

Evaluation of maxillary molar distalization with a skeletally-anchored distal jet appliance assisted by micro-osteoperforations: A randomized clinical trial

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Aim: This prospective clinical study aimed to evaluate the effects of maxillary molar distalization via a skeletally-anchored distal jet appliance assisted with micro-osteoperforations (MOPs) during the orthodontic treatment of Class II malocclusion.

Materials and methods: The trial design was a randomized clinical trial. Twenty patients aged 14 to 17 were enrolled from the outpatient clinic of the Orthodontic Department at the Faculty of Dental Medicine, Al-Azhar University, and randomly divided into two equal groups. They received MOPs after activation of the distalization appliance on both buccal and palatal sides or none (control group). The force magnitude utilized was 240 gms per side and activated every four weeks (T1, T2, and T3) for an observation period of 4 months (T4). The primary outcomes of the present study were to assess the rate of maxillary molar distalization and the total amount of distalization throughout the observation period. Maxillary molar rotation, tipping, and extrusion were evaluated as secondary outcomes.

Results: The repeated applications of MOPs successfully accelerated maxillary molar distalization, which was statistically significant ($P \leq 0.05$) during the first and second months. This significant distalization continued throughout the study's observation period, with a statistically significant rate of movement observed in the MOPs group.

Conclusion: Incorporating micro-osteoperforations during maxillary molar distalization via a skeletally-anchored distal jet appliance could substantially accelerate both the rate and the total distance of distalization.

Keywords: micro-osteoperforation, distalization, distal jet, skeletally-anchored

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Introduction

Orthodontic treatment aims to improve dentofacial esthetics. Malocclusions like Class II molar relationship and crowding can hinder this objective. To address these issues, maxillary molar distalization is a commonly used non-extraction treatment modality in the maxillary arch. This process can alleviate crowding and correct Class II malocclusion by establishing a Class I molar and canine relationship.¹⁻³ However, maxillary molar distalization often produces undesirable tooth movement, such as distal tipping and extrusion of maxillary molars, together with protrusion of maxillary incisors due to anchorage loss. To overcome anchorage loss, intraoral distalization appliances have recently been supported by temporary skeletal anchorage devices.⁴

The average duration of fixed orthodontic treatment can reach 20 months. It may sometimes be longer, depending on factors like the severity of the case, the operator's experience, and patient cooperation. However, patients frequently expect a much shorter extent of treatment. The prolonged interval of orthodontic treatment may have many drawbacks, which may worsen the periodontal condition, increase the risk of enamel demineralization and root resorption, and diminish patient cooperation. Accelerating orthodontic tooth movement (OTM) to reduce treatment duration has recently become one of the chief research goals in contemporary orthodontics.⁵

Several surgical and nonsurgical techniques are available to speed up the tooth movement. However, surgical techniques like corticectomies, while effective, are invasive and may not be practical for routine use alongside orthodontic treatment.⁶⁻⁸ Micro-osteoperforation (MOP) is a slightly invasive method suggested for accelerating orthodontic tooth movement (OTM). This technique consists of performing small, shallow, and flapless osteoperforations in the

alveolar bone between roots of the teeth buccally or palatally on the surface of cortical plates to reduce the bone density surrounding the active teeth with minimum surgical insult while leaving the bone density around the anchor teeth unchanged.⁹

It was hypothesized that MOPs offer a simple, minimally invasive method with an affordable, efficient approach to accelerate OTM and reduce orthodontic treatment duration. The biological changes that MOPs cause in the cell were described as a regional acceleratory phenomenon (RAP).¹⁰ The basis of RAP was that direct injury to maxillary and mandibular alveolar or basal bones, such as minor osteo-corticoperforations, initiated an inflammatory cascade causing increased osteoclastogenesis, thereby accelerating orthodontic tooth movement by inducing RAP, just like a wound healing process.¹¹

Human studies on MOPs have focused on canines' retraction, and animal studies have investigated the anterior movement of molars. However, little data is available concerning the effects of MOPs during other stages of orthodontic treatment.^{9, 12, 16} Accordingly, further clinical investigations are needed regarding minimally invasive methods that might accelerate OTM. Consequently, this study aims to evaluate the effects of MOPs during maxillary molar distalization.

Materials and methods

Trial design

The current study is a single-center, multi-arm randomized clinical trial with a 1:1 allocation ratio and superiority trial framework. The protocol was registered in clinicaltrials.gov with the number NCT05171738.

Participants & eligibility criteria

The study's participants were selected based on specific criteria. They were young adults aged 14 to 17 with a bilateral class II

molar relationship, skeletal class I or mild class II, normal or decreased vertical height, good oral hygiene, fully erupted first and second molars, and missing or extracted third molars. However, individuals with congenital dental-skeletal disorders requiring surgical correction, posterior crowding or spacing, periodontally compromised teeth, or poor oral hygiene were excluded from the study. Participants who repeatedly missed appointments or broke their appliances were also discontinued from the trial.

