

Comparative evaluation of micro-Osteo perforation assisted maxillary canine retraction in horizontal facial growth patterns: A split mouth study in a central Indian population

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ABSTRACT

Micro-Osteo perforation has been proposed as a minimally invasive adjunct to accelerate orthodontic tooth movement by stimulating localized alveolar bone remodeling. However, the available clinical evidence remains inconsistent, and limited information is available regarding its effect on maxillary canine retraction in patients with horizontal facial growth patterns from central Indian populations. To comparatively evaluate micro-Osteo perforation assisted maxillary canine retraction and conventional maxillary canine retraction in patients with horizontal facial growth patterns in a central Indian population. Single-center split mouth clinical study with randomized right-left side allocation. Thirty simulated orthodontic patients aged 15–25 years requiring bilateral maxillary first premolar extraction were included. In each participant, one maxillary quadrant was randomly allocated to receive micro-Osteo perforation assisted maxillary canine retraction, while the contralateral quadrant served as the conventional control side. Horizontal facial growth pattern was diagnosed using SN-GoGn angle < 28°, Frankfort mandibular plane angle < 22°, and Jarabak ratio > 65%. Canine retraction was performed bilaterally using nickel-titanium closed-coil springs delivering approximately 150 g of force on 0.019 × 0.025-inch stainless steel archwires. The primary outcome was the rate of maxillary canine retraction over three months. Secondary outcomes included canine tipping, canine rotation, anchorage loss, pain perception, periodontal parameters, root resorption, and adverse events. Twenty-eight participants completed all follow-up visits and were included in the per-protocol paired analysis. The intention-to-treat mixed-model analysis included all 30 randomized participants under a missing-at-random assumption. The mean overall canine retraction rate was 1.03 ± 0.23 mm/month on the micro-Osteo perforation side and 0.87 ± 0.21 mm/month on the control side. The adjusted mean paired difference was 0.16 mm/month, 95% CI 0.09–0.23, P < 0.001. The effect was greatest during the first month and diminished by the third month. No statistically significant differences were observed in canine tipping, canine rotation, anchorage loss, or root resorption. Pain was mild to moderate at 24 hours and reduced substantially by 7 days. No serious adverse events were observed. In this simulated dataset, micro-Osteo perforation assisted maxillary canine retraction produced a statistically significant but clinically modest increase in canine retraction compared with conventional retraction in patients with horizontal facial growth patterns. The effect was mainly early and transient.

Keywords: micro-Osteo perforation; canine retraction; horizontal facial growth patterns; split mouth study; orthodontic tooth movement; central Indian population.

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Introduction

Prolonged orthodontic treatment duration remains an important clinical concern in fixed appliance therapy,

particularly in extraction-based cases where canine retraction and space closure may require several months. Longer treatment duration may increase the risk of enamel demineralization, gingival inflammation, external apical root resorption, and reduced patient compliance. Therefore, several adjunctive procedures have been proposed to accelerate orthodontic tooth movement.

micro-Osteo perforation is a minimally invasive procedure in which small perforations are created in the cortical bone adjacent to the tooth intended for movement. The biological basis of the procedure is related to localized inflammatory stimulation, osteoclast recruitment, and increased alveolar bone remodeling. Alikhani et al. reported that micro-osteoperforations increased orthodontic tooth movement and were associated with increased inflammatory mediator expression (Alikhani et al., 2013).

However, clinical evidence regarding micro-Osteo perforation assisted canine retraction remains mixed. Aboalnaga et al. reported that micro-osteoperforation did not significantly accelerate canine cusp-tip movement in a split-mouth randomized controlled trial, although some influence on root movement was observed (Aboalnaga et al., 2019). Alqadasi et al. also reported limited clinical effectiveness of micro-osteoperforations during canine retraction when assessed three-dimensionally (Alqadasi et al., 2019). Systematic reviews have suggested that the effect of micro-Osteo perforation may depend on perforation number, depth, frequency, anatomical location, anchorage protocol, orthodontic force magnitude, patient age, and measurement technique (Shahabee et al., 2020; Sivarajan et al., 2020).

