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Retrospective analysis of mini-implant assisted micro-osteoperforation for accelerating canine movement in adult orthodontics

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Abstract

Background Traditional orthodontic treatment methods are associated with long treatment durations and patient discomfort. The mini-implant assisted micro-osteoperforation (MOP) has shown great potential in clinical practice, but systematic research on this technology remains limited.

Methods A retrospective analysis of 106 adult patients requiring extraction of both maxillary first premolars were conducted, with patients randomly grouped: experimental group (EG, mini-implant assisted MOP) and control group (CG, conventional orthodontic treatment), with 53 cases in each. Tooth movement distances, root resorption amounts, craniofacial relationship measurement angles (SNA, SNB, ANB), maxillary anterior tooth positions and angles (U1-X, U1-Y, U1-SN), maxillary first molar positions and angles (U6-X, U6-Y, U6-X), and soft tissue angles (NLA) were compared.

Results The distance of canine movement in the EG was (1.89±0.28) mm after 1 month of force application, and (3.67±0.54) mm after 2 months of force application. In the CG, the distance of canine movement was (0.96±0.32) mm after 1 month of force application, and (1.88±0.34) mm after 2 months of force application. The EG suggested visibly greater canine movement distances one month and two months after force application as against the CG, with visibly lower U1-X and U1-Y angles, and visibly lower U6-X and U6-Y angles ($P<0.05$). No visible distinctions were noted in soft tissue angles between the EG and the CG one month and two months after force application ($P>0.05$).

Conclusion Compared to existing orthodontic treatment methods, implant-supported mini-screw perforation surgery, as an auxiliary approach to accelerate orthodontic treatment, can significantly accelerate tooth movement without significantly increasing the risk of root resorption, and has minimal impact on craniofacial relationships and soft tissues. This finding provides a new and effective adjunct for orthodontic treatment, with the potential to shorten treatment duration and improve the patient experience in clinical practice, making it of significant importance for advancing the development of orthodontic techniques.

Keywords Orthodontic treatment, Min-implant, MOP, Tooth movement distance, Root resorption amount

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Background

Orthodontic treatment is an important part of modern dentistry, aiming to correct abnormalities in teeth, jaws, and occlusion to improve patients' facial aesthetics, function, and oral health. Malocclusions and misaligned teeth not only affect patients' appearance but may also lead to a series of oral diseases, such as gingivitis, periodontal disease, dental caries, and masticatory dysfunction [1, 2].

Malocclusions can lead to tooth wear, difficulty in chewing, speech disorders, severely affecting patients' quality of life (QoL). Moreover, poor occlusion may have potential impacts on the digestive system and overall health [3]. Therefore, orthodontic treatment is not only conducive to enhancing patients' aesthetics but also an effective means of improving oral health and QoL.

Traditional orthodontic treatment methods include fixed appliances, removable appliances, and some auxiliary devices. Fixed appliances are the most commonly used orthodontic treatment method, typically consisting of brackets, arch wires, and various auxiliary materials, which slowly move teeth to the ideal position by applying continuous corrective forces [4]. Although fixed appliances provide relatively accurate and stable forces during treatment, due to the complex biological processes involved in tooth movement, treatment durations are usually long, especially in adult patients, which may take a year or longer. Additionally, long-term wear of fixed appliances can lead to oral discomfort, such as mouth ulcers and toothache, and patient compliance may be affected. Removable appliances are more commonly used for mild tooth misalignment or pediatric patients, who can wear and remove them by themselves, but their treatment effects and stability are usually not as good as fixed appliances, thus limiting their clinical application [5]. In addition to traditional appliances, transparent aligners have become a widely concerned new treatment method in recent years, especially among adult patients, due to their invisible and comfortable characteristics, gaining widespread application. Aligners gradually adjust tooth positions through a series of custom-made transparent plastic brackets, but their treatment effects are influenced by the patient's wearing time and compliance, and treatment durations may be longer than traditional methods [6]. Although traditional orthodontic treatment methods have achieved visible results, issues such as long treatment durations, patient discomfort, side effects during treatment, and poor compliance still exist [7]. Therefore, how to shorten treatment durations, improve treatment effects, reduce patient discomfort and side effects has always been an important topic in orthodontic research.

In recent years, with the rapid development of biomedical and materials science, accelerated orthodontic techniques have become a research hotspot. Micro-osteoperforation (MOP), as a key breakthrough in this field, involves performing minimally invasive perforations in specific regions of the alveolar bone to activate local bone remodeling mechanisms, thereby accelerating tooth movement and potentially shortening the duration of orthodontic treatment [8, 9]. However, current research on MOP technology varies in terms of puncture sites, depth, frequency, and the combined application with orthodontic appliances, and no unified standard or optimal protocol has yet been established. MOP can be performed manually or with mechanical assistance [10]. Manual perforation is relatively simple but requires a high level of precision in controlling the depth and force, which depends largely on the operator's experience. Mechanical-assisted perforation, using specialized equipment, allows for more precise control over the perforation parameters, ensuring stability and reproducibility, though it comes with higher equipment costs and a more complex operational process. If the perforation depth is too shallow, it may fail to effectively stimulate bone remodeling,if it is too deep, it could potentially damage the tooth root and periodontal tissues. The selection of puncture sites must be accurately tailored to the movement direction and requirements of the target tooth, while the frequency of perforations should consider both the bone tissue's ability to repair itself and the efficiency of tooth movement [11, 12].