For this study, participants were randomly chosen from the outpatient clinic of the Orthodontic Department at the Faculty of Dental Medicine, Al-Azhar University (Boys) in Cairo, Egypt. Eligible patients were informed about the study procedures and, after providing informed consent, were enrolled and randomly assigned to receive either MOPs or no MOPs (control) following activation of the distalization appliance. The Ethics Committee at the Faculty of Dental Medicine (Boys), Al-Azhar University, Cairo, Egypt (code 651/2053) approved this study.

Sample size calculation

The sample size was determined using G*power software¹⁷ by considering the findings of previous studies.^{12,18} The following parameters were used: 80% power, an independent t-test for comparing two means, a two-sided significance level of 5%, and an effect size of 1.41. It was estimated that a minimum of 18 participants would be required to detect a clinical difference with adequate power. The total sample size was increased to 20 patients for possible dropouts.

Randomization and blinding

The allocation sequence for this study was generated using computer-generated simple randomization via online software.¹⁹ After enrolling eligible participants, they were randomly assigned to one of two groups, with ten participants in each group. Allocation sequence concealment was carried

out via telephone, as the random number list was kept secure with the supervisor, who was not involved in the procedures or the outcome assessment. Due to the nature of the intervention, it was impossible to blind the operators and the patients. Only the statistician was blinded to the data analysis, using codes assigned to different groups.

Interventions

All patients who received orthodontic treatment underwent standardized extraoral and intraoral photography, orthodontic model creation, and panoramic and lateral cephalometric radiography. Maxillary molar distalization was performed using a distal jet appliance (American Orthodontics, Washington, Sheboygan, USA) after the first maxillary molars and premolars were separated and banded. The appliance was manufactured as a single unit with four solder joints at the first premolar and first molar bands. Mini-implant insertion slots were positioned 1 mm distal to the third rugae area, 3 mm lateral to the mid-palatal raphe, and 3 mm from the palatal mucosa. Before mini-implant placement, patients were advised to follow oral hygiene measures for two weeks as a prophylaxis. Following local anesthesia and disinfection of the site, two mini-implants (OAS-T1511, Biomaterials Korea Inc. Company) were installed into the (2mm diameter) insertion slot. These mini-implants were positioned perpendicular to the palate and directed away from the roots of the adjacent teeth. Figure 1 shows the distal jet appliance with the mini-implants inserted in their slots.



Figure 1: Distal jet appliance with mini-implants inserted in their slots.

Before the MOPs application, patients were instructed to rinse their mouths with a 0.2% chlorhexidine mouthwash. During the study's observation period, the subjects in the MOPs group received repeated MOPs with each activation.^{20,21} During the procedure, two MOPs were applied under local anesthesia. Orthodontic mini-screws that were 1.4 mm wide and manufactured by Hubit, Korea, were used to apply the MOPs between the second premolars and first molars, first molars and second molars, and distal to the second molars, as shown in Figure 2.



Figure 2: Sites of micro-

osteoperforations used in the study.

The MOPs were performed at a depth of 5 to 6 mm, and the drill was inserted until it crossed through the cortical plate and reached the spongy bone.¹² The participants in the MOP group received six MOP applications on the buccal and palatal sides. After the first activation, the subjects were asked to come in weekly for four weeks for subsequent activation. After each MOP application, the participants were instructed to use chlorhexidine mouthwash three times daily for three days and avoid non-steroidal anti-inflammatory drugs, as they could hinder tooth movement.²²

Outcomes

The primary outcomes of the present study were to assess the rate of distalization of the maxillary molars and the total amount of distalization throughout the observation period. Secondary outcomes included evaluating maxillary molar rotation. For each patient, upper impressions were taken just

before molar distalization (T0) and after each activation (T1, T2, T3, T4). After each visit, the impressions were immediately poured with dental stone and marked with the patient's identification data (name, number, and date). Each stone model was then scanned using a 3Shape E4 scanner to obtain the STL format of the digital model. The sequential digital models of each patient were superimposed using the accompanying 3Shape computer software. Five points were selected on the most anterior, prominent, and posterior points of the incisive papilla and the medial two-thirds of the right and left third rugae areas for superimposition (Figure 3).

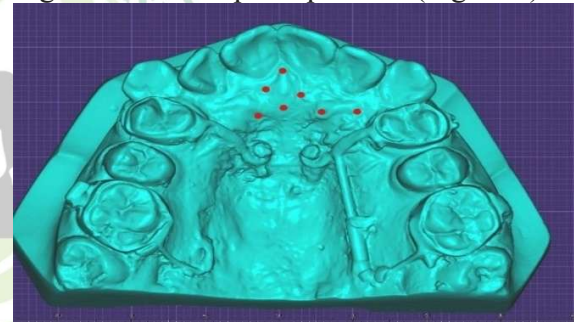


Figure 3: Reference points used for 3D model superimposition.

