Dental Research Journal

Original Article

Comparison of two micro-osteoperforation protocols using mini-screws on the rate and type of extraction space closure: A randomized clinical trial

Mostafa Abtahi[1], Arezoo Jahanbin[1], Farzin Memari[1], Shayan Yousefi[2]

[1]Department of Orthodontic, Mashhad University of Medical Sciences, [2]Student Research Committee, Faculty of Dentistry, Mashhad University of Medical Sciences, Mashhad, Iran

ABSTRACT

Background: Accelerating orthodontic space closure while minimizing anchorage loss remains a clinical priority. Micro-osteoperforation (MOP) has emerged as a minimally invasive technique to enhance tooth movement. This study aimed to compare the effectiveness of two MOP protocols on the rate and pattern of maxillary extraction space closure.

Materials and Methods: In this parallel three-arm randomized controlled trial, 30 patients (17–30 years) with 3–4 mm of residual maxillary extraction space were randomly assigned to MOP1, MOP2, or control groups (n = 10 each). All underwent space closure using 0.019” × 0.025” stainless steel archwires and 150 g NiTi closed coil springs. MOP1 involved four perforations (two buccal, two palatal) at the extraction site center; MOP2 included additional perforations mesial and distal to the first molar. MOPs were performed monthly for 3 months. Primary outcome was space closure rate assessed via monthly three-dimensional intraoral scans. Secondary outcomes included angular tipping (PA radiographs) and relative anterior/posterior tooth movement. Statistical analysis used ANOVA, Kruskal–Wallis, and nonparametric *post hoc* tests ($P < 0.05$).

Results: Thirty patients (11 males, 19 females) were equally divided into MOP1, MOP2, and control groups. After 3 months, mean space closure was 0.88 mm greater in MOP1 and 0.90 mm greater in MOP2 compared to control. The 0.02 mm difference between MOP1 and MOP2 was clinically negligible. Control showed the greatest tipping, whereas MOP2 had the least. No adverse events were observed.

Conclusion: Monthly application of MOP significantly accelerates space closure and reduces tipping without increasing anchorage loss. The difference between MOP protocols was minimal and clinically negligible.

Key Words: Orthodontic anchorage technique, orthodontic space closures, orthodontic tooth movement, orthodontics

Received: 03-Jul-2025
Revised: 30-Aug-2025
Accepted: 14-Oct-2025
Published: 30-Dec-2025

Address for correspondence:
Dr. Farzin Memari,
Park Square, Vakilabad Blvd., School of Dentistry, Mashhad University of Medical Sciences, Mashhad, Iran.
E-mail: farzinmemari75@gmail.com

INTRODUCTION

Extended orthodontic treatment duration on average 2–3 years[1-3] poses challenges such as increased risk of dental caries, root resorption, periodontal complications, and reduced patient compliance.[4-7]

Access this article online

Website: www.drj.ir
www.drjjournal.net
www.ncbi.nlm.nih.gov/pmc/journals/1480
DOI: 10.4103/drj.drj_347_25

How to cite this article: Abtahi M, Jahanbin A, Memari F, Yousefi S. Comparison of two micro-osteoperforation protocols using mini-screws on the rate and type of extraction space closure: A randomized clinical trial. Dent Res J 2025;22:54.

As a result, accelerating orthodontic tooth movement (OTM) has become a key area of interest in clinical orthodontics.

Recent findings showed that patients are willing to undergo additional procedures to reduce treatment duration and bear additional costs.[8] In addition, bone anatomy and cortical bone thickness are also negatively associated with orthodontic treatment duration.[9] Among the various strategies proposed for this purpose, including pharmacological agents, mechanical stimuli, and surgical methods,[10-21] micro-osteoperforation (MOP) has emerged as a minimally invasive technique with considerable clinical potential.[22-24] MOP enhances bone remodeling by inducing the regional acceleratory phenomenon (RAP), which temporarily increases local metabolic activity and facilitates faster tooth movement. This method offers the advantage of being flapless, simple to perform, and well-tolerated by patients. Most MOP techniques utilize mini-screws to create small perforations in the cortical bone. However, the clinical outcomes of MOP may vary depending on the number, location, and frequency of the perforations. While previous studies have confirmed the effectiveness of MOP compared to conventional treatment, few have compared different protocols of MOP using the same instrument, especially under controlled clinical conditions. The speed of tooth movement in more invasive surgeries, such as corticotomy, is higher than MOP, but adverse effects, such as pain, impact on quality of life, and swelling after corticotomy, have been reported to be longer and more severe.[25]