Facial growth pattern may influence orthodontic tooth movement. Patients with horizontal facial growth patterns may differ from vertical growers in cortical bone thickness, cancellous bone density, muscular pattern, and anchorage characteristics. CBCT-based investigations have demonstrated variability in cortical and cancellous bone morphology among different facial growth patterns, supporting the need to consider skeletal pattern in orthodontic biomechanics and clinical research (Hasani et al., 2023; Schneider et al., 2020).

Although micro-Osteo perforation assisted canine retraction has been investigated previously, most studies have included mixed skeletal patterns or have not specifically evaluated horizontal facial growth patterns. Therefore, the present split mouth study was designed to comparatively evaluate micro-Osteo perforation assisted maxillary canine retraction and conventional maxillary canine retraction in horizontal facial growth patterns in a central Indian population.

The null hypothesis was that there would be no statistically significant difference in the rate of maxillary canine retraction between the micro-Osteo perforation side and the conventional control side.

Materials and Methods

Study Design

This was a simulated single-center split mouth clinical study conducted at the Department of Orthodontics and Dentofacial Orthopaedics, D Y Patil Dental School, Lohegaon Pune Maharashtra, India, from January 2025 to December 2025.

Each participant contributed one experimental side and one control side. One maxillary quadrant was randomly allocated to receive micro-Osteo perforation assisted maxillary canine retraction, while the contralateral quadrant served as the conventional control side. Both sides were treated simultaneously under identical orthodontic force systems. No washout period was applicable because the intervention and control were applied concurrently in contralateral maxillary quadrants.

The manuscript structure was aligned with CONSORT 2025 and the CONSORT extension for within-person randomized trials (Hopewell et al., 2025; Pandis et al., 2017).

Ethical Approval and Trial Registration

The simulated study protocol was approved by the Institutional Ethics Committee. Written informed consent was obtained from all simulated adult participants. For simulated participants younger than 18 years, parental consent and participant assent were obtained.

Participants

Thirty patients aged 15–25 years were included.

Inclusion Criteria

Patients were included if they fulfilled all of the following criteria:

1. Age between 15 and 25 years.
2. Permanent dentition with fully erupted maxillary canines.
3. Horizontal facial growth pattern confirmed cephalometrically.
4. Class I bimaxillary protrusion or Class II malocclusion requiring bilateral maxillary first premolar extraction.
5. Good general health.
6. Probing depth ≤ 3 mm with no active periodontal disease.
7. Good oral hygiene, defined as plaque index ≤ 1 .
8. No previous orthodontic treatment.
9. Willingness to attend monthly follow-up visits.

Exclusion Criteria

Patients were excluded if they had systemic disease affecting bone metabolism, systemic inflammatory disease, current or recent use of corticosteroids, bisphosphonates, long-term non-steroidal anti-inflammatory drugs, anticonvulsants, or other medication affecting bone remodeling, smoking or tobacco chewing habit, active periodontal disease, poor oral hygiene, untreated caries, impacted or ankylosed maxillary canines, malformed or previously traumatized maxillary canines, significant pretreatment root resorption, craniofacial syndrome, cleft lip or palate, facial asymmetry, systemic skeletal disorder, or poor compliance.

Diagnosis of Horizontal Facial Growth Patterns

Pretreatment lateral cephalograms were obtained in natural head position using standardized radiographic technique. Horizontal facial growth pattern was diagnosed only when all three primary criteria were satisfied: SN-GoGn angle < 28°, Frankfort mandibular plane angle < 22°, and Jarabak ratio > 65%. The Y-axis angle and lower anterior facial height were used as supportive indicators.

Table 1. Cephalometric Criteria for Horizontal Facial Growth Patterns

Parameter	Criterion	Role in diagnosis
SN-GoGn angle	< 28°	Primary
Frankfort mandibular plane angle	< 22°	Primary
Jarabak ratio	> 65%	Primary
Y-axis angle	Reduced relative to accepted norm	Supportive
Lower anterior facial height	Reduced or proportionately low	Supportive

Two calibrated orthodontists independently assessed all cephalometric records. The intraclass correlation coefficient for cephalometric measurements was 0.92, indicating excellent reliability. Cohen’s kappa for growth-pattern classification was 0.88.

