Am J Transl Res 2025;17(9):7449-7457
www.ajtr.org /ISSN:1943-8141/AJTR0166026

Original Article

Clinical efficacy of micro-implant anchorage in orthodontic treatment

Huan Sun[1,2], Qian Guo[1,3], Rong Huang[1,2], Jun Hu[1,2], Pei Ye[1,2], Yu-Ying Zheng[1,2], Yang Wu[1,4]

[1]State Key Laboratory of Oral & Maxillofacial Reconstruction and Regeneration, Key Laboratory of Oral Biomedicine Ministry of Education, Hubei Key Laboratory of Stomatology, School & Hospital of Stomatology,Wuhan University, Wuhan 430079, Hubei, China; [2]Comprehensive Emergency, School and Hospital of Stomatology, Wuhan University,Wuhan 430079, Hubei, China; [3]Center for Orthodontics and Pediatric Dentistry, School and hospital of stomatology (Optics Valley Branch), Wuhan University, Wuhan 430073, Hubei, China; [4]Department of Oral and Maxillofacial Surgery, School and Hospital of Stomatology, Wuhan University, Wuhan 430079, Hubei, China

Received May 14, 2025; Accepted September 9, 2025; Epub September 15, 2025; Published September 30, 2025

Abstract: Objective: To evaluate the clinical effectiveness of micro-implant anchorage (MIA) in orthodontic therapy. Methods: A total of 92 orthodontic patients were analyzed, with 45 assigned to a control group, treated using conventional techniques, and 47 in an observation group receiving MIA-assisted correction. Comparative analyses were performed on treatment efficacy, dental structural changes, periodontal inflammation biomarkers, safety, periodontal health indices, mental health status, and patient satisfaction. Results: The observation group exhibited superior therapeutic outcomes compared to the control group, showing greater improvements in dental structure and higher patient satisfaction (all $P<0.05$). Post-treatment, MIA patients had significantly reduced inflammatory marker levels, fewer adverse events, improved periodontal health indices, and enhanced psychological well-being (all $P<0.05$). Conclusions: MIA proves to be more effective than conventional orthodontic methods, offering improved therapeutic outcomes, enhanced periodontal health, and greater patient satisfaction.

Keywords: Orthodontics, micro-implant anchorage, treatment outcomes, periodontal health

Introduction

Recent advancements in clear aligner technology and evolving standards of facial aesthetics have significantly increased the demand for orthodontic treatment [1]. Data from the American Association of Orthodontists indicate a 40% rise in orthodontic cases among adults in the U.S. and Canada between 2012 and 2016 [2]. As a technically sophisticated and time-intensive procedure, orthodontic therapy plays a pivotal role in achieving optimal tooth alignment, optimizing occlusal-jaw relationships, and enhancing facial aesthetics through improved dental arch morphology and lip-tooth harmony [3, 4]. Contemporary orthodontic applications address malocclusion, dental crowding, and periodontal conditions, providing benefits in facial appearance, masticatory function, oral health-related quality of life, and periodontal stability [5-7]. A key factor in the success of orthodontic treatment is anchorage control-the biomechanical mechanism that governs tooth movement and prevents undesirable displacement [8]. Despite their historical use, conventional anchorage devices (e.g., headgear, transpalatal arches) present clinical limitations such as inconsistent retention and poor patient compliance, which can compromise treatment accuracy [9]. Micro-implant anchorage (MIA) systems have emerged as a superior alternative, offering three-dimensional stability through direct osseous integration, enhanced biomechanical efficiency, minimally invasive placement, and simplified clinical procedures [10, 11]. Hong et al. [12] demonstrated the clinical superiority of MIA in managing skeletal Class II malocclusion, highlighting its ability to reduce maxillary first molar mesialization, prevent molar extrusion, and improve facial profile

https://doi.org/10.62347/QWJQ4016

outcomes compared to conventional methods. The present study evaluates the clinical performance of MIA, providing valuable insights for improving orthodontic precision and treatment outcomes.

This study innovatively assesses the clinical benefits of MIA in orthodontics by evaluating treatment effectiveness, dental structural changes, periodontal inflammation markers, safety outcomes, periodontal health, mental health, and patient satisfaction, validating its superiority over conventional orthodontic techniques.