Compared to previously published studies, this research presented unique contributions. On one hand, it focused on a specific patient group, such as adolescents with mild periodontitis undergoing orthodontic treatment, and explored the applicability and optimal application protocol of MOP technology tailored to the oral physiological characteristics and orthodontic needs of this population. This approach aims to provide more targeted clinical guidance for orthodontic treatment in this special patient group. On the other hand, in terms of study design, this research employed an innovative methodology, such as a multicenter, large-sample randomized controlled trial, to rigorously control for confounding factors and comprehensively evaluate the efficacy, safety, and patient comfort associated with MOP technology in accelerating orthodontic tooth movement. The goal was to provide a stronger scientific basis for the broader clinical application of MOP technology. Therefore, this article aims to explore the clinical application effects of the mini-implant assisted MOP technique in accelerating orthodontic tooth movement. By comparing the distinctions in treatment duration, tooth movement speed, treatment effects, and patient comfort between patients who used this technique and those who did not, the clinical application value of this technique is assessed. Through the summary and analysis of relevant clinical data, it is expected to provide a scientific basis for the widespread application of MOP technology and to provide more technical support and guidance for clinical orthodontic treatment.

Materials and methods

Subjects

A retrospective analysis of the clinical data of 106 adult patients who required the extraction of both maxillary first premolars treated at Wuwei Hospital of Traditional Chinese Medicine from February 2020 to February 2024 was conducted. Among them, there were 46 males and 50 females, aged 18 to 45 years old.

Inclusion criteria: Good oral hygiene and periodontal condition; individuals informed about the trial, with the informed consent form; no contraindications to local anesthesia; no history of maxillofacial trauma; complete dentition without missing lower anterior teeth and no history of dental and periodontal treatment; individuals requiring extraction of maxillary bilateral first premolars for orthodontic treatment; no need for other intraoral or extraoral devices during orthodontic treatment. Exclusion criteria: Individuals with systemic diseases and bone metabolic diseases; those with abnormal coagulation function; those with a history of mental illness; individuals undergoing a second round of orthodontic treatment.

Sample size calculation

During the study design phase, sample size estimation was performed using *G*Power 3.1*. The distance of canine movement was chosen as the primary efficacy endpoint. Based on preliminary experiments and relevant literature, the expected difference in canine movement between the EG and CG was [*X*] mm, with a standard deviation of [*SD*] mm. The significance level was set at $\alpha = 0.05$ (two-tailed) and the power at $1-\beta = 0.80$. Based on these parameters, the required sample size per group was calculated to be [sample size]. Considering potential dropout, a 10% increase in sample size was applied, resulting in a final total of 53 patients per group, with a total of 106 participants.

Surgical methods

All subjects underwent orthodontic treatment with straight arch wire self-ligating brackets (Hangzhou Shinye) after the extraction of both maxillary first premolars. According to the surgical methods, participants were randomly assigned to the experimental group (EG) and control group (CG). In the EG, MOP was performed using micro-implant anchorage screws under 2% lidocaine local anesthesia. The micro-implant anchorage screws used in this study were made of medical-grade pure titanium, with a diameter of 1.5 mm and a length of 8 mm. The procedure was performed on the cortical bone between the maxillary canine and second premolar on one side. A specialized slow-speed handpiece was used during the operation, with a rotation speed of 150–200 rpm, gently and steadily rotating the tool to slowly insert the micro-implant anchorage screw until the perforation depth reached 7 mm. After achieving the required depth, the tool was gently rotated in reverse at the same speed to remove it. Immediately post-surgery, a 100-gram force was applied to both canines at the perforation site using ligature wire and elastic chains. Regular measurements were taken before and during the force application to ensure the force remained close to 100 grams, with an error margin controlled within ±5 grams. In the CG, no perforation was performed. Instead, participants received conventional orthodontic treatment, following the standard protocol of straight-wire arch mechanics. They were fitted with Hangzhou Xinya self-ligating brackets and underwent regular adjustments of the archwire by the orthodontist based on the tooth movement, guiding the teeth to move gradually.

The standard definition of root resorption was as follows. In CBCT images, root resorption was diagnosed when a continuous low-density image appeared on the root surface, with a width exceeding 0.5 mm, and when the root outline showed noticeable depression or irregularities.

