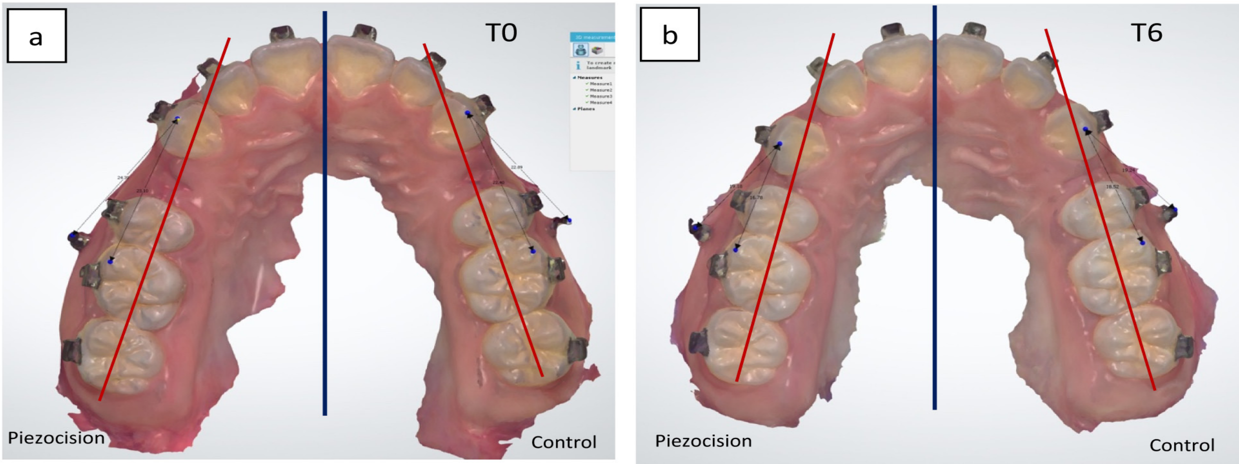

Figure 10 Molar rotation was assessed from intraoral scans at T0 (a) and T6 (b), using the angle formed by a line drawn from the mesial to distal surfaces of the U6s through the central groove (red) to the median palatine raphe (blue).

Pain and discomfort

Most participants reported zero to mild pain post-operatively, while only two participants reported moderate to severe pain, yet no pain-relieving medication was taken (Table 8).

Discussion

This split-mouth randomized controlled trial was conducted to investigate whether piezocision would accelerate the rate of canine retraction.

It has been suggested that RAP is proportional to the amount of bone injury as previous studies that used one incision appeared to be non-effective [12]. In contrast, three incisions may cause extensive injury [13]. For this reason, our study chose to perform a double incision for the piezocision procedure.

From the measured outcomes using intraoral scans in our study, our results indicated that piezocision was not significantly effective in accelerating canine tooth movement, which contradicts the results of previous studies. In those studies, measurements were made with calipers

Table 7 Comparison of molar tipping and rotation between the control and piezocision sides.

	Molar tipping (°) (mean ± SD)	Molar rotation (°) (mean ± SD)
Control side	2.80 ± 0.85	1.79 ± 0.06
Piezocision side	3.13 ± 0.66	2.61 ± 0.40
Paired t-test	0.742	0.603

Table 8 Mean and standard deviation of visual analogue scale (VAS) scores for the piezocision side at immediate post-piezocision and at Days 1, 3, 5, and 7.

Time (Post-piezocision)	VAS Score (Piezocision Side)	
	Mean ± SD	*P*-value
Immediate	2.86 ± 0.83	0.004*
Day 1	2.80 ± 0.64	0.001*
Day 3	2.25 ± 0.58	0.003*
Day 5	0.93 ± 0.39	0.034*
Day 7	0.73 ± 0.30	0.028*

*Significant difference $p < 0.05$

either directly in the oral cavity or on dental models, which could pertain to inaccuracies [5, 6, 8-9]. To improve reliability and avoid introducing possible distortions from the multiple steps involved in making impressions and producing plaster casts, our study relied on digital data collection from intraoral scans.