Therefore, the aim of this randomized clinical trial was to compare two distinct MOP protocols using mini-screws. A standard protocol with four perforations in the center of the extraction site (MOP1), and a modified protocol involving the center of the extraction site, mesial and distal perforations adjacent to the first molar (MOP2) with regard to the rate and pattern of extraction space closure. We also evaluated whether these approaches differ in their effects on posterior versus anterior tooth movement and anchorage preservation.

MATERIALS AND METHODS

Study design and participants

This three-arm parallel-group randomized clinical trial included 30 patients (11 males, 19 females; aged 17–30 years) selected from an initial pool of 34 individuals referred to the Orthodontics Department at a university-affiliated dental school. Inclusion criteria were age 17–30 years, maxillary crowding requiring extraction of the maxillary first premolars, and at least 3–4 mm of residual extraction space at the start of space closure. Exclusion criteria included systemic diseases, poor oral hygiene, periodontal issues, deep caries, medications affecting bone metabolism, and contraindications for MOP. Patients missing follow-ups or experiencing bracket debonding were also excluded from the study. The trial design remained unchanged, with no interim analyses or stopping criteria.

Sample size calculation

The sample size was calculated using a two-sided significance level of 0.05 and a statistical power of 90% ($\beta = 0.10$), based on a clinically meaningful difference in canine retraction of 0. 24 mm between groups, as reported by Babanouri *et al*. The standard deviations for the intervention and control groups were assumed to be 0.10 mm and 0.15 mm, respectively. Using the following formula:

$$n = [(Z_{1-\alpha/2} + Z_{1-\beta})^2 \times (\sigma_1^2 + \sigma_2^2)]/(\mu_1 - \mu_2)^2$$

The minimum sample size required was 6 patients per group. To compensate for potential dropout and to enhance statistical power, the final sample size was increased to 10 participants per group, resulting in a total of 30 patients across the three study groups.

Randomization and allocation

After obtaining informed written consent, participants were randomly assigned to one of three groups (Control, MOP1, or MOP2) in a 1:1:1 ratio using block randomization (block size of six) generated through Random.org. Each participant received a unique three-digit code. An independent statistician created the randomization sequence, and allocation concealment was maintained using sequentially numbered, opaque, sealed envelopes prepared by a research assistant not involved in enrollment. To minimize bias, the outcome assessor was blinded, although blinding of patients and operators was not feasible due to the intervention's nature.

Orthodontic treatment protocol

All patients underwent fixed appliance therapy using 0.022″ MBT prescription brackets in both arches. Once space closure was clinically indicated and at least 3–4 mm of space remained, patients were enrolled in the study.

Space closure was initiated using 0.019″ × 0.025″ stainless steel archwires and 150 g NiTi closed coil springs (Yahong, China) placed between the hook of the canine bracket and the first molar tube. Anterior teeth (canine to canine) were ligated using ligature wire (3-3) Depending on the space available, 3 mm or 6 mm coil springs were used.

At the start and end of the intervention, all participants underwent parallel periapical (PA) radiography and intraoral three-dimensional (3D) scanning (Maestro 3D dental studio).

Micro-osteoperforation intervention protocol

Prior to each MOP session, patients rinsed with 0.2% chlorhexidine mouthwash. Local anesthesia was administered (2% lidocaine with 1:80,000 epinephrine, DarouPakhsh, Iran), and MOPs were performed flaplessly. The insertion points were determined using periodontal probing and sounding to locate the alveolar bone crest.

Group micro-osteoperforation 1

Four MOPs were made using a JEIL 1.4 mm × 8 mm mini-screw. Two perforations were placed on the buccal side (first at 5 mm from the free gingival margin, second deeper in the vestibule), and two matching perforations were placed palatally at the middle of extraction space. The screw was inserted perpendicular to the bone to a depth of 5 mm, then removed.

Group micro-osteoperforation 2

Four perforations were also performed using the same mini-screw: one buccal and one palatal at the middle of the extraction space, and one mesial and one distal to the first molar buccal side.

Control group

No MOP intervention was performed. Space closure proceeded as in the intervention groups.