Color-coded superimposition was used to verify its accuracy.²³

The reconstruction of the reference planes involved the following steps: First, the mid-sagittal plane was positioned, followed by the construction of the rugae plane perpendicular to the mid-sagittal plane at the medial two-thirds level of the right third rugae (Figure 4).

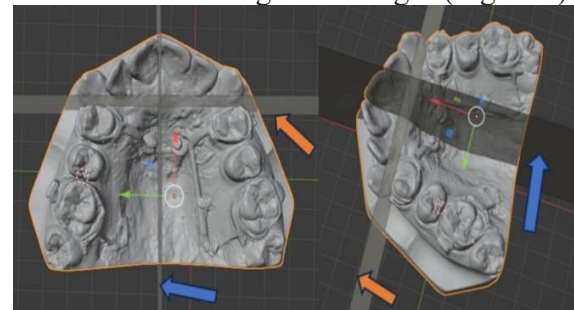


Figure 4: Reference planes used for the 3D model measurements, the mid-sagittal plane (blue arrows), and the rugae plane (orange arrows).

Reference points were identified on the mesiobuccal and disto-palatal cusps of the maxillary first molars. These reference points were used to measure the maxillary molar distalization regarding the constructed plane. The degree of distalization was measured in millimeters at each study point (T0, T1, T2, T3, and T4) using 3Shape Ortho Analyzer software. The total distalization distance was calculated by summing the individual measurements at each period and was verified by comparing the pre-and post-distalization digital model scans. The rotation of the maxillary molars was evaluated by determining the angle between a line connecting the distobuccal and mesial-palatal cusps of the first permanent molar and the midpalatal raphe.^{23–25} Table 1 shows the reference points and measurements taken for each point.

Table 1: measurements of the 3D digital model analysis

Abbreviation	Definition
I- Distances measuring the amount of molar distalization at different intervals during the study's observation period.	
UR6 (MB)– RP (mm)	The sagittal distance (mm) between the upper suitable MB cusp tip and the rugae plane (RP) in the digital model.
UL6 (DB)– RP(mm)	The sagittal distance (mm) between the upper left MB cusp tip and the rugae plane (RP) in the digital model.
II- Angles used to assess first molar rotation (°)	
UR6 RL-MSP (°)	The angle between UR6 RL and the mid-sagittal plane (MSP)
UL6 RL-MSP (°)	The angle between UL6 RL and the mid-sagittal plane (MSP)

RL: rotational line extending between the mesiobuccal cusp tip to the distobuccal cusp tip in each right or left maxillary molar on the digital model.

Statistical methods

Quantitative data were presented as mean and standard deviation, with estimated confidence intervals (CI) at a 95% confidence level. Qualitative variables were presented as numbers and percentages. Statistical analysis was conducted using IBM SPSS Statistics Version 20 for Windows, and data handling was done using Microsoft Excel. Appropriate statistical tests were chosen based on data behavior, with an independent sample t-test

used for normally distributed data. Intergroup comparison was conducted using an independent t-test, and time-dependent variables were analyzed using the general linear model for repeated measurements. Confidence intervals were set at a 95% confidence level, with a 5% margin of the accepted α error. Shapiro-Wilk test was used to assess the data normality.

Results

Participants flow and dropouts

In the present study, 20 participants were initially enrolled and assigned randomly to one of the two groups of ten each. Seven males and thirteen females were included. However, one female participant in each group was lost to follow-up, and the remaining 9 participants were available for the final analysis. The consort flow diagram shows the participants' flow (Figure 5).