Materials and methods

Study population

This retrospective study was approved by the Ethics Committee of the School & Hospital of Stomatology, Wuhan University. We enrolled 92 patients who underwent orthodontic treatment at the School & Hospital of Stomatology, Wuhan University, between March 2023 and March 2025. Of these, 45 patients were assigned to the control group (conventional orthodontic treatment) and 47 to the observation group (MIA intervention).

Inclusion and exclusion criteria

Inclusion criteria: Eligibility for orthodontic treatment based on standard indications [13]; no prior history of oral diseases or orthodontic procedures; normal periodontal hard and soft tissue morphology; first-time orthodontic treatment; no infectious diseases.

Exclusion criteria: Poor oral hygiene; intolerance to orthodontic treatment; presence of oral mucosal lesions; pregnant or lactating women; prior oral treatments; concurrent oral diseases, coagulation disorders, or cardiovascular/cerebrovascular diseases.

Treatment protocols

Control group (conventional orthodontic treatment): Prior to treatment, patients underwent CT imaging to evaluate dental alignment and malocclusion severity. After oral disinfection with chlorhexidine gluconate (Heze Jiatuo Biotechnology Co., Ltd., 5) and local anesthesia with lidocaine injection (Chongqing Kangzhou Zhitong Pharmaceutical Technology Co., Ltd., 12MHB18), metal archwires were applied for tooth correction, reinforced with a transpalatal arch for stabilization. Following satisfactory correction, radiographic assessment (X-ray) confirmed root apex positioning and occlusal contact. Patients were instructed to wear the appliance for 8-12 hours daily, maintaining a unilateral traction force of ~250 g, with scheduled follow-ups for force adjustments. Pretreatment and post-treatment photographs following conventional orthodontic therapy are shown in **Figure 1**.

Observation group (MIA): After premolar extraction and initial dental alignment confirmation, micro-titanium implant screws were placed bilaterally in the critical parallel zone between the maxillary second premolars and first molars, positioned 3 mm toward the root or at the mucogingival junction. Stainless steel wires and traction hooks were used to connect the implants and facilitate anterior tooth retraction. Force application was adjusted monthly until achieving: (1) restoration of normal occlusal relationships, and (2) complete closure of extraction spaces. Implants were removed as the final treatment step. Medical staff guided patients on oral hygiene maintenance (gently brushing teeth, using dental floss regularly) and diet (avoiding hard or sticky foods), and advised cessation of smoking and drinking. Regular check-ups ensured implant stability and tissue health. Pretreatment and post-treatment effect pictures are shown in **Figure 2**.

Outcome measures

(1) Orthodontic Treatment Efficacy [14]: Therapeutic outcomes were classified as excellent (complete alignment with significant correction), effective (noticeable enhancement in dental alignment), or ineffective (no observable improvement). The overall efficacy rate was the combined percentage of cases with excellent or effective outcomes relative to the total cohort.

(2) Dental Structural Changes [15]: At 3 months post-intervention, the upper central incisor protrusion difference (measured with a dental caliper), molar displacement distance, and intercanine width (both assessed via X-ray cephalometric analysis, Guangzhou Linuo Automation Equipment Co., Ltd., Point 800 HD 3D PLUS), were recorded in both groups.

(3) Periodontal Inflammatory Markers [16]: Periodontal tissue samples were collected at

Figure 1. Pre- and post-treatment changes with conventional orthodontics. A, B. Pretreatment status: Malocclusion and asymmetric dental arches were observed. C, D. Posttreatment results: Post-therapy, the dentition displayed uniform alignment, corrected torsions/overlapping, overbite reduction, and optimized posterior occlusion.

baseline and 3 months post-treatment from the anchorage region, cultured in vitro. Supernatants were quantified by Enzyme-Linked Immunosorbent Assay (ELISA) for matrix metalloproteinase (MMP)-2, MMP-9, tumor necrosis factor (TNF)-α, and intercellular adhesion molecule (ICAM)-1 levels (Abbkine Scientific Co., Ltd., KTE4055, KTE6027, KTE6032, KTE6003), using an automated biochemical analyzer (Xi'an Tianlong Science and Technology Co., Ltd., ZY-680).

(4) Safety Profile [17]: Adverse events (tooth mobility, gingival infections, gingival swelling) were documented, and incidence rates were computed.