MOP procedures were repeated three times at 1-month intervals in both intervention groups. Following the final intervention, PA radiographs and intraoral scans were repeated.

Outcome measurements

- The primary outcome of this study was the rate of extraction space closure over a 3-month period, measured as the linear distance between the mesial height of contour of the second premolar and the distal height of contour of the canine, using 3D intraoral scans and digital measurement software. Secondary outcomes included:[1] the angulation of the canine and second premolar relative to the occlusal plane assessed on standardized parallel PA radiographs using manual angular analysis. Tooth movement was assessed on 3D digital models using a reference line perpendicular to the posterior border of the incisive papilla. Specifically,[2] anterior movement was measured at the distal point of the second premolars, and[3] posterior movement was measured at the cusp tip of the canines, allowing precise evaluation of the direction and magnitude of tooth displacement during the study period. All outcome variables were assessed at baseline and at 1-month intervals up to 3 months. No changes were made to the outcome definitions or measurement procedures after the trial commenced. Rate of space closure was calculated by measuring the distance between the mesial height of contour of the second premolar and the distal height of contour of the canine
- Type of tooth movement was assessed by measuring the change in the long axis of adjacent teeth relative to the occlusal plane on PA radiographs using manual angular analysis. Measurements were taken three times by one blinded examiner, and the mean was used to reduce error
- Anterior and posterior movement was quantified separately by measuring the distance from the incisive papilla to the cusp tip of the canine (anterior) and the distal point of the second premolar (posterior), using reference lines perpendicular to the posterior border of the incisive papilla.

Blinding

The examiner responsible for measuring tooth movement was blinded to group allocation. Due to the nature of the intervention, patient and operator blinding was not feasible. However, because the outcome measures were objective and image-based, the lack of full blinding is unlikely to have biased the results.

Statistical analysis

The normality of quantitative data was evaluated using the Shapiro–Wilk test. Descriptive statistics (mean ± standard deviation) were calculated for all variables. The primary outcome, rate of space closure, was analyzed using the Mann–Whitney *U*-test for between-group comparisons. Secondary outcomes, including angular changes in the long axis of the canine and second premolar, were assessed using paired *t*-tests for within-group comparisons and one-way ANOVA for between-group differences, with *post hoc* tests applied as appropriate. Inter-rater reliability was determined using the intraclass correlation coefficient (ICC). Statistical significance was set at $P < 0.05$. No adjusted or subgroup analyses were preplanned or conducted.

RESULTS

Thirty patients (11 males, 19 females) participated in the study, randomly assigned to three equal groups: MOP1, MOP2, and a control group, each with 10 patients. All completed the study, and their results were included in the final analysis per the intention-to-treat principle. Tooth movement was assessed on both sides of the maxillary arch.

Thirty-four individuals were assessed for eligibility, with four excluded (one did not meet criteria, three opted out). Thus, 30 patients (11 males, 19 females) were included and randomly assigned to three equal groups: MOP1, MOP2, and control (10 patients each). All participants completed the study and were included in the final analysis based on the intention-to-treat principle. Tooth movement was assessed on both sides of the maxillary arch.

A CONSORT flow diagram illustrating participant progression throughout the trial is presented in Figure 1.

Baseline characteristics

Baseline demographic and clinical characteristics of the three groups are presented in Table 1. The mean age of the participants was 23.47 ± 3.02 years. Gender distribution and other baseline characteristics are summarized descriptively in Table 1, showing comparable profiles across the groups.

Measurement reliability

All measurements were performed by a single calibrated examiner. To assess measurement reliability, six samples were re-evaluated by a second examiner, and the ICC was calculated. The ICC value was 0.97 for space closure rate and 0.83 for angular changes, indicating excellent interexaminer agreement.