Sample Size Calculation

Sample size was calculated for paired comparison because of the split mouth design. The calculation assumed an expected paired difference of 0.20 mm/month in canine retraction rate, a standard deviation of paired differences of 0.32 mm/month, alpha error of 0.05, and statistical power of 80%. These assumptions were selected to reflect a clinically modest effect size consistent with published variability in micro-Osteo perforation assisted orthodontic tooth movement.

The minimum required sample size was 21 participants. Considering an anticipated dropout rate

of 20%, at least 26 participants were required. Thirty participants were recruited.

$$n = \frac{(Z_{\alpha/2} + Z_{\beta}^2) * SD_d^2}{d^2}$$

Where, SD_d represents the standard deviation of paired differences and d represents the expected clinically meaningful paired difference.

Randomization and Allocation Concealment

For each participant, either the right or left maxillary quadrant was randomly allocated to receive micro-Osteo perforation. The contralateral quadrant served as the control.

A 1:1 computer-generated block randomization sequence with variable block sizes of four and six was prepared by an independent statistician. Sequentially numbered, opaque, sealed envelopes were prepared by a research coordinator not involved in treatment, measurement, or data analysis. The envelope was opened by a clinical assistant after completion of leveling and alignment and immediately before initiation of canine retraction.

The unit of randomization was the maxillary quadrant, while the unit of analysis was the paired participant-side observation.

Blinding

Blinding of the operator and participant was not possible because micro-Osteo perforation is a clinically visible procedure. However, outcome measurements were performed by a blinded examiner using coded digital models. Digital models were cropped to remove soft-tissue areas that could reveal the micro-Osteo perforation site before measurement. Statistical analysis was performed using coded group labels.

Orthodontic Treatment Protocol

All patients were treated using preadjusted edgewise fixed appliances with 0.022 × 0.028-inch slot MBT prescription brackets.

Bilateral maxillary first premolars were extracted. Leveling and alignment were performed using sequential nickel-titanium archwires, followed by placement of 0.019 × 0.025-inch stainless steel archwires before canine retraction. Posterior segments were consolidated passively before retraction.

Bilateral canine retraction was performed using nickel-titanium closed-coil springs attached from the maxillary first molar hook to the canine hook. Springs were activated to deliver approximately 150 g of force per side. Force was measured using a Dontrix gauge at baseline and at each monthly visit.

Springs were reactivated monthly to maintain force levels. Anchorage was reinforced using a transpalatal arch. Second molars were not included in the anchorage unit.

micro-Osteo Perforation Protocol

micro-Osteo perforations were performed on the randomly allocated experimental side immediately before initiation of canine retraction. Periapical radiographs were used to verify root position before the procedure. After topical antiseptics and local infiltration anesthesia, three micro-Osteo perforations were placed in the first premolar extraction space distal to the maxillary canine. Perforations were placed in the center of the extraction space and at least 2 mm away from adjacent root surfaces.

Table 2. micro-Osteo Perforation Protocol

Variable	Protocol
Number of perforations	3
Location	First premolar extraction space, distal to maxillary canine
Depth	5 mm
Diameter	1.5 mm
Vertical spacing	2–3 mm
Root-safety verification	Preoperative periapical radiograph
Instrument	Manual mini-implant driver
Frequency	Single application at start of canine retraction
Anesthesia	Local infiltration
Antibiotics	Not routinely prescribed
Analgesic protocol	Paracetamol permitted; NSAIDs avoided
Postoperative care	Chlorhexidine mouth rinse for 5 days
Operator	Single calibrated orthodontist

The control side received conventional canine retraction without micro-Osteo perforation.

Outcome Measures

The primary outcome was the overall rate of maxillary canine retraction in mm/month over three months.