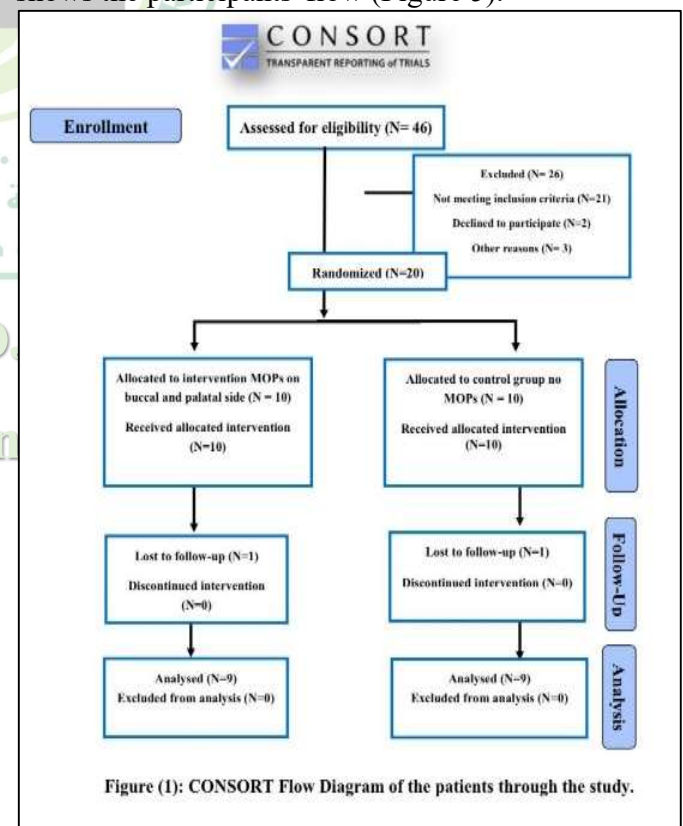


Figure 5: CONSORT Flow Diagram of the patients through the study.

Mean age values for each group were 16 ± 0.5 and 16.5 ± 0.4 for the control and MOPs group, respectively. Data were normally distributed, as evidenced by a non-significant ($p > 0.05$) Shapiro-Wilk test and no significant difference between baseline characteristics ($p > 0.05$).

Intragroup comparison

Table 2 shows the intragroup comparison of the treatment effects in both groups on the position and rotation of the maxillary molar before and after treatment using the 3D-scanned digital models. Significant differences only existed in the MOPs group regarding the position of the right and left maxillary molars and the rotation of the left maxillary molar.

Table 2: Descriptive statistics and comparison of the 3D scanned digital study model measurements before treatment (T0) and after distalization (T4) in the control and MOPs group (N= 9), using paired t-test

Variable (mm)	Descriptive values (T4-T0)				Intergroup difference (MOPs - control)					
	Control group		MOPs group		t-value	Sig. (2-tailed)	Mean dif.	S.E.	95% CI	
	mean	SD	mean	SD					Lower limit	Upper limit
Changes in UR6 position	1.56	2.29	2.88	2.47	-1.153	0.27 NS	-1.31	1.14	-3.72	1.09
Changes in UL6 position	1.4	1.82	2.24	1.74	-1.0	0.33 NS	-0.84	0.84	-2.63	0.94
Changes in UR6 rotation	2.88	3.44	2.0	8.46	0.27	0.79 NS	0.88	3.19	-5.9	7.65
Changes in UL6 rotation	3.13	7.34	2.98	3.73	0.06	0.96 NS	0.15	2.67	-5.49	5.78

Intergroup comparison

Table 3 shows the intergroup comparison between the two groups before and after treatment regarding the position and rotation of the maxillary molar using 3D-scanned digital models. Results show no significant differences between different groups regarding the changes in position or rotation.

Table 3: Descriptive statistics and comparison of the digital study model measurements before treatment (T0) and after (T4) distalization between groups (control and MOPs) using independent t-test

Variables	Control Group									
	Descriptive statistics				Changes from baseline (T4-T0)					
	T0		T4		Mean	SD	95% CI		T-value	Sig. (2-tailed)
	Mean	SD	Mean	SD			Lower Limit	Upper Limit		
Changes in the UR6 position	13.29	4.12	14.85	3.04	1.56	2.3	-0.36	3.49	1.92	0.1 NS
Changes in the UL6 position	16.09	2.25	17.49	2.8	1.4	1.82	-0.12	2.92	2.18	0.07 NS
Changes in the UR6 rotation	43.5	9.56	46.38	7.91	2.88	3.44	-0.0	5.75	2.36	0.05 NS
Changes in the UL6 rotation	46.88	11.32	50	8.62	3.13	7.34	-3.01	9.26	1.21	0.27 NS
MOPs group										
Changes in UR6 position	19.48	5.9	22.35	5.44	2.88	2.47	1.11	4.64	3.68	0.01**
Changes in UL6 position	22.29	3.97	24.53	4.38	2.24	1.74	1	3.48	4.08	0.0***
Changes in UR6 rotation	64.62	4.48	66.62	9.4	2	8.46	-4.05	8.05	0.75	0.47 NS
Changes in UL6 rotation	66.5	6.97	69.48	5.73	2.98	3.73	0.31	5.65	2.53	0.03*

SD Standard deviation, P- value = Probability value, sig. = Significance, NS =Non-significant ($P > 0.05$), * = Significant ($P \leq 0.05$), T0= before treatment, T4=after distalization, CI= Confidence interval.

Analysis of changes in the rate of maxillary molar distalization for the 3D model measurements over time.

The general linear model for repeated measurements was utilized to analyze time-dependent variables for the control group, the MOPs group, and the intergroup comparison (Tables 4 and 5). The MOPs group only experienced a significant change over time in the right and left maxillary molar positions. This change was also significant during the comparison between both groups over time.

Table 4: Descriptive statistics and comparison of the 3D scanned digital study model measurements at time points T1, T2, T3, and T4 to analyze the time-dependent variables (rate changes) for the control group using the Wilks Lambda test.

