

THE EFFECT OF REPEATED MICRO OSTEOPERFORATION USING ORTHODONTIC IMPLANTS ON THE RATE OF TOOTH MOVEMENT DURING EXTRACTION SPACE CLOSURE- A SPLIT MOUTH STUDY

Orthodontics

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ABSTRACT

Background: Micro-osteoperforations (MOPs) delivered through orthodontic mini-implants offer a minimally invasive means of accelerating orthodontic tooth movement via a localized regional acceleratory phenomenon (RAP). Because RAP is transient and declines by four weeks, repeated MOP application has been proposed as a way to sustain acceleration, though supporting evidence remains mixed. **Methods:** Twenty-one patients (age 16–23 years) requiring bilateral maxillary first premolar extraction were enrolled in a split-mouth randomized controlled trial. On the experimental side, three MOPs were placed distal to the maxillary canine using 1.5×8 mm miniscrews at baseline (T0) and again at one month (T1). Canine retraction was carried out bilaterally with 150 g nickel-titanium closed-coil springs, and dental casts were recorded at T0, T1, and T2. Pain was tracked with a Visual Analogue Scale (VAS). **Results:** Retraction on the MOP side exceeded the control side at T1 (1.52 ± 0.37 mm vs. 1.06 ± 0.23 mm; $p < 0.001$; Cohen's $d = 1.70$) and cumulatively at T2 (3.12 ± 0.76 mm vs. 2.10 ± 0.43 mm; $p < 0.001$; Cohen's $d = 2.12$). Anchorage loss was clinically negligible (cumulative difference 0.034 mm; $p = 0.051$). MOP-related pain peaked at 12 hours (VAS 3.52) and had resolved by Day 5, and patient acceptance reached 90.5%. **Conclusion:** Repeated mini-implant-assisted MOPs accelerate maxillary canine retraction across two consecutive months, with negligible anchorage loss, self-limiting pain, and high patient acceptance.

KEYWORDS

Micro-osteoperforations; Canine Retraction; Orthodontic Tooth Movement; Regional Acceleratory Phenomenon

INTRODUCTION

Orthodontic treatment often runs beyond two years, and this duration carries real clinical costs — root resorption, enamel decalcification, and periodontal complications chief among them.

The biological rationale for surgically accelerated tooth movement rests on the Regional Acceleratory Phenomenon (RAP), a localized rise in bone turnover first described by Frost in 1983.[1] Controlled surgical injury triggers RAP, producing transient osteopenia in the alveolar region; resistance to tooth movement falls as osteoclastic activity and inflammatory mediators such as interleukin- 1β (IL- 1β) and tumor necrosis factor- α (TNF- α) are upregulated.[2]

Techniques for surgically accelerating tooth movement have moved from extensive corticotomy and Periodontally Accelerated Osteogenic Orthodontics (PAOO) toward less invasive alternatives.[3,4] Alikhani et al. introduced micro-osteoperforations (MOPs) in 2013 — small cortical perforations created with orthodontic mini-screws that induce a RAP-like response without raising a flap, making the technique more accessible clinically and better tolerated by patients.[5]

The clinical literature on MOPs, however, remains heterogeneous. Some randomized trials report substantial acceleration;[5] others report negligible effects.[6,7,8] A critical biological limitation of single-application protocols is the transient nature of RAP, which peaks within 2–4 weeks and subsequently diminishes as tissue enters the reparative phase. Repeated MOP application has been proposed to reinstate the inflammatory cascade and sustain accelerated bone remodeling beyond this window.

Evidence for repeated MOP protocols remains limited and

inconsistent, with conflicting findings across trials attributed to methodological heterogeneity including perforation depth, force delivery system, and measurement methodology.[11] The present split-mouth randomized controlled trial was designed to evaluate the effectiveness of two sequential MOP applications, performed one month apart using orthodontic mini-implants, on the rate of maxillary canine retraction, anchorage loss, and patient-reported outcomes.

MATERIALS AND METHODS

Ethical approval and study design

This prospective split-mouth randomized controlled trial was conducted at the Department of Orthodontics and Dentofacial Orthopaedics, Guru Nanak Dev Dental College and Research Institute, Sunam, Punjab, India. Ethical clearance was obtained from the Institutional Ethics Committee. The study was conducted in accordance with the Declaration of Helsinki. The CONSORT 2010 checklist was followed throughout.