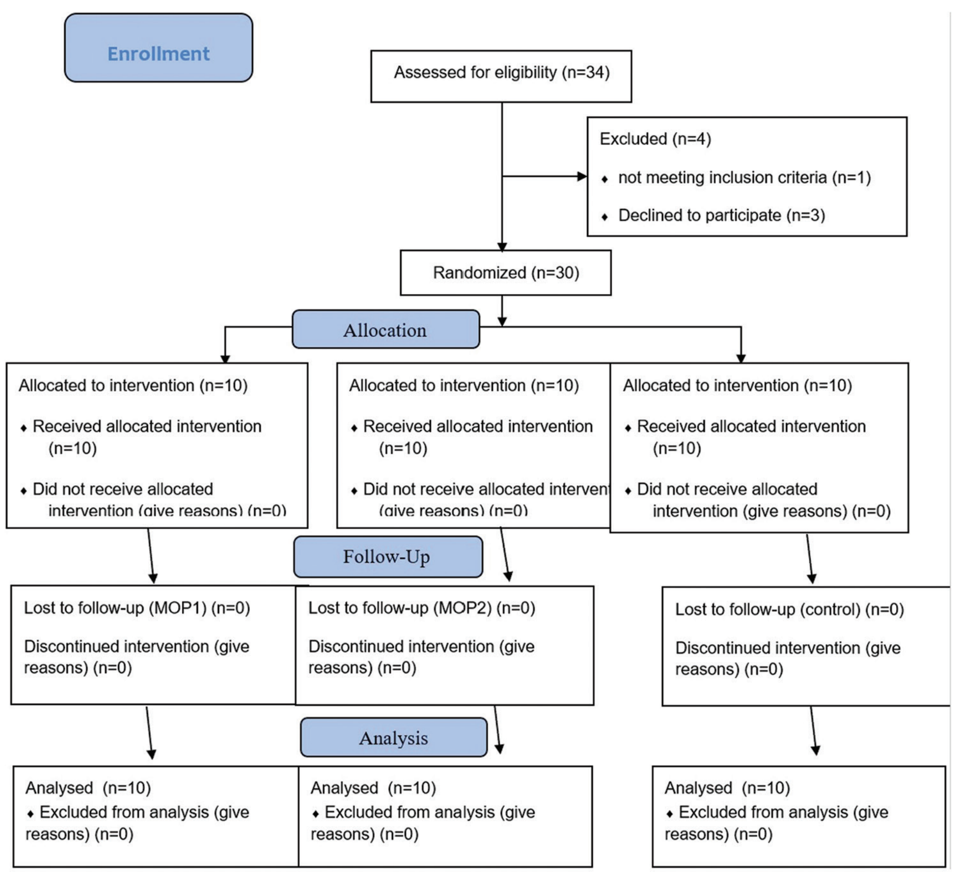

Figure 1: CONSORT flow diagram.

Space closure rates

The average amount of space closure was measured monthly over 3 months for all three groups. Kruskal–Wallis tests were used to compare space closure rates across the groups at each time point, and where statistically significant differences were observed ($P < 0.05$), pairwise comparisons were performed using the Mann–Whitney *U*-test with Bonferroni correction to control for multiple comparisons ($P < 0.0167$).

As shown in Figure 2, the MOP1 and MOP2 groups demonstrated significantly faster space closure than the control group in all 3 months ($P < 0.001$). The average total space closure at the end of the 3rd month was approximately 0.88 mm greater in MOP1 and 0.90 mm greater in MOP2 compared to the control group. The 0.02 mm difference between MOP1 and MOP2 was not statistically significant ($P > 0.0167$), it was considered clinically negligible, as clinical significance in orthodontics typically requires a difference of at least 1 mm or more.

Anterior versus posterior tooth movement

The movement of anterior and posterior teeth was measured against a reference line perpendicular to the incisive papilla's posterior edge. Figure 3 shows that anterior teeth consistently moved more than posterior teeth across all groups. However, no significant differences were found between groups for anterior versus posterior movement at any time point (Mann–Whitney *U*-test, $P > 0.05$). This suggests that a larger sample size or longer observation periods may be needed for clearer conclusions.

Table 1: The mean and the standard deviation of angular changes for the control group, micro-osteoperforation 1 and micro-osteoperforation 2

Group	Angular change (°), mean±SD
Control	−6.59±0.9
MOP1	−3.03±0.51
MOP2	−2.91±0.64

SD: Standard deviation; MOP: Micro-osteoperforation

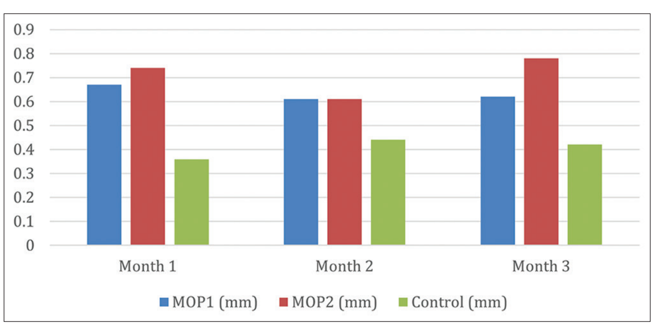

Figure 2: Comparison of average tooth movement for the control group, micro-osteoperforation (MOP) 1 and MOP2 in different time intervals. MOP: Micro-osteoperforation.

