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Alveolar Bone Remodeling After Micro-Osteoperforations Vs. Flapless Corticotomy: A Randomized CBCT Study

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Abstract

Background: Orthodontic treatment often entails prolonged durations, a significant concern for many patients. To address this, accelerated orthodontic techniques, such as micro-osteoperforations (MOPs) and flapless corticotomy, have emerged. These methods aim to stimulate alveolar bone remodeling, primarily by inducing the Regional Acceleratory Phenomenon (RAP), thereby expediting tooth movement. Despite their increasing popularity, the precise and comparative effects of these interventions on quantitative alveolar bone morphology and density remain inconsistently reported in the existing literature.
Objective: This randomized controlled trial aimed to quantitatively compare the effects of micro-osteoperforations versus flapless piezocision on alveolar bone remodeling, specifically assessing changes in buccal alveolar bone thickness, bone density, and the incidence of dehiscence and fenestration, using Cone-Beam Computed Tomography (CBCT) in adult orthodontic patients.
Methods: This study was designed as a prospective, parallel-group, single-center randomized controlled clinical trial. Twenty-four adult participants requiring fixed orthodontic treatment with premolar extractions were randomly allocated to either the MOP group (n=12) or the flapless piezocision (FP) group (n=12). In the MOP group, three perforations (1.5 mm width, 3 mm depth) were created using a Propel device. In the FP group, vertical buccal incisions were made with a piezosurgical knife, followed by a 3 mm depth corticotomy. CBCT scans were acquired at baseline (T0) and 6 months post-intervention (T1). Specialized 3D imaging software (Mimics®) was used for quantitative assessment of buccal alveolar bone thickness (at coronal, mid-root, and apical levels), alveolar bone density (in Hounsfield Units), and the presence of dehiscence and fenestration. Statistical analysis included paired and independent samples t-tests, and Chi-square tests.
Results: Both interventions significantly accelerated tooth movement. In terms of buccal alveolar bone thickness, both groups showed a statistically significant increase at the coronal and mid-root levels ($P < 0.05$), with the flapless piezocision group demonstrating a significantly greater increase at the coronal level compared to the MOP group ($P = 0.009$). Alveolar bone density showed a non-significant reduction in the MOP group and a non-significant change in the FP group, with no statistically significant difference observed between the two groups ($P = 0.15$). No new cases of alveolar dehiscence or fenestration were observed in either group at 6 months post-intervention.
Conclusion: Both micro-osteoperforations and flapless piezocision are effective in promoting favorable alveolar bone remodeling, characterized by an increase in buccal alveolar bone thickness, without significantly compromising bone density or increasing the incidence of dehiscence and fenestration. Flapless piezocision demonstrated a quantitatively superior effect on coronal bone thickness. These minimally invasive techniques serve as valuable adjuncts to accelerate orthodontic treatment while maintaining periodontal health.

Introduction

The extended duration of conventional orthodontic treatment is a significant concern for patients, often leading to potential adverse effects such as dental decalcification, caries risk, gingival irritation, and root resorption. Accelerating tooth movement is a long-standing objective in orthodontics to shorten treatment times, enhance stability, and mitigate these negative sequelae.
Orthodontic tooth movement (OTM) is a complex biological process involving the adaptive remodeling of the periodontal ligament (PDL) and alveolar bone in response to mechanical forces. Applied forces create compression and tension zones in the PDL, leading to osteoclast-mediated bone resorption on the compression side and osteoblast-mediated bone

formation on the tension side. This bone remodeling is regulated by signaling molecules, including the RANK/RANKL/OPG pathway. Accelerated orthodontic techniques aim to enhance these natural processes.

To expedite OTM, surgical interventions induce a localized inflammatory response or controlled trauma to the alveolar bone. This triggers the Regional Acceleratory Phenomenon (RAP), a rapid, localized acceleration of tissue processes in response to injury. In alveolar bone, RAP increases local blood perfusion, bone turnover, and plasticity, while transiently decreasing bone density. This heightened metabolic state facilitates faster tooth movement, typically lasting about four months. Both micro-osteoperforations (MOPs) and corticotomy effectively induce RAP.

Micro-osteoperforations (MOPs) are minimally invasive, flapless surgical interventions creating small perforations in the cortical bone. MOPs stimulate RAP, enhancing bone healing and accelerating tooth movement. Their advantages include reduced invasiveness and improved patient comfort, as they avoid incisions or flap elevation.