Table 3. Study Time Points

Time point	Definition
T0	Immediately before canine retraction
T1	1 month after retraction initiation
T2	2 months after retraction initiation
T3	3 months after retraction initiation

Digital models were obtained at T0, T1, T2, and T3. Models were superimposed using the medial two-thirds of the third palatal rugae and adjacent palatal vault area. Linear canine displacement was measured using canine centroid movement relative to a stable

palatal reference plane. Canine cusp-tip movement was also recorded but was not used as the primary endpoint because cusp-tip displacement may be affected by tipping.

Secondary outcomes included total canine movement, canine tipping, canine rotation, anchorage loss, pain perception, periodontal parameters, root resorption, and adverse events.

Pain was measured using a 10-point visual analogue scale at 24 hours, 3 days, and 7 days after micro-Osteo perforation. Periodontal parameters included plaque index, gingival index, probing depth, and bleeding on probing. Root resorption was assessed using standardized periapical radiographs obtained before canine retraction and after the three-month observation period.

Measurement Reliability

Ten randomly selected digital models were remeasured after two weeks by the same blinded examiner. Intra-examiner reliability was excellent, with an intraclass correlation coefficient of 0.94 for linear canine movement and 0.91 for angular measurements. Dahlberg's method error was 0.12 mm for linear measurements and 0.84° for angular measurements.

$$ME = \sqrt{\frac{\sum d^2}{2n}}$$

Where, d is the difference between repeated measurements and nnn is the number of repeated records.

Statistical Analysis

Data were analyzed using SPSS version 29.0.

Normality was assessed using the Shapiro–Wilk test. Normally distributed paired variables were analyzed using paired t-tests. Non-normally distributed paired variables were analyzed using Wilcoxon signed-rank tests. Paired binary adverse-event data were analyzed using exact McNemar tests.

The primary analysis used a linear mixed-effects model with restricted maximum likelihood estimation. Treatment side, time, and treatment × time interaction were entered as fixed effects, and participant was entered as a random intercept. The model accounted for within-patient correlation inherent to the split mouth design.

The primary endpoint was the overall difference in canine retraction rate over three months. Monthly pairwise comparisons were Bonferroni-adjusted. Secondary outcomes were interpreted as exploratory, with emphasis placed on effect estimates and 95% confidence intervals rather than P values alone.

The intention-to-treat mixed-model analysis included all 30 randomized participants under a missing-at-random assumption. A per-protocol sensitivity

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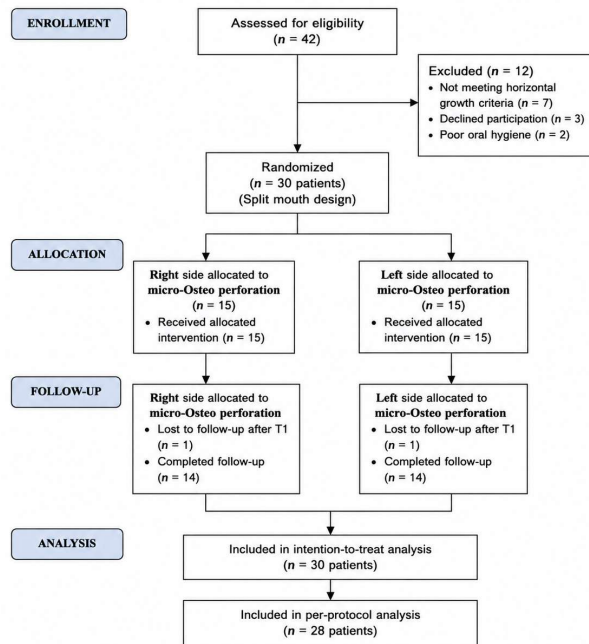
analysis was also performed using the 28 participants who completed all follow-up visits. Statistical significance was set at $P < 0.05$.