The canine movement distance and root resorption were measured at 1 and 2 months after force application in both the EG and CG. In evaluating root resorption, panoramic radiographs (X-ray) provide a comprehensive view of the entire dentition and jawbone, offering an initial observation of the root's overall shape, length, and its relationship with surrounding tissues. This helps in the preliminary screening of root resorption and provides a broad overview. In contrast, cone-beam computed tomography (CBCT) offers more precise three-dimensional imaging, allowing for clearer detection of subtle changes in root resorption, such as localized depressions on the root surface or resorption at the root curvature. This helps accurately measure the changes in root length. By combining both imaging techniques, a comprehensive assessment of root resorption can be made from different perspectives. All measurements were recorded by two independent orthodontists, and statistical software was used to analyze the differences between the two groups in terms of canine movement distance and root resorption.

Observational indicators

(1) Tooth movement distance

A coordinate system was established with the midpoint of the mesio-buccal cusp tips of the bilateral maxillary first molars as the origin. Customized trays were fabricated, and precise maxillary impressions were taken from the patient using silicon rubber, followed by pouring with high-strength dental stone. Anatomically, the premolars exhibit a mesial marginal ridge, whereas the canines lack a “distal marginal ridge” and instead have a “distal cusp ridge” that curves toward the tooth apex, making precise measurement challenging. Therefore, the highest point of the canine contour (height of contour, HoC) was chosen as the reference point for measurements. Using a vernier caliper, the distance between the HoC of the canine and the mesial marginal ridge of the second premolar was measured. Three measurements were taken before and after the experiment, and the average value was calculated. The difference between the pre- and post-experiment average values was used to determine the tooth movement distance. All measurements were performed by the same highly trained operator with extensive experience to ensure the accuracy and consistency of the measurements.

(2) Root resorption amount

Cone-beam CT (Siemens, Germany) was taken before and after force application to measure the length of the canine root. The distinction in root length before and after force application was the root resorption amount.

(3) Lateral cephalograms

The following angles and distances in patients were measured using the Japanese Rigaku intelligent multifunctional X-ray diffractometer: SNA angle (the angle formed by the cranial base point S, the nasal root point N, and the most anterior point of the maxillary bone A), SNB angle (the angle formed by the cranial base point S, the nasal root point N, and the most anterior point of the mandibular bone B), ANB angle (the angle formed by the most anterior point of the maxillary bone A, the nasal root point N, and the most anterior point of the mandibular bone B), U1-X (upper central incisor – maxillary dental protrusion), U1-Y (upper central incisor – vertical height), U1-SN angle (the angle between the upper central incisor and the cranial base plane SN), U6-X (maxillary first molar – maxillary dental protrusion), U6-Y (maxillary first molar – vertical height), U6-X angle (the angle between the maxillary first molar and the alveolar bone), and NLA angle (nasolabial angle). The measurement steps included locating key anatomical points, calibrating the X-ray equipment, ensuring the subject’s correct posture, and accurately recording the measurement values of each angle and distance for comparative analysis.

Statistical processing

Data were analyzed using *SPSS 22.0* statistical software. For quantitative data, normality was assessed using the Shapiro-Wilk test, with $P > 0.05$ considered indicative of a normal distribution. Data were presented as mean ± standard deviation ($\bar{x} \pm s$), and intergroup comparisons were performed using one-way analysis of variance (ANOVA). For data that did not meet the assumption of normality, the Mann-Whitney test was used. Categorical data, such as patient gender and adherence to inclusion or exclusion criteria, were presented as frequencies and percentages (%), and group comparisons were conducted using the Chi-square test. A P value of < 0.05 was considered statistically significant.

Results

Contrast of canine movement distance after force application in subjects

In Fig. 1, the distance of canine movement in the EG was (1.89±0.28) mm after 1 month of force application, and (3.67±0.54) mm after 2 months. In the CG, the canine movement distance was (0.96±0.32) mm after 1 month and (1.88±0.34) mm after 2 months. The canine movement distances in the EG after 1 month and 2 months of force application were significantly greater than those in the CG, and the differences were statistically significant (P<0.05).

Contrast of root resorption amounts in subjects after force application

In Fig. 2, the root resorption in the EG was (0.51±0.16) mm after 1 month of force application and (0.85±0.22) mm after 2 months. In the CG, the root resorption was (0.44±0.12) mm after 1 month and (0.79±0.18) mm

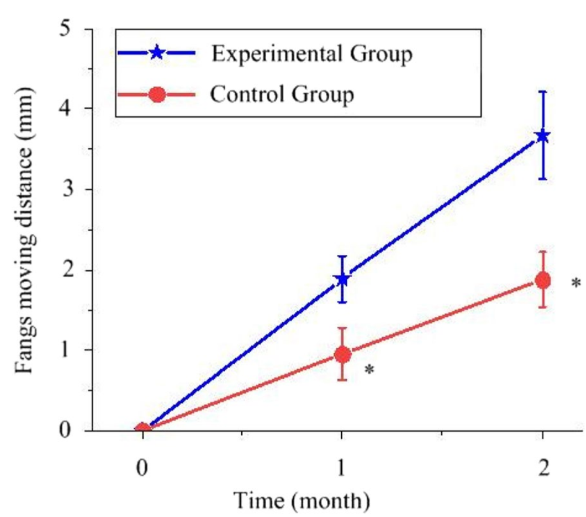

Fig. 1 Contrast of canine movement distances after force application in subjects. Note: *as against the EG, P <0.05