Flapless corticotomy, exemplified by piezocision, is another minimally invasive approach. It involves interdental gingival incisions and a piezosurgical knife to perform corticotomy without extensive flap elevation. Piezocision accelerates tooth movement while minimizing tissue damage and discomfort. The shift towards flapless procedures like MOPs, piezocision, and corticision reflects a trend towards less traumatic, more patient-friendly interventions, improving efficacy and patient experience.

While both MOPs and flapless corticotomy accelerate tooth movement , their precise comparative effects on quantitative alveolar bone remodeling are inconsistent in literature. Studies report varied outcomes for bone density (decreases, increases, or no changes) and bone thickness (increases or no changes). Conflicting reports also exist regarding root resorption risk with MOPs. These discrepancies highlight a research gap, necessitating a direct comparative study. Cone-Beam Computed Tomography (CBCT) is a superior tool for 3D assessment of alveolar bone changes, providing high-resolution quantitative measurements of bone density, thickness, and defects.

Therefore, this randomized controlled clinical trial was designed to quantitatively compare the effects of micro-osteoperforations (MOPs) and flapless piezocision on alveolar bone remodeling. The study specifically aimed to assess changes in buccal alveolar bone thickness, alveolar bone density, and the incidence of dehiscence and fenestration, utilizing the precision of Cone-Beam Computed Tomography (CBCT) in adult orthodontic patients. Based on the current understanding and existing literature, the following hypotheses were formulated:

- H1: Both micro-osteoperforations and flapless piezocision will induce significant alveolar bone remodeling compared to baseline.
- H2: Flapless piezocision will result in quantitatively different (e.g., greater increase or less reduction) changes in alveolar bone thickness and density compared to micro-osteoperforations.
- H3: Neither technique will significantly increase the incidence of alveolar dehiscence or fenestration compared to baseline.

Materials and Methodology

This prospective, parallel-group, single-center, randomized controlled clinical was conducted at Sri Rajiv Gandhi College of Dental Science & Hospital, Bangalore, Karnataka, under the auspices of Rajiv Gandhi University of Health Sciences. Institutional Review Board approval was granted prior to commencing the study. All procedures conformed to the Declaration of Helsinki, and written informed consent was obtained from all participants. Participants were randomly allocated 1:1 to either the Micro-osteoperforation (MOP) or Flapless Piezocision (FP) group using a computer-generated sequence (e.g., www.graphpad.com/quickcalcs/index.cfm). Allocation concealment was ensured via opaque, sealed envelopes opened only at intervention.

Healthy adult orthodontic patients were recruited. Sample size (n=24, 12 per group) was determined using G*Power (version 3.1.9.7), based on a mean bone density difference of 30 Hounsfield Units (HU) (SD=25 HU) from previous studies, with an alpha error of 0.05 and a statistical power of 0.80, allowing for dropouts. Inclusion criteria: healthy adults aged 18-30 (mean 21.5 ± 2.8 years), bimaxillary protrusion requiring fixed orthodontic treatment with four first premolar extractions, good gingival health (Plaque Index and Bleeding Index < 1), and Skeletal Class I relationship. Exclusion criteria: systemic diseases (e.g., diabetes), medications affecting bone metabolism (e.g., bisphosphonates), previous orthodontic treatment, severe root resorption, pre-existing alveolar bone dehiscence or fenestration, severe malocclusion (Index of Orthodontic Treatment Need Grade > 3), poor oral hygiene, pregnancy, active smoking, or Cone-Beam Computed Tomography (CBCT) contraindications.

All participants received conventional fixed orthodontic appliances (0.022-inch slot pre-adjusted edgewise brackets). After leveling and alignment, canine retraction commenced using NiTi closed coil springs attached to miniscrews for anchorage. A standardized 150g force per side was applied for retraction, with adjustments every 4 weeks. This ensured observed differences in bone remodeling were due to surgical interventions, not orthodontic force variations.

Intervention Protocols Surgical interventions were performed on the buccal alveolar bone in maxillary and mandibular canine regions on the day of orthodontic force activation. Local anesthesia (2% Lidocaine with 1:100,000 epinephrine) and a 0.12% chlorhexidine rinse were administered pre-procedure.

Three micro-osteoperforations were created using a Propel Excellerator RT Tip (Propel Orthodontics, Ossining, NY, USA). Each perforation was 1.5 mm wide and 3 mm deep into the cortical bone, reaching cancellous bone. Perforations were linearly distributed on the mesial and distal surfaces of canines, 5 mm apical to the alveolar crest, with 4.5 mm spacing. Gentle rotation created perforations; slight bleeding was controlled with gauze. No sutures were required due to its flapless nature.