Control group									
Variables	T1		T2		T3		T4		Test sig.
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Changes in UR6 position (mm)	13.28	4.12	13.76	3.31	14.11	3.01	14.85	3.04	0.06 NS
Changes in UL6 position (mm)	16.08	2.25	16.56	2.62	17.34	3.65	17.49	2.79	0.35 NS
Changes in UR6 rotation (°)	43.5	9.56	45.75	10.48	45.63	8.65	46.38	7.91	0.09 NS
Changes in UL6 rotation (°)	46.87	11.32	47.63	10.09	48.86	8.2	50.0	8.62	0.76 NS
MOPs group									
Changes in UR6 position (mm)	19.47	5.9	20.12	6.06	21.87	5.34	22.35	5.437	0.003*
Changes in UL6 position (mm)	22.28	3.97	22.9	4.16	23.96	4.25	24.53	4.378	0.017*
Changes in UR6 rotation (°)	64.62	4.48	65.03	4.97	67.17	7.17	66.62	9.40	0.19 NS
Changes in UL6 rotation (°)	66.5	6.97	67.42	7.32	68.77	7.33	69.48	5.734	0.24 NS

Test sig. = Wilks Lambda test significance, NS =Non-significant ($P>0.05$), T1= After the first month of distalization, T2= After the second month of distalization, T3= After the third month distalization T4=After distalization, CI= Confidence interval.

Table 5: Descriptive statistics and comparison of the 3D scanned digital study model measurements at time points T1, T2, T3, and T4 to analyze the time-dependent variables (rate changes) for the intergroup comparison using Greenhouse-Geisser test significance.

Variable		T1		T2		T3		T4		Test sig.
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Changes in UR6 position (mm)	Control (N=9)	13.29	4.12	13.76	3.31	14.11	3.01	14.85	3.04	0.004**
	MOP (N=9)	19.49	5.9	20.12	6.06	21.87	5.34	22.35	5.44	
Changes in UL6 position (mm)	Control	16.09	2.25	16.56	2.62	17.34	3.65	17.49	2.79	0.001***
	MOP	22.29	3.97	22.9	4.16	23.96	4.25	24.53	4.38	
Changes in UR6 rotation (°)	Control	43.50	9.56	45.75	10.48	45.63	8.65	46.38	7.91	0.191 NS
	MOP	64.62	4.48	65.03	4.96	67.17	7.17	66.62	9.4	
Changes in UL6 rotation (°)	Control	43.50	9.56	45.75	10.48	45.63	8.65	46.38	7.91	0.191 NS
	MOP	64.62	4.48	65.03	4.97	67.17	7.17	66.62	9.4	

N= Number, Test sig. = Greenhouse-Geisser test significance, NS =Non-significant ($P>0.05$), **= Highly significant ($P\leq 0.01$), ***=Extremely significant ($P\leq 0.001$), T1= After the first month of distalization, T2= After the second month of distalization, T3= After the third month distalization T4=After distalization, CI= Confidence interval.

Discussion

The current study aimed to evaluate the distalization of maxillary molars using the skeletally-anchored distal jet appliance assisted with micro-osteoperforations. Maxillary molar distalization is a conservative treatment option for creating space and correcting class II molar relationships when necessary.¹² Distalization has always been challenging in orthodontics due to anchorage requirements and anatomical limitations. However, introducing temporary anchorage devices (TADs) with various advantages has minimized these challenges.^{18,24,26,27} Numerous techniques have been proposed in the literature for speeding up orthodontic tooth movement, both surgical and nonsurgical. Corticotomies, although found to produce favorable outcomes^{7,28}, are invasive and may not be practical for routine use. The application of micro-osteoperforations (MOPs) is considered the most crucial technique in acceleration biology due to its minimally invasive nature, low cost, short operative time, and relative comfort for the patient.^{9,29}

In recent years, there has been conflicting evidence regarding the ability of MOPs to accelerate orthodontic tooth movement. Some studies have reported that MOP application is a safe procedure to accelerate tooth movement, increase cellular activity, and facilitate root movement. On the other hand, other studies have shown that MOPs have limited and temporary effects on the bone and do not significantly impact tooth movement.^{9,12,20,21,29}

All participants in the current study underwent maxillary molar distalization using the skeletally anchored distal jet appliance assisted with or without MOPs. The same activation protocol was followed for a 4-month observation period, as per previous studies.^{9,12,29} Regarding the activation force, subjects received a force of 240 grams per side at each activation (T0)

after four weeks (T1), eight weeks (T2), and 12 weeks (T3) (which was the final activation of the distalization appliance). The study continued for 16 weeks (T4), in agreement with previous studies.³⁰⁻³² As for the MOPs application protocol, 2 MOPs were applied on both the buccal and palatal sides between the second premolars and first molars, first molars, second molars, and distal to the second molars. The MOPs were performed at a depth of 5 to 6 mm by crossing through the cortical plate until the tip of the drill entered the spongy bone, and this process was repeated with each activation of the distalizing appliance.³¹