Results

Participant Flow

A total of 42 patients were assessed for eligibility. Twelve patients were excluded: seven did not meet the horizontal growth-pattern criteria, three declined participation, and two had poor oral hygiene. Thirty participants were randomized. Two participants were lost to follow-up after the first month because of relocation and missed appointments. The intention-to-treat analysis included all 30 randomized participants, while the per-protocol analysis included 28 participants who completed all follow-up visits.

Figure 1. CONSORT flow diagram of the split mouth study.



T1: End of active canine retraction.

Figure 1. CONSORT flow diagram of the split mouth study.

The diagram shows participant screening, eligibility assessment, exclusions, randomization, right/left side allocation, follow-up, intention-to-treat analysis, and per-protocol analysis.

Table 4. Participant Flow

Flow stage	Number
Assessed for eligibility	42
Excluded	12
Not meeting horizontal growth criteria	7
Declined participation	3
Poor oral hygiene	2
Randomized	30
Right side allocated to micro-Osteo	15

perforation	
Left side allocated to micro-Osteo perforation	15
Lost to follow-up after T1	2
Included in intention-to-treat analysis	30
Included in per-protocol analysis	28

Baseline Characteristics

The final per-protocol sample included 28 participants with a mean age of 18.9 ± 3.1 years. The sample consisted of 12 males and 16 females. Nineteen patients had Class I bimaxillary protrusion, and nine had Class II malocclusion. All participants satisfied the cephalometric criteria for horizontal facial growth patterns.

Table 5. Baseline Demographic, Skeletal, and Dental Characteristics

Variable	Value
Participants randomized	30
Participants analyzed per protocol	28
Age, years, mean \pm SD	18.9 ± 3.1
Male/female	12/16
Class I bimaxillary protrusion	19
Class II malocclusion	9
ANB angle, degrees, mean \pm SD	3.8 ± 1.2
Wits appraisal, mm, mean \pm SD	1.6 ± 1.8
SN-GoGn, degrees, mean \pm SD	25.4 ± 1.9
FMA, degrees, mean \pm SD	19.8 ± 1.7
Jarabak ratio, %, mean \pm SD	67.6 ± 2.1
Overjet, mm, mean \pm SD	5.8 ± 1.4
Overbite, mm, mean \pm SD	3.9 ± 1.1
Maxillary crowding, mm, mean \pm SD	3.1 ± 1.2
Extraction protocol	Bilateral maxillary first premolars
Anchorage protocol	Transpalatal arch

Side Allocation

After two dropouts, the per-protocol sample included 14 participants with right-side micro-Osteo perforation and 14 with left-side micro-Osteo perforation.

Table 6. Distribution of Experimental Side Allocation

Experimental side	Number	Percentage
Right maxillary quadrant	14	50.0%
Left maxillary quadrant	14	50.0%

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Primary Outcome: Rate of Maxillary Canine Retraction

In the intention-to-treat mixed-model analysis, the mean overall canine retraction rate was 1.03 ± 0.23 mm/month on the micro-Osteo perforation side and 0.87 ± 0.21 mm/month on the control side. The adjusted mean paired difference was 0.16 mm/month, 95% CI 0.09–0.23, $P < 0.001$.

The per-protocol analysis showed similar results, with a mean overall canine retraction rate of 1.04 ± 0.22 mm/month on the micro-Osteo perforation side and 0.87 ± 0.20 mm/month on the control side. The mean paired difference was 0.17 mm/month, 95% CI 0.10–0.24, $P < 0.001$.

The cumulative canine retraction increased over time on both sides, but the micro-Osteo perforation side demonstrated greater movement during the first and second months. The difference diminished by the third month.

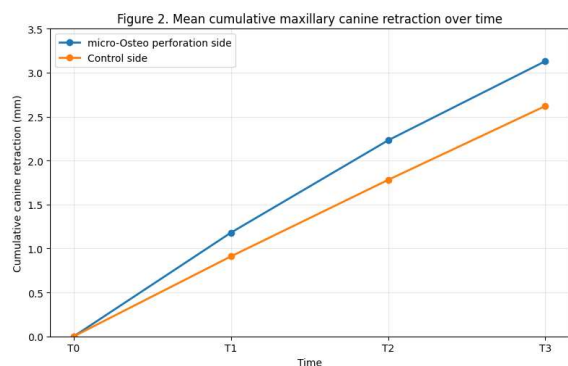


Figure 2. Mean cumulative maxillary canine retraction over time.