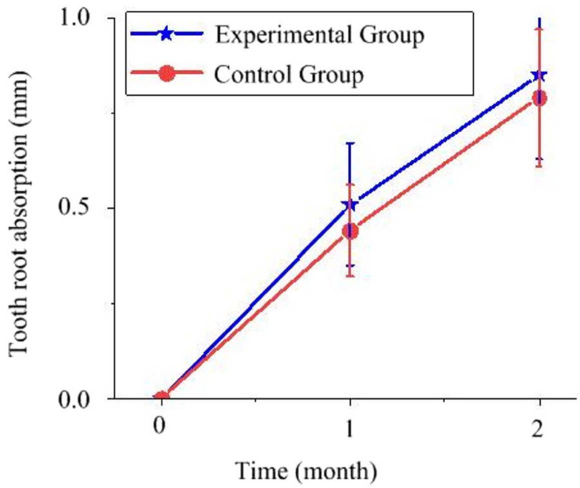

Fig. 2 Contrast of root resorption amounts in subjects after force application. Note: *as against the EG, *P* <0.05

after 2 months. It can be observed that root resorption increased in both the EG and CG after 1 month and 2 months of force application, but the differences between the groups were not statistically significant (*P*>0.05).

Contrast of craniofacial relationship measurement angles in subjects

In Fig. 3, no visible distinctions were noted in the SNA, SNB, and ANB angles before force application; the distinctions in the SNA, SNB, and ANB angles between the EG and the CG one month and two months after force application were also not visible (*P* >0.05).

Contrast of the position and angles of the maxillary anterior teeth in subjects

In Fig. 4, no visible distinctions were noted in the U1-X, U1-Y, and U1-SN angles before force application; one month and two months after force application, the distinction in the U1-SN angle between the EG and the CG was not visible (*P* >0.05), but the U1-X and U1-Y in the EG were markedly lower as against the CG (*P* <0.05).

Contrast of the position and angles of the maxillary first molars in subjects

In Fig. 5, no visible distinctions were noted in the U6-X, U6-Y, and U6-X angles before force application; one month and two months after force application, the

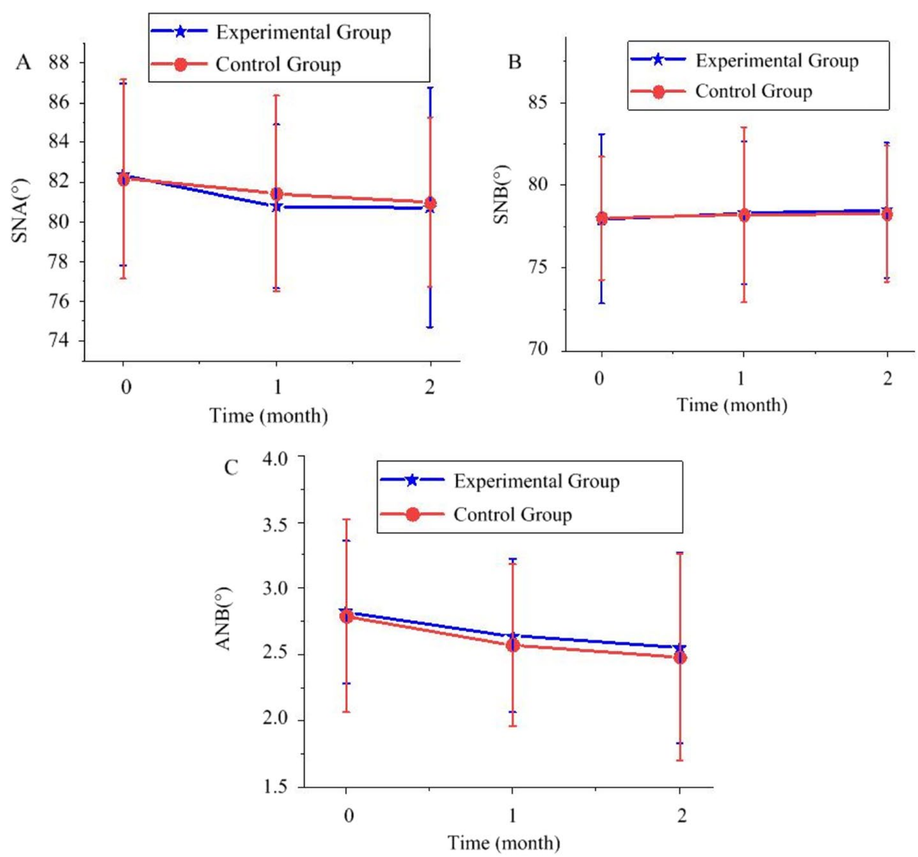

Fig. 3 Contrast of craniofacial relationship measurement angles in subjects. (**A**-**C** represent SNA, SNB, and ANB angles, respectively)