Another factor that may have contributed to the insignificant effect on the rate of canine tooth movement in our study is the timing of the premolar extractions. Fernandes *et al.* reported in their RCT that starting canine retraction immediately after extractions could produce greater canine tooth movement as the extraction procedure itself would induce RAP [13]. On the contrary, our study performed the piezocision four weeks after the extractions.

Although the overall rate of canine tooth movement was not significantly different in our study, our results showed accelerated canine tooth movement on the piezocision side during the first two to three months. Alfawal *et al.* [9] who experimented with a combination of piezocision and corticotomy reported similar findings in the first two months after the intervention, while Al-Naoum *et al.* [14] found a threefold increase in canine tooth movement after corticotomy during the immediate postoperative period. Besides the higher rate of canine tooth movement after piezocision found by Aksakalli *et al.* [7], the amount of anchorage loss on the experimental side was also reduced.

Mini-screws were used as skeletal anchorage for canine retraction in this study instead of the palatal rugae or the U6s because these are not stable. For instance, transeptal fiber pull could affect the position of the teeth [15], while differing bone physiology and metabolism could have varying effects on anchorage loss [13].

Besides, the mini-screws could serve as stable reference points. Although mini-screw displacement has been found at 2 to 3 months after loading, it was not considered to be clinically significant [16, 17]. A success rate of 93% for mini-screws used during canine retraction with and without corticotomy was reported by Aboul-Ela *et al*. [18]. This rate could easily be improved by avoiding excessive loading and ensuring good oral hygiene maintenance [16].

One of the key factors for mini-screw stability is bone density, where failures are more commonly encountered in areas of low bone density and inadequate cortical thickness. According to the classification of bone density by Lekholm and Zarb [11, 19], D1 to D3 bone types are optimal for self-drilling mini-screw placement as this would reduce the stress at the screw-bone interface [10]. Although participants' age range was large, 12-25 years, most of the participants presented with a D2 bone type which is suitable for miniscrew placement as evaluated by the CBCTs taken before the piezocision procedure.

The placement of mini-screws was done under local anesthesia in the inter-radicular area between U5 and U6. This area was chosen to provide a wide inter-radicular span to reduce the risk of root proximity as well as being a favorable site of sufficient bone quality for the first 90 days of canine retraction [19, 20]. The recommended dimensions of mini-screws placed in the inter-radicular area are a diameter of 1.3 to 1.5 mm and a length of 6 to 8 mm to ensure mini-screw stability [21]. The mini-screws used in our study were 1.4 mm in diameter and 8 mm long. An initial phase of levelling and alignment was done to create an adequate inter-radicular space before mini-screw placement.

For canine retraction, NiTi closed coil springs were attached from the miniscrew to the hook of the canine bracket to produce continuous and constant forces with no decay. A force of 150 g was employed, following the recommended force range from the literature for canine retraction with miniscrews to reduce stress on the miniscrew [10, 22]. A significantly higher rate of space closure was reported by Chaudhari *et al*. from the use of NiTi closed coil springs compared to elastomeric chains, but more anchorage loss was also seen [23]. This could be because their study did not utilize skeletal anchorage as our study did not show significant differences in terms of molar movement, rotation, and tipping for either the control or piezocision sides. Similar findings were seen in the study by Aboul-Ela *et al.* [18] who also used mini-screws for anchorage preservation.

External apical root resorption (EARR) is a common consequence of orthodontic tooth movement, but as it is often asymptomatic, additional diagnostic tools are required to evaluate EARR. With the advancements in CBCT technology, it has become the most reliable method to measure and evaluate EARR as compared to traditional two-dimensional radiographs. The degree of severity and geometry of the resorption can be more precisely appreciated from CBCT images [24].