(5) Periodontal Health Status [18]: Periodontal health was evaluated before and 3 months after orthodontic treatment using the Sulcus Bleeding Index (SBI; 0-5 scale), Gingival Index (GI; 0-3 scale), and Plaque Index (PLI; 0-3 scale). Higher scores indicated worse periodontal conditions.

(6) Psychological Evaluation: Anxiety and depression levels were assessed before and after intervention using the Self-Rating Anxiety Scale (SAS) and Self-Rating Depression Scale (SDS) [19], respectively. Both scales were scored on 100-point scales, where higher scores indicated greater symptom severity.

(7) Patient Satisfaction [20]: A self-designed orthodontic satisfaction scale was used to evaluate patient satisfaction, categorized as unsatisfied (<60), satisfied (60-80), or highly satisfied (>80). The total satisfaction rate was the sum of the "highly satisfied" and "satisfied" rates.

Statistical methods

All data were processed using SPSS 21.0 (IBM Corp.), with graphical representations generated in GraphPad Prism 7.0. Continuous data were expressed as mean ± SEM and compared using t-tests (between groups) or paired t-tests (pre- vs. post-treatment). Categorical data were presented as rates (percentages) and com-

Figure 2. MIA before and after treatment. A, B. Before MIA treatment: Marked labial inclination of upper anterior teeth (protrusive appearance) was observed, often accompanied by lip incompetence. Concurrent malocclusion was noted, including Class II (excessive upper molar prominence) or Class III (anterior crossbite) tendencies. C, D. After MIA treatment: The edentulous space was fully consolidated, anterior projection significantly corrected, and lip contour softened. Molars established a stable Class I relationship, with normalized anterior overlap. Implant-site mucosa healed optimally, absent of erythema, edema, or fibrosis. Note: MIA, micro-implant anchorage.

Table 1. Demographic and clinical characteristics of study participants

Data	Control group (n=45)	Observation group (n=47)	χ^2/t	P
Gender (male/female)	25/20	24/23	0.186	0.666
Age (years)	28.62±5.83	30.62±8.44	1.317	0.191
Body mass index (kg/m^2)	22.27±2.43	22.64±2.72	0.687	0.494
Treatment duration (years)	3.36±1.28	3.81±1.78	1.387	0.169
Angle's classification (I/II/III)	14/18/13	13/20/14	0.136	0.934
Educational attainment (<senior high school/≥senior high school)	22/23	20/27	0.372	0.542

pared using chi-square (χ^2) tests. Statistical significance was set at $P<0.05$.

Results

Baseline characteristics

The control and observation groups demonstrated comparable baseline characteristics, with no statistically significant differences (all $P>0.05$) in gender distribution, mean age, body mass index (BMI), treatment duration, Angle's classification, or educational attainment (**Table 1**).

Orthodontic treatment efficacy

The observation group exhibited superior clinical outcomes, with 42 cases achieving treatment effectiveness compared to 33 in the con-

Table 2. Comparative analysis of orthodontic treatment efficacy

Orthodontic effect	Control group (n=45)	Observation group (n=47)	X^2	P
Markedly effective	21 (46.67)	27 (57.45)		
Effective	12 (26.67)	15 (31.91)		
Ineffective	12 (26.67)	5 (10.64)		
Total effectiveness	33 (73.33)	42 (89.36)	3.921	0.048

trol group. This resulted in a significantly higher total effective rate in the observation group (P<0.05, **Table 2**).

Dental structural changes

Quantitative assessments revealed significant intergroup differences in dental structural parameters at the 3-month follow-up. The observation group showed increased upper central incisor protrusion differences, greater intercanine width expansions, and reduced molar displacement distances compared to the control group (all P<0.05; **Figure 3**).

Inflammatory biomarker profiles

While baseline inflammatory markers showed no significant intergroup differences (all P>0.05), post-treatment analysis revealed a significant elevation of all biomarkers in both groups (all P<0.05). Furthermore, the observation group exhibited markedly reduced inflammatory responses, with lower MMP-2 and MMP-9 levels and decreased TNF-α and ICAM-1 expression compared to the control group (all P<0.05; **Figure 4**).

Safety profiles

The micro-implant approach demonstrated superior safety, with a reduced incidence of tooth mobility, gingival infections, and gingival swelling. The overall adverse event rate in the observation group was 6.38%, compared to 22.22% in the control group (P<0.05; **Table 3**).