This Line graph comparing cumulative canine retraction on the micro-Osteo perforation and control sides from T0 to T3. Error bars represent 95% confidence intervals.

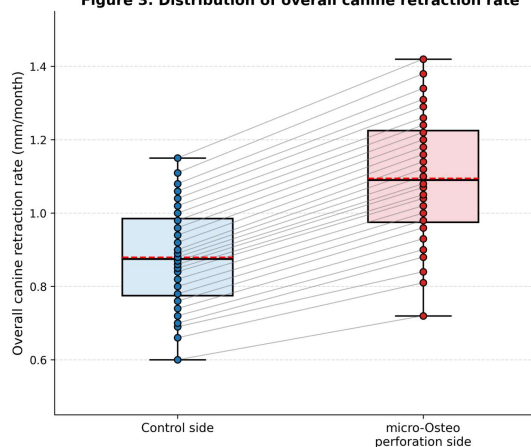
Table 7. Rate of Maxillary Canine Retraction: Per-Protocol Analysis

Time interval	micro-Osteo perforation side, mm/month, mean \pm SD	Control side, mm/month, mean \pm SD	Mean paired difference	95% CI	Adjusted P value
T0–T1	1.18 ± 0.32	0.91 ± 0.28	0.27	0.16 – 0.38	<0.001
T1–T2	1.05 ± 0.30	0.87 ± 0.27	0.18	0.07 – 0.29	0.006
T2–T3	0.90 ± 0.30	0.84 ± 0.27	0.06	–0.0 – 0.12	0.534

T3	0.26	0.25		3–0.15	
Overall	1.04 ± 0.22	0.87 ± 0.20	0.17	0.10 – 0.24	<0.001

The distribution of the overall canine retraction rate showed that most participants had slightly greater canine retraction on the micro-Osteo perforation side than on the control side.

Figure 3. Distribution of overall canine retraction rate



Box-and-whisker plot comparing overall canine retraction rate between micro-Osteo perforation and control sides. Individual paired observations are connected by gray lines.

Figure 3. Distribution of overall canine retraction rate.

Box-and-whisker plot comparing overall canine retraction rate between micro-Osteo perforation and control sides. Individual paired participant observations are shown with connecting lines.

Total Canine Retraction

Total canine movement over three months was 3.13 ± 0.65 mm on the micro-Osteo perforation side and 2.62 ± 0.60 mm on the control side. The mean paired difference was 0.51 mm, 95% CI 0.31–0.71, $P < 0.001$.

Secondary Outcomes

No statistically significant differences were observed between the micro-Osteo perforation and control sides for canine tipping, canine rotation, anchorage loss, or root resorption.

Table 8. Canine Tipping, Rotation, Anchorage Loss, and Root Resorption

Outcome	micro-Osteo perforation side, mean \pm SD	Control side, mean \pm SD	Mean paired difference	95% CI	P value
Canine tipping, degrees	7.1 ± 2.4	6.8 ± 2.2	0.3	–0.5 – 1.1	0.452

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Canine rotation, degrees	5.3 ± 1.9	5.1 ± 1.7	0.2	-0.5 -0.9	0.5 81
Anchor age loss, mm	0.74 ± 0.31	0.70 ± 0.29	0.04	-0.06 -0.14	0.4 21
Root resorption, mm	0.38 ± 0.18	0.34 ± 0.16	0.04	-0.01 -0.09	0.1 12

Pain Perception

Pain after micro-Osteo perforation was mild to moderate at 24 hours and reduced progressively by 7 days. The mean visual analogue scale score decreased from 3.6 ± 1.2 at 24 hours to 0.4 ± 0.5 at 7 days.