The present study observed significant distalization ($P \leq 0.05$) for the control group's right and left maxillary first molars. The distalization was measured at 1.56 mm and 1.4 mm, respectively, compared to 2.9 mm and 2.2 mm in the MOPs group. However, there was no significant difference between the two groups. Although the mean values of first molar movement in the MOPs group appeared slightly higher at the end of the 4-month observation period (1.34 mm and 0.8 mm for the right and left molars, respectively), the intergroup comparison revealed non-significant differences. These non-significant differences may be attributed to the small effect size and sampling. Previous studies have also found that MOPs positively affect orthodontic tooth movement, specifically in maxillary molar distalization.^{12,29,33}

The present study showed no significant differences ($P > 0.05$) in the time-dependent variables of the control group (0.5 ± 0.1 mm/month and 0.46 ± 0.1 mm/month for the upper right and left maxillary first molars, respectively). In contrast, the rate of maxillary molar distalization in the MOPs group showed significant results ($P \leq 0.05$) when comparing T1 Vs. T2 and T1 Vs. T4. Additionally, the intergroup comparison revealed significant differences ($P \leq 0.05$) in

the time-dependent variables of the right and left maxillary first molars, both in total and monthly distalization rates. However, the remaining investigated parameters showed non-significant differences ($P > 0.05$).

These findings support Gulduren et al.¹², who reported that MOPs accelerate maxillary molar distalization. Various human studies, including Babanouri et al., have examined the effects of MOPs on the rate of OTM²¹, Sivarajan et al.³⁴, Aboalnaga et al.³⁵, Mehta et al.³⁶, and Alikhani et al.³⁷ These studies assessed the effect of MOPs during maxillary canine retraction and demonstrated that MOPs effectively accelerate orthodontic tooth movement. Babanouri et al.²¹ reported that MOP interventions positively affect the rate of tooth movement over three months. Conversely, Sivarajan et al.³⁴ found no significant difference in tooth movement when using MOPs at 4, 8, and 12 weeks. Alkebsi et al.³⁸ did not observe a significant effect of MOPs on the rate of orthodontic tooth movement. The findings of Alikhani et al.³⁷ align with the results of this study, which found that using the propel device and a NiTi coil spring that exerted 100 gm force for 28 days significantly increased distal canine movement by 2.3-fold on the MOPs side. Furthermore, Feizbakhsh et al.²⁰ reported similar results to Alikhani et al.³⁷ after evaluating the rate of canine retraction in 20 adult patients following 28 days of MOP treatment. The results indicated that MOPs increased the rate of canine retraction by more than 2-fold.

No significant differences ($P > 0.05$) regarding maxillary molar rotation were observed in this study in both groups. Limited data were available on molar rotation while using MOPs for distalization. However, these results align with previous studies^{23,29,32} that used skeletally anchored molar distalizers. The study presented a significant increase in intermolar width for the control and MOPs groups, 1.4 mm and 2.6 mm, respectively.

However, the intergroup comparison showed no significance. Despite the lack of a significant difference between the groups, the mean value of increased intermolar width in the MOPs group exceeded that in the control group by 1.2 mm, which may be associated with the increased mean value of distalization between groups and supported by previous studies.^{23,24,32,39} The increase in intermolar width could be considered an inherent phenomenon related to the horse-shoe geometry of the upper jaw, as arch width increases with distal movement.^{23,24,40}

The current study has several limitations. Firstly, blinding the patient and operator was impossible, and blinding was only implemented during the analysis stage. Additionally, changes in soft tissues were not evaluated. It is important to note that the results may vary when a larger sample size or a more extended observation period is used. Moreover, it would be beneficial to examine the effect of MOPs on bone density, root resorption, and periodontal status of the teeth. Finally, alternative distalization appliances and application protocols could be compared for long-term treatment and stability.

Conclusions

Incorporating microosteoperforations (MOPs) within the process of maxillary molar distalization, utilizing a skeletally-anchored distal jet appliance, can significantly enhance the speed of molar movement. During the initial and subsequent two months of the investigation, the MOPs group demonstrated a notable increase in distal molar movement compared to the control group. This distinction persisted throughout the four-month duration of the study. Furthermore, implementing MOPs yielded a more significant overall maxillary molar distalization distance than the control group.

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Data availability

Data for this study are available upon reasonable request from the authors.

Declarations

Ethics approval and consent to participate

The Ethics Committee at the Faculty of Dental Medicine (Boys), Al-Azhar University, Cairo, Egypt (code 651/2053) approved this study. All eligible participants' parents or guardians signed written informed consent.