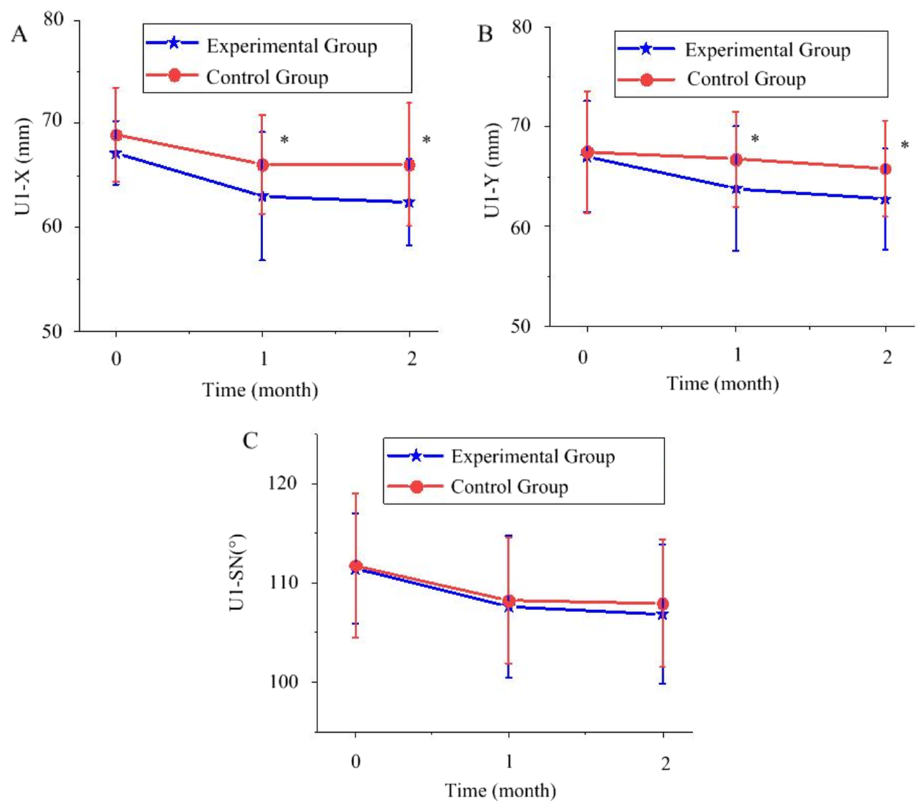

Fig. 4 Contrast of the position and angles of the maxillary anterior teeth in subjects. (**A**-**C** represent U1-X, U1-Y, and U1-SN angles, respectively). Note: *as against the EG, P <0.05

distinction in the U6-X angle between the EG and the CG was not visible (P >0.05), but the U6-X and U6-Y in the EG were markedly lower as against the CG (P <0.05).

Contrast of soft tissue angles in subjects

In Fig. 6, the soft tissue angle (NLA) in the EG before force application was (98.31±6.05)°, and in the CG, it was (97.79±8.14)°. There was no significant difference in the soft tissue angle between the two groups before force application (P>0.05). After 1 month of force application, the soft tissue angle in the EG was (100.11±9.32)°, and in the CG, it was (99.68±6.37)°. After 2 months of force application, the soft tissue angle in the EG was (100.21±10.44)°, and in the CG, it was (100.13±8.35)°. The differences in soft tissue angle between the EG and CG after 1 month and 2 months of force application were not statistically significant (P>0.05).

Discussion

Orthodontic treatment aims to facilitate tooth movement by applying continuous external forces. However, traditional orthodontic treatment often requires a long time to complete, which not only demands a high level of patience and cooperation from patients but may also be accompanied by some side effects during the long treatment process, such as root resorption and periodontitis [13]. Therefore, how to accelerate the speed of tooth movement and shorten the treatment period has become an important research topic in the field of orthodontics. In recent years, MOP (Wilckodontics) has received widespread attention as an adjuvant treatment method because it can accelerate tooth movement. MOP stimulates local bone remodeling by inflicting small-scale trauma on the alveolar bone, thereby improving the efficiency of force transmission and shortening treatment time [14, 15]. Although studies have explored the effects of MOP, most have focused on its impact on the speed of tooth movement, with relatively fewer studies on its effects on root resorption and overall treatment outcomes [16]. Therefore, this article retrospectively analyzed the clinical data of 106 adult patients who required the extraction of both maxillary first premolars, to explore the impact of MOP on canine movement during orthodontic treatment. By comparing the canine movement distance, root resorption amount, craniofacial relationships, and tooth angles between the EG