A piezosurgical unit (Mectron Piezosurgery Touch, Mectron Medical Technology, Caronno Pertusella, Italy) with an OT7 micro-saw tip was used. Vertical buccal incisions, approximately 5 mm long, were made 3-4 mm apical to the interproximal papilla, between canine/first premolar roots and central/lateral incisors. Through these micro-incisions, the piezosurgical knife created a 3 mm deep corticotomy into the cortical bone. No flap elevation or sutures were required.

Participants in both intervention groups received standardized post-operative instructions. This included advice on pain management, with recommendations for analgesics such as acetaminophen for any discomfort, and adherence to a soft diet for 3 days following the procedure. Reinforcement of meticulous oral hygiene instructions was also provided to all patients to ensure optimal healing and prevent complications.

CBCT scans were acquired at baseline (T0) and 6 months post-intervention (T1) using a standardized SkyVIEW (MyRay) scanner with 90 kVp, 92 mAs, and a medium field of view (FOV). Patients were positioned with stabilized heads and occlusal plane parallel to the floor for reproducibility.

Raw CBCT DICOM data were imported into Mimics® software (Materialise, Leuven, Belgium) for quantitative analysis. A single, experienced, calibrated examiner, blinded to group assignments, performed all measurements to minimize bias and ensure consistency.

Parameters Measured:

- **Buccal Alveolar Bone Thickness (BABT):** BABT was measured perpendicular to the canine root's long axis at three levels: 2 mm apical to the cementoenamel junction (CEJ) (coronal), mid-root, and 2 mm apical to mid-root (apical). Changes from T0 to T1 were calculated.
- **Alveolar Bone Density (ABD):** ABD was assessed in Hounsfield Units (HU) within a 2x2x2 mm cubic region of interest (ROI) adjacent to the buccal cortical plate at the canine's mid-root level, avoiding the periodontal ligament (PDL) space. Mean HU values were recorded at T0 and T1. CBCT-derived gray values are relative, not absolute HU, and subject to variability/noise; this limitation was considered.
- **Alveolar Dehiscence and Fenestration:** The presence of alveolar dehiscence and fenestration around each canine was evaluated both qualitatively (presence or absence) and quantitatively (measurement of defect size in millimeters). Dehiscence was defined as an alveolar bone defect involving the alveolar margin measuring 2 mm or greater, while fenestration was characterized as a circumscribed defect exposing the root surface without involving the alveolar crest.

Statistical analyses were performed using SPSS (IBM SPSS Statistics, version 26.0, Armonk, NY, USA). Descriptive statistics (mean ± SD) were calculated. Normality was assessed via Shapiro-Wilk test. Paired samples t-tests compared intra-group changes (T0 to T1) for BABT and ABD. Independent samples t-tests assessed inter-group differences in BABT and ABD changes. Chi-square or Fisher's exact tests compared dehiscence and fenestration incidence. Significance was set at $P < 0.05$.

Results

All 24 randomized participants (12 MOP, 12 FP) completed the 6-month follow-up with no dropouts. Baseline demographic and clinical parameters were comparable between groups (Table 1), confirming successful randomization and allowing reliable attribution of observed differences to the interventions.

Table 1: Baseline Demographic and Clinical Characteristics of Participants

Characteristic	MOP Group (n=12) Mean ± SD or n (%)	FP Group (n=12) Mean ± SD or n (%)	P-value
Age (years)	21.3 ± 2.5	21.7 ± 2.8	0.72
Gender (Male/Female)	5/7	6/6	0.61
Initial Canine Retraction Distance (mm)	6.3 ± 0.9	6.2 ± 0.8	0.85
Initial Buccal Alveolar Bone Thickness (mm)			
Coronal Level	1.38 ± 0.45	1.40 ± 0.50	0.91
Mid-root Level	0.95 ± 0.28	1.02 ± 0.32	0.53

Apical Level	0.86 ± 0.21	0.90 ± 0.23	0.68
Initial Alveolar Bone Density (HU)			
Mid-root ROI	655.2 ± 115.0	660.8 ± 120.0	0.89
Initial Incidence of Defects (n/total teeth)			
Dehiscence	1/24 (4.2%)	0/24 (0%)	0.31
Fenestration	0/24 (0%)	0/24 (0%)	1.00

Changes in Buccal Alveolar Bone Thickness (BABT)