Competing interests

The authors declare that there are no competing interests or conflicts.

References

1. Alhammadi MS, Halboub E, Fayed MS, Labib A, El-Saaidi C. Global distribution of malocclusion traits: A systematic review. *Dental Press J Orthod* 2018;23(6):e1–e10.
2. Umalkar SS, Jadhav V V, Paul P, Reche A. Modern Anchorage Systems in Orthodontics. *Cureus* 2022;14(11).
3. Al-Argi AMA, Abbas IT, Saifeldin H. Correction of Class II Malocclusion with Carrière Distalizer Appliance: (A case report). *Ain Shams Dental Journal* 2021;22(2):100–104.
4. Costello BJ, Ruiz RL, Petrone J, Sohn J. Temporary skeletal anchorage devices for orthodontics. *Oral Maxillofac Surg Clin North Am* 2010;22(1):91–105.
5. Wazwaz F, Seehra J, Carpenter GH, Ireland AJ, Papageorgiou SN, Cobourne MT. Duration of tooth alignment with fixed appliances: A systematic review and meta-analysis. *Am J Orthod Dentofacial Orthop* 2022;161(1):20–36.
6. El-Angebawi A, McIntyre G, Fleming PS, Bearn D. Non-surgical adjunctive interventions for accelerating tooth movement in patients undergoing orthodontic treatment. *Cochrane Database Syst Rev* 2023;6(6).
7. Fleming PS, Fedorowicz Z, Johal A, El-Angebawi A, Pandis N. Surgical adjunctive procedures for accelerating orthodontic treatment. *Cochrane Database Syst Rev* 2015;2015(6).
8. Diraz H, Abbas IT, Sabet NE. Clinical evaluation of the effect of Piezocision on the rate of tooth movement during distalization of maxillary molars. *Ain Shams Dental Journal* 2020;18(2):223–232.
9. Maspero C, Cappella A, Dolci C, Cagetti MG, Inchingolo F, Sforza C. Is Orthodontic Treatment with

Microperforations Worth It? A Scoping Review. *Children (Basel)* 2022;9(2).

10. Frost H. The Regional Acceleratory Phenomenon: A Review. *Henry Ford Hosp Med J* 1983;31(1).

11. Zhang JM, An J. Cytokines, inflammation, and pain. *Int Anesthesiol Clin* 2007;45(2):27–37.

12. Gulduren K, Tumer H, Oz U. Effects of micro-osteoperforations on intraoral miniscrew anchored maxillary molar distalization: A randomized clinical trial. *J Orofac Orthop* 2020;81(2):126–141.

13. Bahaa El-Din AM, Hendy KAK, Mohamed RE, et al. Appraisal of Anchorage Loss During Maxillary Molar Distalization Assisted With Two Approaches of Micro-osteoperforations: A Prospective Clinical Investigation. *Journal of Clinical Otorhinolaryngology, Head, and Neck Surgery* 2014;28(1):105–115.

14. Mohammed Bahaa El-Din A, Abd El Khalik Hendy K, Elghetany Mohamed R, et al. Pain Intensity of Skeletally Anchored Maxillary Molar Distalization in Conjunction with Micro-osteoperforations: A Randomized Clinical Trial. *Cureus* 2024;

15. Awady AA El, Abd Allah KFA, Mohammed A-DA. Efficacy of Micro-Osteoperforations on the Rate of Maxillary Canine Retraction: A Randomized Controlled Trial. *Ain Shams Dental Journal* 2019;16(4):13–18.

16. Awady AA El, Bkallied BF, Mohammed ADA. Effect of flapless micro-osteoperforations on maxillary canine retraction rate and anchorage loss; a CBCT comparative study. *Ain Shams Dental Journal (Egypt)* 2019;16(4):145–152.

17. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods* 2007;39(2):175–191.

18. Cozzani M, Pasini M, Zallio F, et al. Comparison of maxillary molar distalization with an implant-supported distal jet and a traditional tooth-supported distal jet appliance. *Int J Dent* 2014;2014.

19. Haar M. RANDOM.ORG: True Random Number Service [Homepage on the Internet]. 2018; Available from: <https://www.random.org>

20. 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(2):56–60.

21. 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(1).

22. Fang J, Li Y, Zhang K, Zhao Z, Mei L. Escaping the Adverse Impacts of NSAIDs on Tooth Movement

During Orthodontics: Current Evidence Based on a Meta-Analysis. *Medicine* 2016;95(16).

23. Nalcaci R, Kocoglu-Altan AB, Bicakci AA, Ozturk F, Babacan H. A reliable method for evaluating upper molar distalization: Superimposition of three-dimensional digital models. *Korean J Orthod* 2015;45(2):82–88.