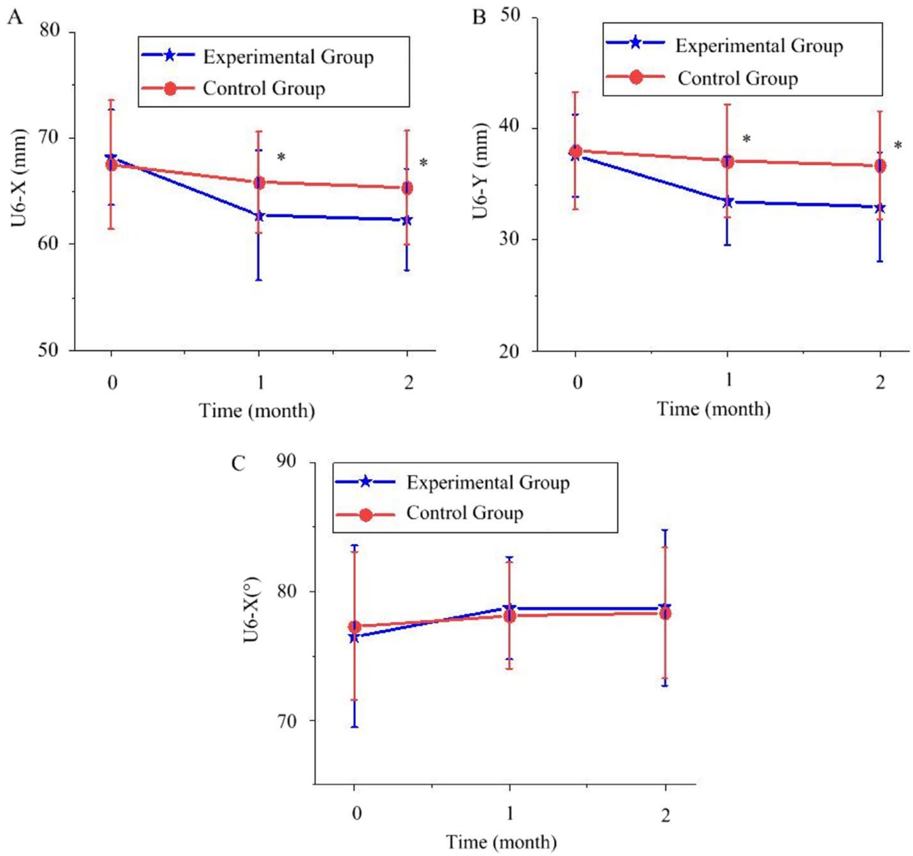

Fig. 5 Contrast of the position and angles of the maxillary first molars in subjects. (**A**-**C** represent U6-X, U6-Y, and U6-X angle, respectively). Note: *as against the EG, $P < 0.05$

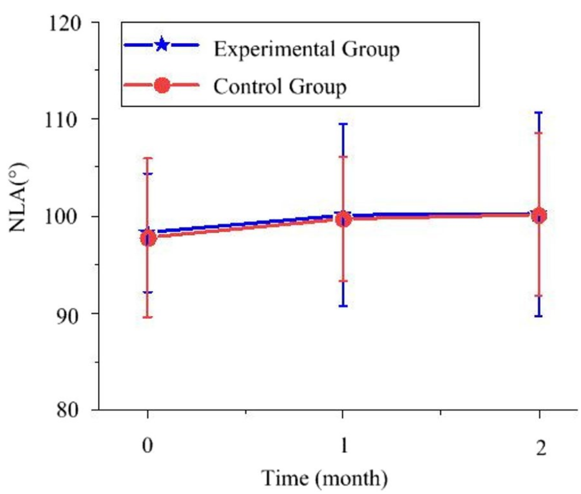

Fig. 6 Contrast of soft tissue angles in subjects

(mini-implant assisted MOP) and the CG (conventional orthodontic treatment), some meaningful conclusions were drawn. The results of this article indicate that the canine movement distance in the EG one month and two months after force application was markedly greater as against the CG, which is consistent with the role of MOP in accelerating tooth movement as documented in existing literature [17, 18]. MOP traumatically alters the biomechanical environment of bone tissue, stimulating local bone remodeling and skeletal reconstruction, increasing the elasticity of the alveolar bone, and the efficiency of force transmission. This bone remodeling process allows teeth to move more rapidly during orthodontic treatment, thereby shortening treatment time. Compared with traditional orthodontic methods, MOP can markedly accelerate tooth movement, reduce the treatment burden on patients, and is in line with the trend of "accelerated orthodontics" in modern orthodontics.