Previous methods in EARR assessment used only the root length, but this could be prone to errors in defining the actual tooth root. As it is generally accepted that crown length does not change due to the orthodontic treatment [25, 26], our study chose to measure the entire length of the tooth instead, using the distance from a point on the cusp tip to another point on the root apex on both coronal and sagittal planes. From these measurements, a greater amount of canine root resorption was found on the piezocision side in both coronal and sagittal planes, but only statistically significant for the latter. The results from other studies, however, have been conflicting, with Patterson *et al.* [27] reporting similar findings to our study, but the opposite was seen by Abbas *et al.* [5], while Charavet *et al*.[28] found no significant differences between the piezocision and control groups [29].

The increased root resorption in the piezocision group could be explained by an increased bone turnover from the RAP effect. It can be stated that an increased osteoclastic activity during bone turnover led to increased root resorption. Moreover, RAP also induced local inflammatory response, leading to increased inflammatory mediators and may increase the root resorption [27].

Sliding mechanics was used for canine retraction in this study; although rectangular wires offer better control during tooth movement, it creates greater binding and friction and needs to use higher retraction force to overcome the friction. For this reason, a round stainless steel archwire was used since it is stiff enough for retraction and provides lesser friction due to a larger clearance between the bracket slot and the wire [30]. However, greater canine tipping should be expected. Hamid *et al.* [31] reported that a faster rate of canine retraction was observed on heavy round stainless steel wires with minimal tipping. In addition, retraction force did not pass through the center of resistance of the canine; tipping usually occurs. For future studies, a power arm should be used to reduce canine tipping.

Molar tipping and rotation can occur during canine retraction with sliding mechanics. The use of miniscrew eliminates the molar rotational moment and modifies the force system. Since the molar was left without anchorage reinforcement, molars were allowed to rotate and moved mesially [32].

A VAS pain assessment was done to determine patient acceptance towards the piezocision procedure. A systematic review concluded that pain levels from corticotomy or piezocision would decline from the third day and continue to decrease until Day 7 [29]. Our study suggests good patient acceptance for piezocision as the highest VAS scores were generally seen immediately post-piezocision as well as one day after, after which the scores decreased to zero by the third day. Only one participant in our study consistently reported some pain and discomfort at every time interval. This individual finding could have been due to the participant's higher pain sensitivity and the fact that the participant did not take any medications to relieve the pain. Most of the other participants stated that the procedure produced slight discomfort and pain, which agrees with the majority of other studies where no serious complications or differences between the control and intervention sides were found [7, 9, 28].

In contrast to piezocision, corticotomy would potentially be less acceptable to patients. In the study by Al-Naoum *et al.* [14], severe pain during eating was reported by half of the participants one day after corticotomy. In contrast, more than half experienced mild to moderate pain during the day and low pain levels at night. Therefore, piezocision would be a beneficial alternative method to reduce pain and discomfort, especially for patients with low pain tolerance [33].

Even though our study was unable to show a positive impact from piezocision on accelerating canine tooth movement. The limitations include a small sample size, limited sample age range, and canine tipping because the retraction force did not pass through the center of resistance. These limitations as highlighted throughout the discussion could be addressed in future research. The effects of piezocision could also be studied in other areas of the oral cavity, such as the posterior regions where bodily tooth movement of the permanent molars can be more challenging with conventional orthodontics alone.

Conclusions

1) Piezocision does not significantly accelerate the rate of maxillary canine retraction in patients after the extraction of the maxillary first bicuspids.

2) Piezocision may lead to significantly higher levels of canine root resorption, but no differences in anchorage loss and pain or discomfort were observed.

Acknowledgement

The authors are grateful to Acteon (Thailand) for providing the piezosurgery equipment as well as to Tomy Inc. for the self-ligating brackets and Osstem (Thailand) for the miniscrews used in this study.

Author contributions

Leehathorn P contributed to conducting the entire methodology of the study, from participant recruitment up to data acquisition, analysis, and manuscript writing. Santiwong P and Chintavalakorn R contributed to the conception and design of the study, verifying the data interpretation, and revising the manuscript.

Conflict of interest

No potential conflict of interest was reported by the authors.

Funding

This research received funding from Mahidol University, Faculty of Dentistry (DTRS-GG-2018-03) for intraoral scan and CBCT fees.