24. Kinzinger GSM, Gulden N, Yildizhan F, Diedrich PR. Efficiency of a skeletonized distal jet appliance supported by miniscrew anchorage for noncompliance maxillary molar distalization. *Am J Orthod Dentofacial Orthop* 2009;136(4):578–586.

25. Jaiswal AA, Siddiqui HP, Samrit VD, Duggal R, Kharbanda OP, Rajeswari MR. Comparison of the efficacy of two-time versus one-time micro-osteoperforation on maxillary canine retraction in orthodontic patients: A split-mouth randomized controlled clinical trial. *Int Orthod* 2021;19(3):415–424.

26. Kanomi R. Mini-implant for orthodontic anchorage. *J Clin Orthod* 1997;31(11):763–7.

27. Costa A, Raffaini M, Melsen B. Miniscrews as orthodontic anchorage: a preliminary report. *Int J Adult Orthodon Orthognath Surg* 1998;13(3):201–9.

28. Hassan AH. Corticotomy-Assisted Orthodontic Treatment: Review. *Open Dent J* 2010;4(1):159–164.

29. Mohaghegh S, Soleimani M, Kouhestani F, Motamedian SR. The effect of single/multiple micro-osteoperforation on the rate of orthodontic tooth movement and its possible complications: A systematic review and meta-analysis. *Int Orthod* 2021;19(2):183–196.

30. Gil APS, Haas OL, Méndez-Manjón I, et al. Alveolar corticotomies for accelerated orthodontics: A systematic review. *J Craniomaxillofac Surg* 2018;46(3):438–445.

31. Hashem BA, El-Hassanein E-HH, El-Awady AA, et al. Clinical Evaluation of Single Versus Repeated Micro-Osteoperforations During Orthodontic Canine Retraction: A Randomized Clinical Trial. *Cureus* 2024;16(1):e52026.

32. Mohamed RN, Basha S, Al-Thomali Y. Maxillary molar distalization with miniscrew-supported appliances in Class II malocclusion: A systematic review. *Angle Orthod* 2018;88(4):494–502.

33. Sotelo Núñez N, Hatamzade Z, Zamiri SS, Safi M. Evaluation the Effect of Micro-osteoperforation on the Tooth Movement Rate and the Level of Pain on Miniscrew-supported Maxillary Molar Distalization: A Systematic Review and Meta-analysis. *International Journal of Scientific Research in Dental and Medical Sciences* 2020;2(3):81–86.

34. 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(2):183–189.

35. Aboalnaga AA, Salah Fayed MM, El-Ashmawi NA, Soliman SA. Effect of micro-osteoperforation on the rate of canine retraction: a split-mouth randomized controlled trial. Prog Orthod 2019;20(1):21.

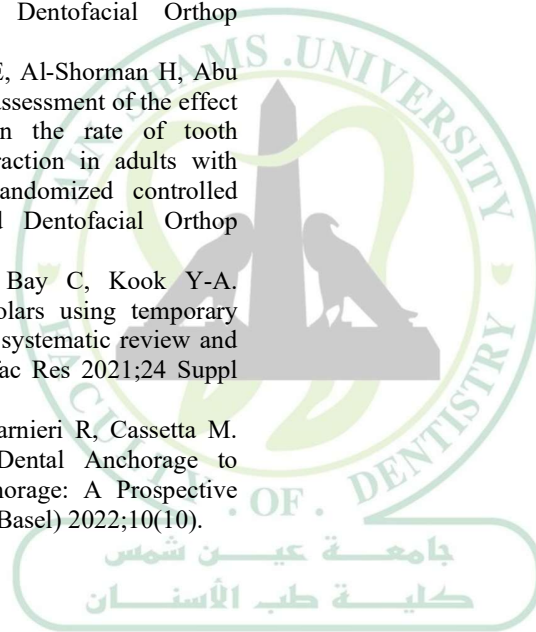
36. Mehta A, Shah A, Patel V, Desai B, Patel R, Patel V. Effect of Micro-osteoperforations on the Rate of Orthodontic Tooth Movement: A Randomized Controlled Trial. Journal of Contemporary Orthodontics 2023;4(1):12–20.

37. Alikhani M, Raptis M, Zoldan B, et al. Effect of micro-osteoperforations on the rate of tooth movement. Am J Orthod Dentofacial Orthop 2013;144(5):639–48.

38. Alkebsi A, Al-Maaitah E, Al-Shorman H, Abu Alhajja 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(6):771–785.

39. Bayome M, Park JH, Bay C, Kook Y-A. Distalization of maxillary molars using temporary skeletal anchorage devices: A systematic review and meta-analysis. Orthod Craniofac Res 2021;24 Suppl 1:103–112.

40. Altieri F, Mezio M, Guarnieri R, Cassetta M. Comparing Distal-Jet with Dental Anchorage to Distal-Jet with Skeletal Anchorage: A Prospective Parallel Cohort Study. Dent J (Basel) 2022;10(10).



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