It is noteworthy that although the EG demonstrated a faster rate of canine movement, there was no statistically significant difference in the amount of root resorption. This finding is consistent with some studies, which suggest that while MOP accelerates tooth movement, it does not significantly increase the incidence of root resorption. Root resorption is a common complication in orthodontics and is closely related to the magnitude of orthodontic force, treatment duration, and individual bone quality [19, 20]. These parameters were also measured during the study, and the results showed that MOP had no significant impact on these oral parameters. Specifically, after 1 and 2 months of force application, there were no significant differences in the SNA angle, SNB angle, ANB angle, and U1-X, U1-Y angles between the EG and CG. This suggests that MOP primarily affects local tooth movement and does not induce noticeable changes in the overall structure of the maxillofacial bones. This is consistent with the mechanism of MOP, which accelerates bone remodeling and tooth movement [21]. Overall, this study confirmed the effectiveness of MOP in adult orthodontic treatment, particularly in accelerating canine movement. The EG showed a significant acceleration in canine movement after 1 to 2 months of force application without significantly increasing the risk of root resorption, indicating that this technique can serve as an effective adjunct to shorten orthodontic treatment time [22]. However, while the short-term effects are evident, long-term effects, particularly in terms of root resorption, bone quality, and other potential complications, still require further validation.

This study has certain limitations. First, as a retrospective study, the data collection relied on previous clinical records, which may have resulted in incomplete or inaccurate data. For example, the documentation of some patients' oral hygiene maintenance was insufficient, which could impact periodontal status and root resorption, but could not be accurately assessed in this study. Second, although randomization was used for grouping, potential selection bias may still exist due to the sample being drawn from patients treated at our hospital within a specific time frame. For instance, patients choosing to undergo orthodontic treatment at our hospital might share similar lifestyle habits or economic conditions, which could affect the generalizability of the findings. Furthermore, during the course of the study, some potential confounding factors may have influenced the results. For example, differences in patient compliance could lead to variations in orthodontic treatment outcomes. Although patients were required to attend regular follow-up visits and wear their appliances as prescribed, non-compliance among some patients might have interfered with an accurate assessment of the effects of MOP. Additionally, the proficiency of different clinicians in performing the procedure could also impact the outcome of MOP. Although every effort was made to ensure that the procedures were carried out by experienced clinicians, the potential interference from this factor could not be fully eliminated. Future studies should continue to focus on the long-term effects and safety of MOP, as well as explore its adaptability and application in different patient populations.

Conclusion

This study retrospectively analyzed data from 106 adult orthodontic patients to explore the application of MOP with implant anchorage screws in orthodontics. The results showed that MOP positively affects adult orthodontic treatment by accelerating tooth movement without significantly increasing the risk of root resorption. It primarily influences the local movement of teeth and does not have a significant impact on the overall structure of the maxillofacial bones or related oral parameters. However, the study has limitations due to its retrospective nature, with potential issues regarding data completeness and accuracy. The sample source may introduce selection bias, and factors such as patient compliance and clinician proficiency may interfere with the results. Despite these limitations, the study provides important evidence for the application of MOP in adult orthodontic treatment. Future research should adopt a prospective design, expand the sample size, and strictly control confounding factors. Further investigations should focus on the long-term effects and safety of MOP and explore its applicability in different patient populations. Continuous optimization of this technique is essential for advancing the field of orthodontics.

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Clinical trial number
Not applicable.

Authors' contributions
All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by XL. The first draft of the manuscript was written by JY, KL and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data availability
The original contributions presented in the study are included in the article.

Declarations

Ethics approval and consent to participate
The study was approved by the local ethics committee of the Wuwei Hospital of Traditional Chinese Medicine. All experiments were performed in accordance with relevant guidelines and regulations such as the Declaration of Helsinki and the patients signed the informed consent form and agreed to be published.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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References