Participants

Twenty-one patients (age range 16–23 years; mean 19.29 ± 2.21 years) were recruited. Inclusion criteria: requiring bilateral maxillary first premolar extraction, complete permanent dentition to first molars, no previous orthodontic treatment, systemically healthy, no active periodontal disease, non-smokers.

Randomization

The MOP-treated side was randomly allocated using coin-flip randomization at the commencement of canine retraction.

Orthodontic mechanics

Fixed pre-adjusted edgewise appliances (0.022-inch MBT

prescription) were placed. Anchorage was reinforced with second molar banding and a transpalatal arch (TPA). After bilateral maxillary first premolar extraction, leveling and alignment were completed to a 0.019×0.025 -inch stainless steel archwire. Canine retraction commenced at least six months post-extraction to ensure healing and eliminate confounding RAP from extraction trauma.



Figure 1: Anchorage setup showing transpalatal arch stabilization and second molar banding.

Micro-osteoperforation procedure

MOPs were performed at baseline (T0) and repeated at one month (T1) on the experimental side. Local anesthesia was administered using 2% lidocaine with 1:100,000 epinephrine with topical surface anesthetic. Three perforations were created using 1.5×8 mm miniscrews (S.K. Surgicals, India) to a standardized depth of 4 mm into alveolar bone (2 mm soft tissue + 4 mm cortical/medullary; protective sleeve preset at 6 mm total). Perforations were placed distal to the canine: first at 3 mm distal and 5 mm from the free gingival margin, subsequent perforations 3 mm apart. Canine retraction was initiated bilaterally using 9 mm nickel-titanium closed-coil springs (Captain Niti, India) delivering 150 g force (verified by force gauge). Acetaminophen was prescribed as needed; other NSAIDs were prohibited.

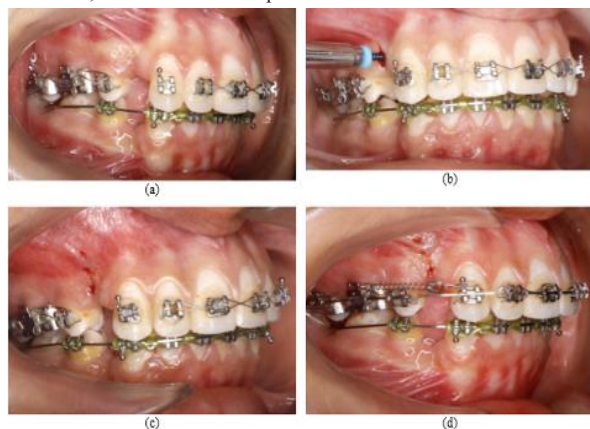


Figure 2: Clinical photographs of the MOP procedure. (a) Before procedure — canine position following leveling and alignment; (b) During MOP procedure — miniscrew insertion into alveolar bone distal to canine; (c) After MOP procedure — bleeding confirms cortical perforation; (d) Nickel-titanium closed-coil spring in position for canine retraction on MOP side.

Outcome measures

Primary outcome: rate of maxillary canine retraction. Secondary outcomes: anchorage loss and patient-reported pain. Dental casts (Neoalgin, Orikam Healthcare India) were obtained at T0, T1, and T2. A palatal rugae-referenced acrylic jig with stainless steel wire extensions was fabricated at T0 and repositioned on follow-up casts for standardized measurement. Canine retraction was measured as distal displacement of the canine cusp tip; anchorage loss as mesial movement of the first molar cusp tip — both by digital vernier caliper. Pain was assessed by 10-point VAS at immediate, 1 hour, 12 hours, Day 1, Day 3, Day 5, and Day 7 following each MOP application. Patient satisfaction and procedural ease (0–10 VAS) and willingness to repeat/recommend (yes/no) were recorded at Day 7.

Figure 3: Study model records at T0, T1, and T2 demonstrating progressive canine retraction on the experimental side.



Figure 4: Palatal rugae-referenced acrylic transfer jig with stainless steel extensions used for standardized measurement of canine retraction and anchorage loss.