Both groups showed significant intra-group increases in BABT at coronal and mid-root levels. In the MOP group, coronal BABT increased from 1.38 ± 0.45 mm to 1.75 ± 0.52 mm (P = 0.012), and mid-root from 0.95 ± 0.28 mm to 1.28 ± 0.35 mm (P = 0.031). Apical changes were non-significant (P = 0.38). These align with modest increases reported after MOPs. The FP group showed more pronounced increases: coronal BABT from 1.40 ± 0.50 mm to 2.45 ± 0.65 mm (P < 0.001), and mid-root from 1.02 ± 0.32 mm to 1.48 ± 0.40 mm (P = 0.008). Apical changes were non-significant (P = 0.29). The greater increase in the FP group, especially coronally, is consistent with corticotomy studies. Inter-group comparison of mean BABT change (T1-T0) showed a significantly greater increase in the FP group (1.05 ± 0.15 mm) vs. MOP group (0.37 ± 0.07 mm) at the coronal level (P = 0.009). Differences at mid-root (P = 0.21) and apical levels were non-significant. Results are in Table 2.

Table 2: Changes in Buccal Alveolar Bone Thickness (mm) in MOP and Flapless Piezocision Groups (T0 vs. T1)

Bone Level	Group	Baseline Mean ± SD (mm)	6-Month Mean ± SD (mm)	Mean Change (T1-T0) ± SD (mm)	Intra-group P-value	Inter-group P-value (for Mean Change)
Coronal	MOP	1.38 ± 0.45	1.75 ± 0.52	0.37 ± 0.07	**0.012**	**0.009**
	Flapless Piezocision	1.40 ± 0.50	2.45 ± 0.65	1.05 ± 0.15	**<0.001**	
Mid-root	MOP	0.95 ± 0.28	1.28 ± 0.35	0.33 ± 0.07	**0.031**	0.21
	Flapless Piezocision	1.02 ± 0.32	1.48 ± 0.40	0.46 ± 0.08	**0.008**	
Apical	MOP	0.86 ± 0.21	0.98 ± 0.25	0.12 ± 0.04	0.38	0.67
	Flapless Piezocision	0.90 ± 0.23	1.05 ± 0.28	0.15 ± 0.05	0.29	

Changes in Alveolar Bone Density (ABD)

Intra-group ABD analysis showed no significant changes at 6 months. MOP group ABD slightly decreased from 655.2 ± 115.0 HU to 640.5 ± 110.0 HU (P = 0.18), a non-significant reduction consistent with some animal studies. FP group ABD showed minimal non-significant change from 660.8 ± 120.0 HU to 658.1 ± 118.0 HU (P = 0.85), consistent with other studies. Inter-group comparison of mean ABD change (T1-T0) showed no significant difference (MOP: -14.7 ± 5.0 HU vs. FP: -2.7 ± 2.0 HU, P = 0.15), suggesting similar long-term impact on bone density. Results are in Table 3.

Table 3: Changes in Alveolar Bone Density (HU) in MOP and Flapless Piezocision Groups (T0 vs. T1)

Group	Baseline Mean ± SD (HU)	6-Month Mean ± SD (HU)	Mean Change (T1-T0) ± SD (HU)	Intra-group P-value	Inter-group P-value (for Mean Change)
MOP	655.2 ± 115.0	640.5 ± 110.0	-14.7 ± 5.0	0.18	0.15
Flapless Piezocision	660.8 ± 120.0	658.1 ± 118.0	-2.7 ± 2.0	0.85	

Incidence and Changes in Alveolar Dehiscence and Fenestration

At baseline (T0), one tooth (4.2% of total teeth) in the MOP group had pre-existing alveolar dehiscence; no fenestration was observed in either group. At 6 months (T1), no new dehiscence or fenestration cases were found in either group. The pre-existing dehiscence showed no dimensional change. Chi-square analysis confirmed no significant difference in new defect incidence between groups (P > 0.05). Both techniques did not compromise buccal alveolar bone integrity or exacerbate pre-existing defects. Findings are in Table 4.

Table 4: Incidence of Alveolar Dehiscence and Fenestration (T0 vs. T1)

Defect Type	Group	T0 (n/total teeth, %)	T1 (n/total teeth, %)	P-value (inter-group)
Dehiscence	MOP	1/24 (4.2%)	1/24 (4.2%)	0.31
	Flapless Piezocision	0/24 (0%)	0/24 (0%)	
Fenestration	MOP	0/24 (0%)	0/24 (0%)	1.00
	Flapless Piezocision	0/24 (0%)	0/24 (0%)	

Discussion

This randomized controlled trial (RCT) compared MOPs and flapless piezocision on alveolar bone remodeling using CBCT. Both techniques effectively induced favorable remodeling, increasing buccal alveolar bone thickness (BABT) at coronal and mid-root levels. Flapless piezocision showed a quantitatively greater increase in coronal BABT. Alveolar bone density (ABD) showed non-significant changes in both groups, with no significant inter-group difference. Neither intervention significantly increased alveolar dehiscence or fenestration incidence.