Angular changes (tipping analysis)

Angular changes in adjacent teeth were analyzed using manual angle measurements on standardized PA radiographs relative to the occlusal plane. As presented in Table 1:

- The control group showed the greatest tipping (the largest angular change)
- Both MOP1 and MOP2 groups showed reduced tipping
- The MOP2 group exhibited the least angular change, suggesting the most favorable control over tooth movement.

A one-way ANOVA revealed a significant difference in angular changes among the three groups ($P < 0.05$). In addition, paired *t*-tests comparing pre- and post-treatment angles within each group confirmed the statistical significance of angular changes.

Harm

No adverse events (e.g., pain, swelling, root resorption, or infection) were observed in any group during the 3-month follow-up period.

DISCUSSION

In the present study, the rate of tooth movement was found to be significantly greater in both MOP intervention groups compared to the control group. These findings are consistent with previous research by Alikhani *et al.*, Attri *et al.*, Feizbakhsh *et al.*, Kundi, Singh *et al.*, Kumar *et al.*, Babanouri *et al.*, and Sivarajan *et al.*[21,26-32] However, the

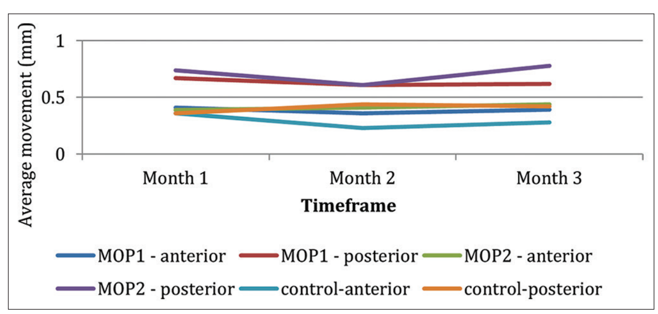

Figure 3: Comparison of average anterior and posterior tooth movement for the control group, micro-osteoperforation (MOP) 1 and MOP2 in different time intervals. MOP: Micro-osteoperforation.

results differ from those reported by Alkebsi *et al*., Golshah *et al*., and Li *et al*.,[24,33,34] who observed no significant difference between MOP and control groups when intraoral or extraoral measurements were used. Sivarajan *et al*.[26] noted that MOP can significantly accelerate tooth movement statistically, but this may not always be clinically relevant. In contrast, Alikhani and Feizbakhsh *et al*.[21,30], found clinically significant improvements in space closure with MOP.

In our study, four MOPs were performed using mini-screws in vertical and horizontal directions. This contrasts with previous studies such as those by Alikhani *et al.* and Attri *et al*.,[21,32] who used three MOPs applied with the PROPEL device, and Feizbakhsh *et al*.,[30] who used only two MOPs per quadrant. Given the ease of access and cost-effectiveness of mini-screws, combined with comparable efficacy to PROPEL, they are recommended as a practical tool for clinical MOP applications.

The optimal number of perforations remains controversial. According to Frost's theory of the RAP, the degree of local inflammation – and thus bone remodeling – is directly related to the extent of surgical injury.[35] However, Blasi and Pavlin suggested that in areas with limited interradicular space, fewer perforations may suffice.[36] Subgroup analysis in recent meta-analyses has shown no significant difference between using two or three perforations, suggesting the number should be based on local anatomy and interradicular space.

In terms of malocclusion types, all participants in our study presented with Class I malocclusion requiring bilateral extraction of maxillary first premolars. Prior studies varied in this regard: Alikhani *et al*.,[21] Alkebsi *et al*.,[24] Golshah *et al*.,[34] and Kundi[28] focused on Class II div. 1, whereas Feizbakhsh *et al*.[30] studied Class I bimaxillary protrusion, and Shrestha Singh and Babanouri *et al*.[31] included both Class I and II. Some researchers, such as Dudic *et al*. and Haralur *et al*., have suggested that malocclusion type and interarch interference may affect tooth movement rate.[37,38] However, a direct and consistent relationship between malocclusion type and tooth movement has not been conclusively established.