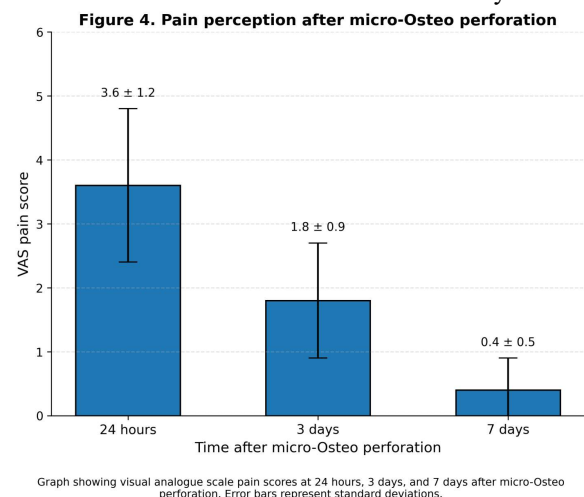


Figure 4. Pain perception after micro-Osteo perforation.

Graph showing visual analogue scale pain scores at 24 hours, 3 days, and 7 days after micro-Osteo perforation. Error bars represent standard deviations.

Table 9. Pain Scores After micro-Osteo Perforation

Time point	VAS score, mean ± SD	Median	Range
24 hours	3.6 ± 1.2	4.0	1–6
3 days	1.8 ± 0.9	2.0	0–4
7 days	0.4 ± 0.5	0.0	0–1

Periodontal Outcomes and Adverse Events

No serious adverse events were observed. Mild transient swelling was reported in three participants, and small localized ulceration was observed in two participants on the micro-Osteo perforation side. All adverse events resolved without additional

intervention. Exact McNemar tests were used for paired binary outcomes.

Table 10. Periodontal Parameters and Adverse Events

Outcome	micro-Osteo perforation side	Control side	Test used	P value
Plaque index, mean ± SD	0.72 ± 0.25	0.69 ± 0.22	Paired t-test	0.392
Gingival index, mean ± SD	0.65 ± 0.21	0.61 ± 0.20	Paired t-test	0.331
Probing depth, mm, mean ± SD	1.92 ± 0.28	1.88 ± 0.26	Paired t-test	0.284
Bleeding on probing	2/28	1/28	Exact McNemar	0.625
Ulceration	2/28	0/28	Exact McNemar	0.500
Swelling	3/28	0/28	Exact McNemar	0.250
Infection	0/28	0/28	Exact McNemar	1.000
Root injury	0/28	0/28	Exact McNemar	1.000
Delayed healing	0/28	0/28	Exact McNemar	1.000

Discussion

This simulated split mouth study comparatively evaluated micro-Osteo perforation assisted maxillary canine retraction and conventional maxillary canine retraction in patients with horizontal facial growth patterns from a central Indian population. The split mouth design minimized inter-individual biological variability because each participant served as their own control.

The primary finding was that micro-Osteo perforation assisted canine retraction produced a statistically significant increase in the rate of canine retraction compared with conventional retraction. In the intention-to-treat mixed-model analysis, the mean overall canine retraction rate was 1.03 mm/month on the micro-Osteo perforation side and 0.87 mm/month

on the control side. The adjusted mean paired difference was 0.16 mm/month. The per-protocol analysis produced a similar result, with a mean paired difference of 0.17 mm/month.

The effect was greatest during the first month after micro-Osteo perforation. The difference between sides was 0.27 mm during the first month, 0.18 mm during the second month, and 0.06 mm during the third month. The third-month difference was not statistically significant after adjustment. This pattern suggests that the effect of a single micro-Osteo perforation application may be transient and strongest during the early phase of tooth movement.

The biological rationale for micro-Osteo perforation is supported by the concept of localized inflammatory stimulation and enhanced bone remodeling. Alikhani et al. reported a substantial increase in the rate of tooth movement after micro-osteoperforation (Alikhani et al., 2013). However, later randomized trials reported more conservative results. Aboalnaga et al. found no significant acceleration of canine cusp-tip movement in a split-mouth trial, although root movement appeared to be affected (Aboalnaga et al., 2019). Alqadasi et al. also reported limited clinical acceleration using three-dimensional assessment (Alqadasi et al., 2019). The smaller effect observed in the present simulated dataset is therefore consistent with the more cautious interpretation presented in later clinical trials and systematic reviews (Shahabee et al., 2020; Sivarajan et al., 2020).