Periodontal health outcomes

Periodontal health was assessed using three standardized indices: SBI, GI, and PLI. Baseline measurements showed no significant intergroup differences (all P>0.05). Post-treatment, both groups exhibited significant reductions in all periodontal indices (all P<0.05), with the observation group showing significantly lower post-treatment scores compared to the control group (all P<0.05; **Figure 5**).

Psychological status evaluation

Mental health assessments using the SAS and SDS scales revealed no intergroup differences at baseline (both P>0.05). Both groups showed significant post-treatment improvements (P<0.05), with the observation group achieving significantly greater reductions in both SAS and SDS scores (both P<0.05; **Figure 6**).

Patient satisfaction rates

Patient satisfaction rates were significantly higher in the observation group, with 91.49% satisfaction compared to 75.56% in the control group (P < 0.05; **Table 4**).

Discussion

Anchorage control is a critical factor in orthodontic biomechanical systems. Conventional anchorage modalities (e.g., extraoral headgear, transpalatal arches), although simple to operate and effective in gradually correcting malocclusion and tooth misalignment, are highly dependent on patient compliance and often lead to significant discomfort and poor aesthetic outcomes [21]. In contrast, MIA systems overcome these limitations, improving treatment effectiveness while reducing the demands on patient compliance [22]. Our comprehensive multidimensional assessment provides robust clinical evidence supporting the advantages of this advanced technique.

Our findings demonstrate superior clinical outcomes with MIA, showing significantly higher treatment efficacy compared to conventional methods. This considerable improvement in treatment success rates reflects MIA's ability to achieve more predictable tooth movement and superior dental alignment. Micro-implants, being small yet reliable in anchorage, are user-friendly. They eliminate anchor loss, can be placed in previously unused areas, and allow for immediate force application upon insertion [23]. These results align with Shi et al.'s [24] study (n=119), which reported greater treatment success rates, a significant reduction in

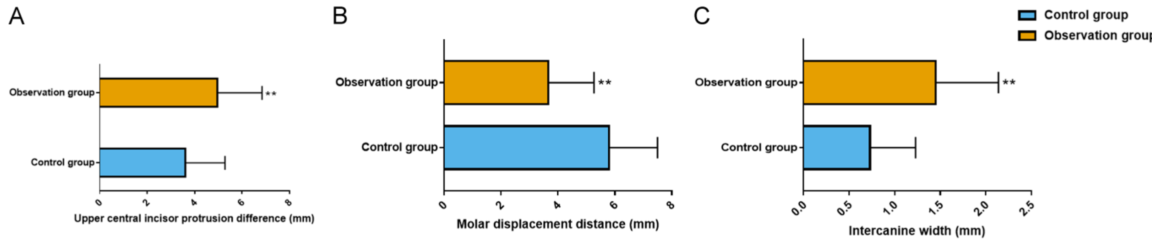

Figure 3. Dental structural changes in the two groups. A. Upper central incisor protrusion differences in two groups. B. Molar displacement distances in two groups. C. Intercanine widths in two groups. Note: **P<0.01 versus control group.