Our research is distinct because it uses en masse retraction with NiTi coil springs, unlike previous studies that relied on canine retraction with mini-screws between the second premolar and first molar, which could skew results due to their closeness to the perforation site.[21,24,30] In addition, tools like elastomeric chains and MBT tie-backs in other studies may introduce variability from inconsistent force application.[26,32]

Age is another well-documented factor influencing the rate of OTM. Studies have shown that younger patients undergoing active growth exhibit faster tooth movement than adults.[24,37] To control for this variable, we limited our sample to individuals aged 17–30 years, with a mean age of 23.47 ± 3.02 years, similar to other studies on MOP efficacy.

Our study tracked participants for 12 weeks, administering MOP three times at monthly intervals. In contrast, most previous studies, including those by Alikhani, Attri, Feizbakhsh, and Kundi *et al*.,[21,28,30,32] only evaluated outcomes up to 4 weeks post-MOP, limiting their long-term analysis. Blasi and Pavlin[36] highlighted the necessity of MOP every 4 weeks for effectiveness. Although Alkebsi *et al*.[24] monitored patients for 12 weeks, they only applied MOP once, which may account for their ambiguous results. Similarly, Sivarajan *et al*.[26] found no significant benefit in increasing MOP frequency, as their assessment was restricted to a single endpoint without considering monthly variations.

Some trials also failed to demonstrate clinical significance. For example, Jiaojiao Li *et al*.[33] applied MOPs with a 5 mm depth twice over 12 weeks, but observed no significant improvement in premolar space closure. Similarly, Amin Golshah *et al*.[34] reported no significant differences in canine retraction over 5 months but did find reduced canine tipping in the MOP group. Importantly, gender had no effect on outcomes in that study.

Prashant Kumar *et al*.[29] demonstrated that MOP significantly accelerated OTM during both intervention (T0–T2) and postintervention (T2–T4) phases over 4 months. Shrestha Singh *et al*.[27] also found a twofold increase in canine retraction on the MOP side versus control after 56 days, though no difference was found between MOP1 and MOP2 groups. In MOP1 patients received 3 buccal MOPs on the experimental side and in MOP2, Patients received 3 buccal MOPs + 3 palatal MOPs on the experimental side. Babanouri *et al*. observed a trend toward faster movement with MOP, although results did not reach statistical significance.[31]

Study limitations include individual variability in biological response to MOP and potential side effects such as pain or inflammation. The procedure requires specialized equipment and time, increasing cost and limiting accessibility. Generalizability is restricted due to the exclusion of patients with systemic conditions or poor bone quality. Recruitment from a single center may have introduced selection bias, and investigator blinding was not feasible. In addition, the small sample size and short follow-up may have limited the ability to detect subtle treatment differences.

The findings of this study are most applicable to young adult patients aged 17–30 years with Class I malocclusion requiring bilateral premolar extraction. Generalizability to other malocclusion types, age groups such as adolescents or older adults, or individuals with poor bone quality is uncertain. As the study was conducted at a single academic center using mini-screws, replication in varied clinical settings with different levels of practitioner expertise and equipment is necessary. Furthermore, the use of en masse retraction with NiTi coil springs may limit applicability to practices using different mechanics.

CONCLUSION

This study demonstrated that MOP significantly enhances the rate of OTM. After 3 months, both MOP1 and MOP2 groups achieved approximately 0.9 mm more space closure than controls, with no clinically meaningful difference between them. MOP also reduced tipping of adjacent teeth, with mean angular changes of $-6.59° \pm 0.9°$ in the control group, $-3.03° \pm 0.51°$ in MOP1, and $-2.91° \pm 0.64°$ in MOP2, indicating the most favorable control of tipping in the MOP2 group. Anterior teeth consistently showed greater movement across all groups. Although MOP is generally safe and effective, its use should be tailored to each patient, considering potential risks alongside the anticipated benefits.

Financial support and sponsorship

Nil.

Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

REFERENCES

1. Najeeb S, Siddiqui F, Qasim SB, Khurshid Z, Zohaib S, Zafar MS. Influence of uncontrolled diabetes mellitus on periodontal tissues during orthodontic tooth movement: A systematic review of animal studies. Prog Orthod 2017;18:5.
2. Mavreas D, Athanasiou AE. Factors affecting the duration of orthodontic treatment: A systematic review. Eur J Orthod 2008;30:386-95.
3. Cramer CL, Campbell PM, Opperman LA, Tadlock LP, Buschang PH. Effects of micro-osteoperforations on tooth movement and bone in the beagle maxilla. Am J Orthod Dentofacial Orthop 2019;155:681-92.
4. Pinto AS, Alves LS, Maltz M, Susin C, Zenkner JEA. Does the duration of fixed orthodontic treatment affect caries activity among adolescents and young adults? Caries Res 2018;52:463-7.
5. Pinto AS, Alves LS, Zenkner JE, Zanatta FB, Maltz M. Gingival enlargement in orthodontic patients: Effect of treatment duration. Am J Orthod Dentofacial Orthop 2017;152:477-82.
6. Talic NF. Adverse effects of orthodontic treatment: A clinical perspective. Saudi Dent J 2011;23:55-9.
7. Justus R. Iatrogenic Effects of Orthodontic Treatment. New York: Springer 2015.
8. Conti AC, Mota Rodrigues CF, Volpato GH, de Miranda Ladewig V, Almeida MR, Almeida-Pedrin RR. Orthodontists'and patients' perceptions regarding techniques to reduce the orthodontic treatment duration. J World Fed Orthod 2020;9:155-8.
9. Landin-Ramos M, Yadav S, Gandhi V, Upadhyay M, Tadinada A. Is there a relationship between mandibular cortical bone thickness and orthodontic treatment time? Angle Orthod 2020;90:794-800.
10. 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.
11. Telatar BC, Gungor AY. Effectiveness of vibrational forces on orthodontic treatment: A randomized, controlled clinical trial. J Orofac Orthop 2021;82:288-94.
12. Nimeri G, Kau CH, Abou-Kheir NS, Corona R. Acceleration of tooth movement during orthodontic treatment – A frontier in orthodontics. Prog Orthod 2013;14:42.
13. Mousa MM, Hajeer MY, Burhan AS, Darwich KM, Almahdi WH, Aljabban O, *et al*. Patient-reported outcome measures of flapless corticotomy with low-level laser therapy in en masse retraction of upper anterior teeth: A Three-arm randomized controlled trial. Clin Pract 2023;13:1501-19.
14. Krishna VB, Duggal I, Sharan J, Mangaraj M, Duggal R, Jena AK. Effect of leukocyte-platelet-rich fibrin (L-PRF) on the rate of orthodontic tooth movement and expression of various biomarkers in gingival crevicular fluid. Clin Oral Investig 2023;27:2311-9.
15. Kim SJ, Park YG, Kang SG. Effects of corticision on paradental remodeling in orthodontic tooth movement. Angle Orthod 2009;79:284-91.
16. Farhadian N, Miresmaeili A, Borjali M, Salehisaheb H, Farhadian M, Rezaei-Soufi L, *et al*. The effect of intra-oral LED device and low-level laser therapy on orthodontic tooth movement in young adults: A randomized controlled trial. Int Orthod 2021;19:612-21.
17. El-Timamy A, El Sharaby F, Eid F, El Dakroury A, Mostafa Y, Shaker O. Effect of platelet-rich plasma on the rate of orthodontic tooth movement: A split-mouth randomized trial. Angle Orthod 2020;90:354-61.