References

1. Alansari S, Sangsuwon C, Vongthongleur T, Kwal R, Teo MC, Lee YB, Nervina, *et al.* Biologic principles behind accelerated tooth movement. ***Semin Orthod*** 2015; 21: 151-61.
2. Serge Dibart EK, and Donald N. Piezocision-assisted orthodontics: past, present, and future. ***Semin Orthod*** 2015; 21: 170-5.
3. Keser EI, Dibart S. Sequential piezocision: a novel approach to accelerated orthodontic treatment. ***Am J Orthod Dentofacial Orthop*** 2013; 144: 879-89.
4. Dibart S, Surmenian J, Sebaoun JD, Montesani L. Rapid treatment of Class II malocclusion with piezocision: two case reports. ***Int J Periodontics Restorative Dent*** 2010; 30: 487-93.
5. Abbas NH, Sabet NE, Hassan IT. Evaluation of corticotomy-facilitated orthodontics and piezocision in rapid canine retraction. ***Am J Orthod Dentofacial Orthop*** 2016; 149: 473-80.
6. Raj SC, Praharaj K, Barik AK, Patnaik K, Mahapatra A, Mohanty D, *et al.* Evaluation and comparison of periodontal status and rate of canine retraction with and without piezocision-facilitated orthodontics: A randomized controlled trial. ***Int J Periodontics Restorative Dent*** 2020; 40: e19-e26.
7. Aksakalli S, Calik B, Kara B, Ezirganli S. Accelerated tooth movement with piezocision and its periodontal-transversal effects in patients with Class II malocclusion. ***Angle Orthod*** 2016; 86: 59-65.
8. Elkalza AR. Evaluation of piezocision in rapid canine retraction. ***Egypt Orthod J*** 2017; 51: 59-71.
9. Alfawal AMH, Hajeer MY, Ajaj MA, Hamadah O, Brad B. Evaluation of piezocision and laser-assisted flapless corticotomy in the acceleration of canine retraction: a randomized controlled trial. ***Head Face Med*** 2018; 14: 4.
10. Chugh T, Jain AK, Jaiswal RK, Mehrotra P, Mehrotra R. Bone density and its importance in orthodontics. ***J Oral Biol Craniofac Res*** 2013; 3: 92-7.
11. Juodzbalys G, Kubilius M. Clinical and radiological classification of the jawbone anatomy in endosseous dental implant treatment. ***J Oral Maxillofac Res*** 2013; 4: e2.
12. Hawkins VM, Papadopoulou AK, Wong M, Pandis N, Dalci O, Darendeliler MA. The effect of piezocision vs no piezocision on maxillary extraction space closure: A split-mouth, randomized controlled clinical trial. ***Am J Orthod Dentofacial Orthop*** 2022: 161: 7-19.
13. Fernandes LSDMCP, Figueiredo DSF, Oliveira DD, Houara RG, Rody WJ, Jr, Gribel BF, *et al.* The effects of corticotomy and piezocision in orthodontic canine retraction: a randomized controlled clinical trial. ***Prog Orthod*** 2021; 22: 37.
14. Al-Naoum F, Hajeer MY, Al-Jundi A. Does alveolar corticotomy accelerate orthodontic tooth movement when retracting upper canines? A split-mouth design randomized controlled trial. ***J Oral Maxillofac Surg*** 2014; 72: 1880-9.
15. Dubravko Pavlin RA, Vishnu Raj, Peter T. Gakunga. Cyclic loading (vibration) accelerates tooth movement in orthodontic patients: A double-blind, randomized controlled trial. ***Semin Orthod*** 2015; 21: 187-94.
16. Pongsamart P, Luppanapornlarp S, Pornprasertsuk-Damrongsri S, Boonpratham S, Santiwong P. Stability of miniscrews with different continuous orthodontic forces as measured by cone-beam computed tomography. ***Orthod Waves*** 2014; 73: 48-54.
17. El-Beialy AR, Abou-El-Ezz AM, Attia KH, El-Bialy AM, Mostafa YA. Loss of anchorage of miniscrews: a 3-dimensional assessment. ***Am J Orthod Dentofacial Orthop*** 2009; 136: 700-7.