Statistical analysis

Statistical analysis was performed using SPSS v23.0 (IBM Corp., Chicago, IL, USA) with significance set at $p \leq 0.05$. Normality was assessed by Shapiro-Wilk test. Paired t-tests were used for inter-group and intra-group comparisons of normally distributed variables; Wilcoxon signed-rank tests for non-normally distributed VAS scores. Results are expressed as mean $\pm$ SD with 95% confidence intervals. Effect size was calculated as Cohen's d. Binomial and McNemar's tests were used for categorical acceptance outcomes.

RESULTS

Sample and baseline

All 21 enrolled patients completed the study with no dropout. Baseline extraction space was comparable between sides ($p > 0.05$), confirming absence of confounding.

Primary outcome: canine retraction

At one month (T1), the MOP side demonstrated significantly greater retraction than the control side (1.52 ± 0.37 mm vs. 1.06 ± 0.23 mm; mean difference 0.46 mm; 95% CI: 0.34–0.58 mm; $p < 0.001$; Cohen's d = 1.70), representing a 43.2% increase in monthly retraction velocity [Table 1, Figure 1].

Second-month retraction (T1–T2) was similarly significant (MOP: 1.60 ± 0.43 mm vs. conventional: 1.03 ± 0.26 mm; mean difference 0.57 mm; 95% CI: 0.44–0.70 mm; $p < 0.001$; Cohen's d = 1.97), confirming the second MOP independently re-induced a full-magnitude acceleratory response.

Cumulative two-month retraction favored the MOP side (3.12 ± 0.76 mm vs. 2.10 ± 0.43 mm; mean difference 1.03 mm; 95% CI: 0.81–1.25 mm; $p < 0.001$; Cohen's d = 2.12).

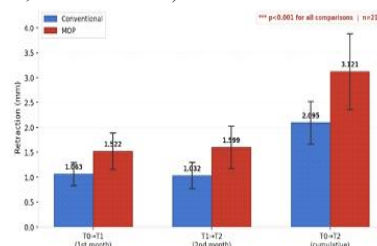


Figure 1: Inter-group comparison of mean canine retraction (mm) at T1 and T2. Error bars represent standard deviation. MOP: micro-osteoperforation side; Conv: conventional side.

Table 1: Inter-Group Comparison of Canine Retraction (mm) — Paired t-test, n = 21

Time Point	Conventional Mean $\pm$ SD (mm)	MOP Mean $\pm$ SD (mm)	Mean Difference (95% CI)	p-value; Cohen's d
T0-T1 (Month 1)	1.063 $\pm$ 0.229	1.522 $\pm$ 0.370	0.459 mm (0.336–0.582)	< 0.001; d = 1.70
T1-T2 (Month 2)	1.032 $\pm$ 0.262	1.599 $\pm$ 0.427	0.567 mm (0.436–0.697)	< 0.001; d = 1.97
T0-T2 (Cumulative)	2.095 $\pm$ 0.429	3.121 $\pm$ 0.761	1.026 mm (0.805–1.246)	< 0.001; d = 2.12

MOP: micro-osteoperforation side; SD: standard deviation; CI: confidence interval; T0: baseline; T1: one month; T2: two months.

Secondary outcome: anchorage loss

Anchorage loss at one month showed a statistically significant but clinically negligible inter-group difference (MOP: 0.163 ± 0.049 mm vs. conventional: 0.140 ± 0.049 mm; difference 0.024 mm; $p = 0.018$). Cumulative two-month anchorage loss did not differ significantly (MOP: 0.332 ± 0.085 mm vs. conventional: 0.298 ± 0.103 mm; difference 0.034 mm; $p = 0.051$) [Table 2].

Table 2: Inter-Group Comparison of Anchorage Loss (mm) — Paired t-test, n = 21

Time Point	Conventional Mean $\pm$ SD (mm)	MOP Mean $\pm$ SD (mm)	Mean Difference (95% CI)	p-value; Cohen's d
AL1 (one month)	0.140 ± 0.049	0.163 ± 0.049	0.024 mm (0.005–0.043)	0.018; d = 0.56*
AL2 (two months)	0.298 ± 0.103	0.332 ± 0.085	0.034 mm (–0.000 to 0.069)	0.051 (NS)

*Statistically significant but clinically negligible — difference within measurement resolution of digital vernier caliper. NS: not significant.