18. Dipalma G, Patano A, Ferrara I, Viapiano F, Netti A, Ceci S, *et al*. Acceleration techniques for teeth movements in extractive orthodontic therapy. Appl Sci 2023;13:9759.
19. Ciobotaru CD, Feştilă D, Dinte E, Muntean A, Boşca BA, Ionel A, *et al*. Enhancement of orthodontic tooth movement by local administration of biofunctional molecules: A comprehensive systematic review. Pharmaceutics 2024;16:984.
20. Carvalho-Lobato P, Garcia VJ, Kasem K, Ustrell-Torrent JM, Tallón-Walton V, Manzanares-Céspedes MC. Tooth movement in orthodontic treatment with low-level laser therapy: A systematic review of human and animal studies. Photomed Laser Surg 2014;32:302-9.
21. Alikhani M, Raptis M, Zoldan B, Sangsuwon C, Lee YB, Alyami B, *et al*. Effect of micro-osteoperforations on the rate of tooth movement. Am J Orthod Dentofacial Orthop 2013;144:639-48.
22. Khoo E, Nervina J. So close, but yet so far. Am J Orthod Dentofacial Orthop 2018;154:611-2.
23. Azeem M, Haq AU, Ilyas M, Hamid WU, Hayat MB, Jamal F, *et al*. Bactériémie après micro-ostéoperforation. Int Orthod 2018;16:463-9.
24. Alkebsi A, Al-Maaitah E, Al-Shorman H, Abu Alhaija E. Three-dimensional assessment of the effect of micro-osteoperforations on the rate of tooth movement during canine retraction in adults with Class II malocclusion: A randomized controlled clinical trial. Am J Orthod Dentofacial Orthop 2018;153:771-85.
25. Bisconti F, Eva M, Thevenet E, Zamora-Martinez N. Comparison of efficacy between micro-osteoperforations and alveolar corticotomies on the rate of orthodontic tooth movement: A systematic review and meta-analysis. J Craniomaxillofac Surg 2025;53:459-75.
26. Sivarajan S, Doss JG, Papageorgiou SN, Cobourne MT, Wey MC. Mini-implant supported canine retraction with micro-osteoperforation: A split-mouth randomized clinical trial. Angle Orthod 2019;89:183-9.
27. Singh S, Jain AK, Prasad RR, Sahu A, Priya P, Kumari P. Effect of mini-implant assisted micro-osteoperforation on the rate of orthodontic tooth movement-A randomized clinical trial. J Orthod Sci 2023;12:62.
28. Kundi I. Effect of flapless cortical perforation on canine retraction rate: A randomized clinical trial. International Medical Journal. 2018 Apr 1;25 (2).
29. Kumar P, Rampurawala AH, Patil AS. Effect of micro-osteoperforations (MOPs) on the rate of en masse orthodontic tooth retraction: A randomized controlled trial. J Orofac Orthop 2024;85:189-98.
30. Feizbakhsh M, Zandian D, Heidarpour M, Farhad SZ, Fallahi HR. The use of micro-osteoperforation concept for accelerating differential tooth movement. J World Fed Orthod 2018;7:56-60.
31. Babanouri N, Ajami S, Salehi P. Effect of mini-screw-facilitated micro-osteoperforation on the rate of orthodontic tooth movement: A single-center, split-mouth, randomized, controlled trial. Prog Orthod 2020;21:7.
32. Attri S, Mittal R, Batra P, Sonar S, Sharma K, Raghavan S, *et al*. Comparison of rate of tooth movement and pain perception during accelerated tooth movement associated with conventional fixed appliances with micro-osteoperforations – A randomised controlled trial. J Orthod 2018;45:225-33.
33. Li J, Papadopoulou AK, Gandedkar N, Dalci K, Darendeliler MA, Dalci O. The effect of micro-osteoperforations on orthodontic space closure investigated over 12 weeks: A split-mouth, randomized controlled clinical trial. Eur J Orthod 2022;44:427-35.
34. Golshah A, Moradi P, Nikkerdar N. Efficacy of micro-osteoperforation of the alveolar bone by using mini-screw for acceleration of maxillary canine retraction in young adult orthodontic patients: A split-mouth randomized clinical trial. Int Orthod 2021;19:601-11.
35. Frost HM. The regional acceleratory phenomenon: A review. Henry Ford Hosp Med J 1983;31:3-9.
36. Blasi I, Pavlin D, Graber LJOCP T. Minimally and noninvasive approaches to accelerate tooth movement. Orthodontics: Current Principles and Techniques; 2017. p. 913-25.
37. Dudic A, Giannopoulou C, Kiliaridis S. Factors related to the rate of orthodontically induced tooth movement. Am J Orthod Dentofacial Orthop 2013;143:616-21.
38. Haralur SB, Addas MK, Othman HI, Shah FK, El-Malki AI, Al-Qahtani MA. Prevalence of malocclusion, its association with occlusal interferences and temporomandibular disorders among the Saudi sub-population. Oral Health Dent Manag 2014;13:164-9.