18. Aboul-Ela SM, El-Beialy AR, El-Sayed KM, Selim EM, El-Mangoury NH, Mostafa YA. Miniscrew implant-supported maxillary canine retraction with and without corticotomy-facilitated orthodontics. *Am J Orthod Dentofacial Orthop* 2011; 139: 252-9.
19. Kravitz ND, Kusnoto B. Risks and complications of orthodontic miniscrews. *Am J Orthod Dentofacial Orthop* 2007; 131: S43-51.
20. Cheng SJ, Tseng IY, Lee JJ, Kok SH. A prospective study of the risk factors associated with failure of mini-implants used for orthodontic anchorage. *Int J Oral Maxillofac Implants* 2004; 19: 100-6.
21. Kuroda S, Yamada K, Deguchi T, Hashimoto T, Kyung HM, Takano-Yamamoto T. Root proximity is a major factor for screw failure in orthodontic anchorage. *Am J Orthod Dentofacial Orthop* 2007; 131: S68-73.
22. Mezomo M, de Lima ES, de Menezes LM, Weissheimer A, Allgayer S. Maxillary canine retraction with self-ligating and conventional brackets. *Angle Orthod* 2011; 81: 292-7.
23. Charushila C, Daokar ST. Comparison of rate of retraction and anchorage loss using nickel titanium closed coil springs and elastomeric chain during the en-masse retraction: A clinical study. *J Orthod Res* 2015; 3: 129-33.
24. Sherrard JF, Rossouw PE, Benson BW, Carrillo R, Buschang PH. Accuracy and reliability of tooth and root lengths measured on cone-beam computed tomographs. *Am J Orthod Dentofacial Orthop* 2010; 137(4 Suppl): S100-8.
25. Elkalza AR, Hashem AS, Alam MK. Comparative study of root resorption between two methods for accelerated orthodontic tooth movement. *J Oral Res* 2018; 7: 348-53.
26. Alqadasi B, Aldhorae K, Halboub E, Mahgoub N, Alnasri A, Assiry A, *et al.* The effectiveness of micro-osteoperforations during canine retraction: A three-dimensional randomized clinical trial. *J Int Soc Prev Community Dent* 2019; 9: 637-45.
27. Patterson BM, Dalci O, Papadopoulou AK, Madukuri S, Mahon J, Petocz P, *et al.* Effect of piezocision on root resorption associated with orthodontic force: A microcomputed tomography study. *Am J Orthod Dentofacial Orthop* 2017; 151: 53-62.
28. Charavet C, Lecloux G, Bruwier A, Rompen E, Maes N, Limme M, *et al.* Localized piezoelectric alveolar decortication for orthodontic treatment in adults: A randomized controlled trial. *J Dent Res* 2016; 95: 1003-9.
29. Viwattanatipa N, Charnchairerk S. The effectiveness of corticotomy and piezocision on canine retraction: A systematic review. *Korean J Orthod* 2018; 48: 200-11.
30. Ribeiro G, Jacob H. Understanding the basis of space closure in orthodontics for a more efficient orthodontic treatment. *Dental Press J Orthod* 2016; 21: 115-25.
31. Hamid F, Bangash AA, Saeed M, Tariq S, Khan, M. Comparison of rate of retraction of canine on round and rectangular wires. *Pak Armed Forces Med J* 2020; 70: 740-5.
32. AlShazly RM, Almohammad AF, ElSayed HS, El-Beialy AR. Evaluation of maxillary first molar rotation during direct miniscrew-supported maxillary canine retraction: a before-and-after study. *Bull Natl Res Cent* 2021; 45: 160-3.
33. Yi J, Xiao J, Li Y, Li X, Zhao Z. Efficacy of piezocision on accelerating orthodontic tooth movement: A systematic review. *Angle Orthod* 2017; 87: 491-8.

CONSORT FLOW DIAGRAM