Patient-reported outcomes

The control side recorded VAS = 0.00 ± 0.00 at all time points, attributing all MOP-side pain to the surgical intervention. Following the first MOP, pain peaked at 12 hours (VAS 3.52 ± 1.44 ; $p < 0.001$) and resolved completely by Day 5. The second MOP produced an identical profile (peak 3.29 ± 1.15 at 12 hours). Cross-MOP comparison revealed no significant inter-application differences at any time point (weekly mean: 1.027 ± 0.545 vs. 1.048 ± 0.541 ; $p = 0.735$), indicating no cumulative sensitization. Patient satisfaction was high (mean 9.24/10) and the procedure was rated easy (0.95/10 difficulty). Nineteen of 21 patients (90.5%) expressed willingness to repeat and recommend the procedure ($p < 0.001$).

DISCUSSION

This split-mouth RCT demonstrates that two sequential mini-implant-assisted MOP applications, spaced one month apart, produce statistically significant and clinically meaningful acceleration of maxillary canine retraction at both monthly intervals.

The foundational MOP trial by Alikhani et al.[5] reported a 2.3-fold increase in canine retraction over 28 days, attributed to upregulation of pro-inflammatory cytokines and osteoclastic recruitment. More recent split-mouth RCTs employing comparable mechanics have reported 30–100% acceleration, consistent with the present findings.[7,12]

Trials reporting negligible MOP effects typically share identifiable methodological limitations: insufficient perforation depth failing to breach cortex and access medullary bone; use of elastomeric chains with progressive force decay complicating interpretation; and reliance on 3D digital superimposition with landmark instability introducing measurement noise.[7,8] The present study addressed all three: standardized cortical penetration by mini-implant, constant-force NiTi mechanics, and a palatal rugae-referenced physical jig with demonstrated high reliability and a stable conventional control side (intra-group $p = 0.570$).

The trial's principal contribution lies in testing directly whether a repeated MOP re-induces RAP at full magnitude. This question follows from RAP's transient biology: osteoclastic activity peaks at 2–4 weeks and returns to baseline within a month, according to biochemical studies.[9] Here, the Month 2 inter-group effect size ($d = 1.97$) closely matched Month 1 ($d = 1.70$), and the MOP side showed no intra-group attenuation between months ($p = 0.159$) — evidence

against biological habituation. Jaiswal et al.[10] offer biochemical support for this, having found renewed IL-1 β elevation and 25% greater cumulative retraction with a two-time protocol. The growing cumulative advantage of the MOP side — 0.46 mm at one month, 1.03 mm at two months — further points to a compounding clinical benefit from repeated application.

The anchorage loss data need some context. The 0.024 mm difference at one month, while statistically significant by paired t-test ($p = 0.018$), falls within the resolution of the digital vernier caliper and carries no real clinical weight. By two months, the cumulative difference was no longer significant ($p = 0.051$), and there was no sign of progressive divergence between groups — consistent with RAP's effects staying localized to the extraction space rather than spreading to compromise anchorage.[14] Absolute anchorage values in this trial (0.30–0.33 mm over two months) were notably lower than the 0.5–1.0 mm typically reported for conventional anchorage systems, likely reflecting the reinforcement provided by the TPA.[14]

Several limitations should be acknowledged. The two-month observation window does not allow assessment of longer-term effects or overall reduction in treatment duration. A sample of 21, though adequate given the large effect sizes, limits subgroup analysis. Without CBCT assessment, root resorption and alveolar bone changes could not be quantified. Operator blinding was not possible given the nature of the intervention, though outcome measurement was performed by a blinded examiner. The single-center design calls for multi-center replication.

CONCLUSIONS

Repeated mini-implant-assisted micro-osteoperforations, applied at baseline and again at one month, produce a significant acceleration of maxillary canine retraction across both months, with a compounding cumulative advantage exceeding 1 mm over the two-month period. The second application re-induces RAP at full magnitude, without habituation or progressive compromise to anchorage. Pain remains acute and self-limiting and does not accumulate across applications, and patient acceptance is high. Repeated MOP application appears to be an effective, minimally invasive, and well-tolerated strategy for accelerating canine retraction in extraction-based orthodontic treatment.

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