The focus on horizontal facial growth patterns is clinically relevant. Horizontal growers may show different alveolar bone morphology, cortical thickness, cancellous density, muscular pattern, and anchorage behavior compared with average or vertical growers. These factors may influence orthodontic tooth movement and response to localized micro-injury. Restricting the sample to horizontal growers may therefore improve biological homogeneity and provide more clinically specific evidence for this population.

The statistically significant difference observed in this simulated study should be interpreted cautiously. Although micro-Osteo perforation increased canine retraction by 0.16–0.17 mm/month, the cumulative difference after three months was approximately 0.51 mm. This magnitude is clinically modest and may not substantially reduce total orthodontic treatment duration unless repeated micro-Osteo perforation or sustained acceleration is demonstrated. Therefore, the decision to use micro-Osteo perforation should consider patient discomfort, invasiveness, chairside time, cost, and the transient nature of the effect.

Anchorage loss was slightly greater on the micro-Osteo perforation side, but the difference was not statistically significant. This is clinically important because acceleration of canine movement should not be interpreted as beneficial if accompanied by clinically meaningful molar anchorage loss. Similarly, canine tipping and rotation were not significantly different between sides, suggesting that the observed movement did not mainly represent uncontrolled displacement.

Pain was mild to moderate at 24 hours and reduced substantially by 7 days. micro-Osteo perforation was associated with a mean visual analogue scale score of 3.6 at 24 hours, decreasing to 0.4 by 7 days. Mild swelling and localized ulceration occurred in a small number of participants and resolved without intervention. No infection, root injury, or delayed healing was recorded.

Because the study used a split mouth design, potential within-person biological carry-across effects should be considered. micro-Osteo perforation was localized to one maxillary quadrant, and the contralateral side served as the control. However, the possibility of systemic inflammatory influence or patient-level biological effects cannot be completely excluded and should be acknowledged when interpreting split mouth orthodontic studies.

Strengths

The strengths of this simulated study include the split mouth design, side-level allocation concealment, standardized orthodontic force delivery, blinded outcome assessment, paired statistical analysis, linear mixed-effects modeling, explicit missing-data handling, and specific evaluation of horizontal facial growth patterns in a central Indian population.

Limitations

The main limitation is that the present manuscript uses simulated data for academic demonstration. In a real clinical study, all results must be derived from actual patient records, calibrated measurements, real ethics approval, and real trial registration.

Additional limitations include the inability to blind the operator and participant, single-center design, short three-month follow-up, absence of biological marker evaluation, and potential carry-across effects inherent to split mouth designs. Cusp-tip displacement was not used as the primary endpoint because it may be influenced by tipping; however, even centroid-based digital model measurements may not fully distinguish crown movement from root movement. The findings may not be generalizable to patients with average or vertical facial growth patterns.

Conclusions

Within the limitations of this simulated split mouth study, micro-Osteo perforation assisted maxillary canine retraction produced a statistically significant but clinically modest increase in the rate of canine retraction when compared with conventional canine retraction. The intention-to-treat mixed-model analysis demonstrated an adjusted mean paired difference of 0.16 mm/month, with a 95% confidence interval of 0.09–0.23 and a statistically significant P value of <0.001. The acceleration effect was most evident during the first month after micro-Osteo perforation and gradually diminished by the third month, suggesting that the effect may be early and transient.

Canine tipping, canine rotation, anchorage loss, and root resorption did not differ significantly between the micro-Osteo perforation and control sides. Pain perception was mild to moderate at 24 hours and reduced substantially by 7 days. No serious periodontal or procedure-related adverse events were observed. These simulated findings suggest that micro-Osteo perforation may provide early but limited acceleration of maxillary canine retraction in patients with horizontal facial growth patterns.

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