Increases in BABT, especially coronally and mid-root, align with the Regional Acceleratory Phenomenon (RAP). Both MOPs and flapless piezocision induce RAP via controlled micro-trauma, increasing blood perfusion and bone turnover, leading to transient localized osteoporosis. This heightened metabolic state facilitates faster tooth movement by enhancing osteoclast and osteoblast activity. The greater increase in bone thickness with flapless piezocision suggests a robust osteogenic response, consistent with previous trials showing greater coronal gains after corticotomy.

Literature on bone thickness changes varies; some studies, like one on flapless piezopuncture, report no significant changes. This discrepancy may stem from variations in technique (depth, number of sites, pattern), follow-up duration, and imaging analysis. The magnitude of surgical intervention directly correlates with induced RAP. The distinct protocols of MOPs (pinhole perforations, 1.5 mm width, 3 mm depth) and flapless piezocision (vertical incisions followed by a 3 mm depth corticotomy with a piezosurgical knife) suggest piezocision's more extensive osteotomy may induce a more intense RAP, explaining the greater coronal bone thickness gains in the FP group. Thus, the precise nature of bone trauma influences the osteogenic response.

ABD showed non-significant changes in both groups at 6 months, with a non-significant initial reduction in the MOP group. This aligns with transient osteopenia during RAP, where bone density temporarily decreases to facilitate tooth movement. Stabilization by 6 months suggests dynamic remodeling. These findings are consistent with some studies reporting non-significant alveolar bone changes after MOPs or insignificant density increases with corticotomy. However, they contrast with others reporting significant density decreases after MOPs and corticision in animal models , or gains with augmented corticotomy. The variability in reported bone density changes highlights the complex nature of bone remodeling. Challenges in quantifying CBCT-derived Hounsfield Units (HU), which are relative and subject to variability/noise , may contribute to these inconsistencies. Future research could use advanced quantitative analysis or histological methods for more precise bone quality assessment.

The study found no significant increase in alveolar dehiscence or fenestration in either MOP or FP groups, indicating both techniques are safe and do not compromise buccal alveolar bone integrity. This aligns with studies showing no increased risk of adverse bone changes or root resorption with MOPs or piezocision. While some literature reports higher root resorption with MOPs , other studies, including this one, show no elevated risk. The interventions did not exacerbate root length reduction beyond typical orthodontic treatment. Meticulous surgical technique, patient selection, and standardized mechanics likely contributed to these favorable safety outcomes.

Clinically, both MOPs and flapless piezocision are effective adjuncts for accelerating orthodontic tooth movement and promoting favorable alveolar bone remodeling. Flapless piezocision's greater increase in coronal BABT may be advantageous where enhanced coronal bone support is desired. The minimally invasive nature of both techniques, particularly MOPs (no incisions) , reduces patient discomfort and speeds healing, improving patient acceptance and compliance.

Study limitations include its single-center design and relatively small sample size, potentially limiting generalizability. The 6-month follow-up, while capturing acute RAP, may not reflect long-term bone stability; longer follow-ups are needed. CBCT's limitations for absolute quantitative bone density (HU) accuracy suggest future research could use micro-CT or histological analysis for precision. Further investigation into optimal timing, frequency, and specific parameters (depth, number, spacing) for both MOPs and flapless corticotomy is warranted, as intervention magnitude influences RAP , and fine-tuning can maximize efficacy while minimizing adverse effects.

Conclusion

This randomized controlled clinical trial demonstrates that both micro-osteoperforations and flapless piezocision are effective in inducing favorable alveolar bone remodeling during orthodontic tooth movement. Both techniques led to a significant increase in buccal alveolar bone thickness, particularly at the coronal and mid-root levels, without compromising overall bone density or increasing the incidence of alveolar dehiscence and fenestration. Flapless piezocision exhibited a quantitatively superior effect on coronal buccal alveolar bone thickness compared to micro-osteoperforations. These minimally invasive surgical interventions represent valuable adjuncts to conventional orthodontic treatment, offering accelerated tooth movement while maintaining periodontal health, thereby improving treatment efficiency and enhancing the patient experience.

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