1. Bumbar, Z.O., Sichkoriz, K.A., Bumbar, O.I. and Minko, L.Y., 2024. The orthodontic treatment and the periodontal status of patients. Wiad. Lek., 77(3):602-607. https://doi.org/10.36740/WLek202403133.
2. El-Angbawi, A., McIntyre, G., Fleming, P.S. and Bearn, D., 2023. Non-surgical adjunctive interventions for accelerating tooth movement in patients undergoing orthodontic treatment. Cochrane Database Syst. Rev., 6(6):CD010887. https://doi.org/10.1002/14651858.
3. Owens, D., Watkinson, S., Harrison, J.E., Turner, S. and Worthington H.V., 2024. Orthodontic treatment for prominent lower front teeth (Class III malocclusion) in children. Cochrane Database Syst. Rev., 4(4):CD003451. https://doi.org/10.1002/14651858.
4. Liu H. Association between sleep duration and depression: A Mendelian randomization analysis. J Affect Disord. 2023;335:152–4. https://doi.org/10.1016/j.jad.2023.05.020.
5. Sim M, Park S. Orthodontic treatment using directly 3D-printed clear aligners. J Clin Orthod. 2023;57(10):606–13.
6. 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):208. https://doi.org/10.3390/children9020208.
7. Liu H, Tang T. MAPK signaling pathway-based glioma subtypes, machine-learning risk model, and key hub proteins identification. Sci Rep. 2023;13(1):19055. https://doi.org/10.1038/s41598-023-45774-0.
8. Bucci R, Rongo R, Zunino B, Michelotti A, Bucci P, Alessandri-Bonetti G, Incerti-Parenti S, D'Antò V. Effect of orthopedic and functional orthodontic treatment in children with obstructive sleep apnea: A systematic review and meta-analysis. Sleep Med Rev. 2023;67:101730. https://doi.org/10.1016/j.smrv.2022.101730.
9. Valentine A, Bosart K, Bush W, Bouley RA, andPetreaca, R.C.,. Identification and characterization of ADAR1 mutations and changes in gene expression in human cancers. Cancer Genet. 2024;288–289:82–91. https://doi.org/10.1016/j.cancergen.2024.10.007.
10. Muro MP, Caracciolo ACA, Patel MP, Feres MFN, Roscoe MG. Effectiveness and predictability of treatment with clear orthodontic aligners: A scoping review. Int Orthod. 2023;21(2):100755. https://doi.org/10.1016/j.ortho.2023.100755.
11. Faik Sahin M, Baysal A. The effect of micro-osteoperforation on the rate of tooth movement during the alignment stage in patients with mandibular crowding: a randomised controlled trial. Eur J Orthod. 2023;45(5):505–16. https://doi.org/10.1093/ejo/cjad017.
12. Perez-Cisneros C, Elías-Boneta AR, Rivas-Tumanyan S, Rodríguez-Reyes M, Polo M. Comparison of corticotomy and micro-osteoperforation during canine retraction: a split-mouth design. P R Health Sci J. 2023;42(4):311–7.
13. 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. https://doi.org/10.4103/jos.jos_18_23.
14. Cai H, Wang Z, Zhang Z, Dai J, Si W, Fu Q, Yang J, Tian Y. Morinda officinalis polysaccharides inhibit the expression and activity of NOD-like receptor thermal protein domain associated protein 3 in inflammatory periodontal ligament cells by upregulating silent information regulator sirtuin 1. Hua Xi Kou Qiang Yi Xue Za Zhi. 2023;41(6):662–70. https://doi.org/10.7518/hxkq.2023.2023114.
15. Kilinc B, Baka ZM. Comparison of the effectiveness of piezocision and microosteoperforation in leveling mandibular anterior teeth. Am J Orthod Dentofacial Orthop. 2023;163(4):491–500. https://doi.org/10.1016/j.ajodo.2022.02.019.
16. Chandorikar H, andBhad, W.A. Impact of micro-osteoperforations on root resorption and alveolar bone in en-masse retraction in young adults: A CBCT randomized controlled clinical trial. Int Orthod. 2023;21(1): 100714. https://doi.org/10.1016/j.ortho.2022.100714.
17. Alikhani M, Raptis M, Zoldan B, Sangsuwon C, Lee YB, Alyami B, Corpodian C, Barrera LM, Alansari S, Khoo E, Teixeira C. Effect of micro-osteoperforations on the rate of tooth movement. Am J Orthod Dentofacial Orthop. 2013;144(5):639–48. https://doi.org/10.1016/j.ajodo.2013.06.017. (PMID: 24182579).
18. Venkatachalapathy S, Natarajan R, Ramachandran UM, Rajakumar P, Rangarajan S, Patil D, andManickavasagam, V. Effect of frequency of micro-osteoperforation on miniscrew- supported canine retraction: a single-centered, split-mouth randomized controlled trial. J Contemp Dent Pract. 2022;23(8):781–7. https://doi.org/10.5005/jp-journals-10024-3385.
19. 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(3):189–98. https://doi.org/10.1007/s00056-022-00420-8.
20. Zhang Z, Dai JY, Cai HX, Si WX, Yang JW, Tian YG. Effects of Morinda officinalis polysaccharides on FN and FN-EDA of periodontal ligament fibroblasts in inflammatory microenvironment. Shanghai Kou Qiang Yi Xue. 2024;33(2):123–9.
21. El-Din MBA, Abd El Khaliq Hendy K, Elghetany Mohamed R, Abouelnour A, Mohamed Ali M, Akram El-Awady A and Ahmed Hussein F. Pain intensity of skeletally anchored maxillary molar distalization in conjunction with micro-osteoperforations: a randomized clinical trial. Cureus. 2024;16(2):e53527. https://doi.org/10.7759/cureus.53527.
22. Aksakalli S, Balaban A, Nazaroglu K and Saglam E. 2017. Accelerated Tooth Movement with Orthodontic Mini-Screws. Case Rep Dent. 2017:2327591. https://doi.org/10.1155/2017/2327591. Epub 2017 Dec 14. PMID: 29387493; PMCID: PMC5745750.

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