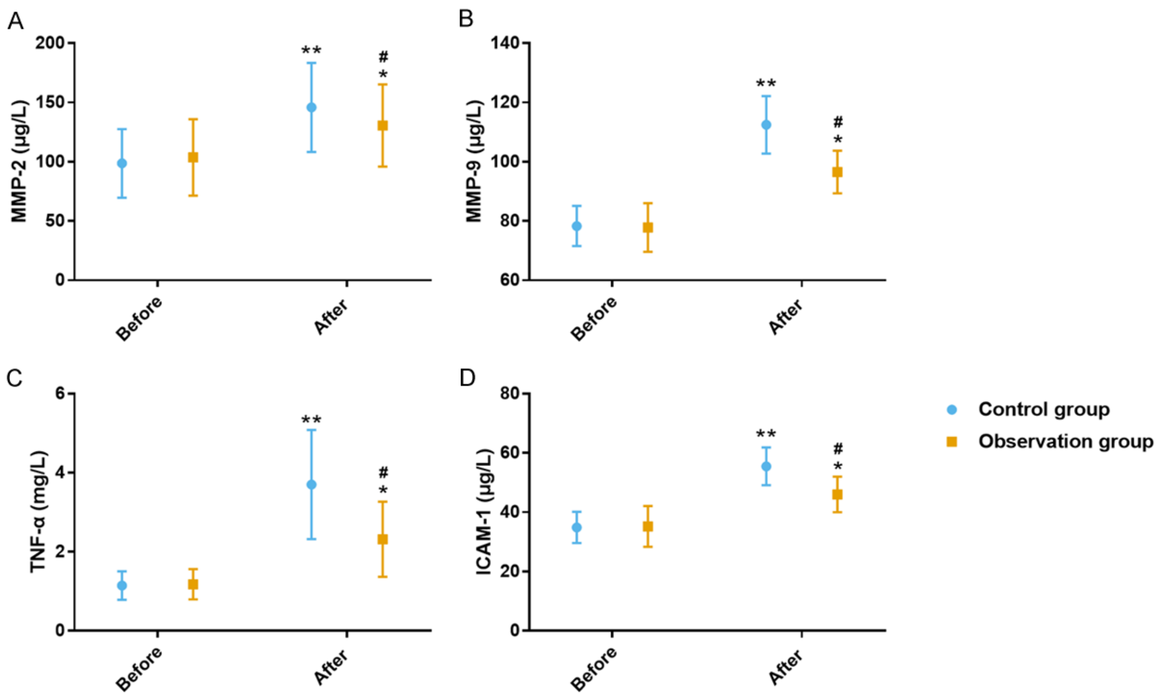

Figure 4. Levels of periodontal inflammatory markers in two groups. A. Pre- and post-treatment matrix metalloproteinase (MMP)-2 levels. B. Pre- and post-treatment MMP-9 levels. C. Pre- and post-treatment tumor necrosis factor (TNF)-α levels. D. Pre- and post-treatment intercellular adhesion molecule (ICAM)-1 levels. Note: *P<0.05, **P<0.01 vs. baseline; #P<0.05 vs. control group.

Table 3. Comparative safety profile analysis

Adverse events	Control group (n=45)	Observation group (n=47)	X^2	P
Tooth mobility	3 (6.67)	0 (0.00)		
Gingival infections	4 (8.89)	2 (4.26)		
Gingival swelling	3 (6.67)	1 (2.13)		
Total	10 (22.22)	3 (6.38)	4.753	0.029

inflammatory markers (IL-6 and hsCRP), and lower complication rates.

Notably, the observation group exhibited significantly better improvements in upper central incisor protrusion distance and intercanine width, further confirming the clinical advantages of MIA in enhancing dental structure. Compared to conventional extracoronal arch reinforcement, MIA significantly reduces trauma to dental tissues. Once implanted, the micro-implant can withstand substantial orthodontic forces within the jawbone, providing stable anchorage that allows the affected teeth to reposition naturally. This partly accounts for the notable improvement in dental structure observed with MIA [25, 26]. Without accelerating root resorption,

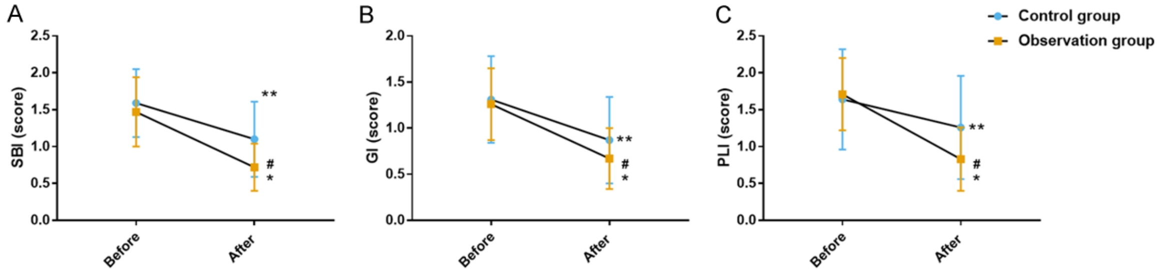

Figure 5. Periodontal health indices. A. Sulcus Bleeding Index (SBI) measurements pre- and post-intervention. B. Gingival Index (GI) measurements pre- and post-intervention. C. Plaque Index (PLI) measurements pre- and post-intervention. Note: *P<0.05, **P<0.01 vs. baseline; #P<0.05 vs. control group.

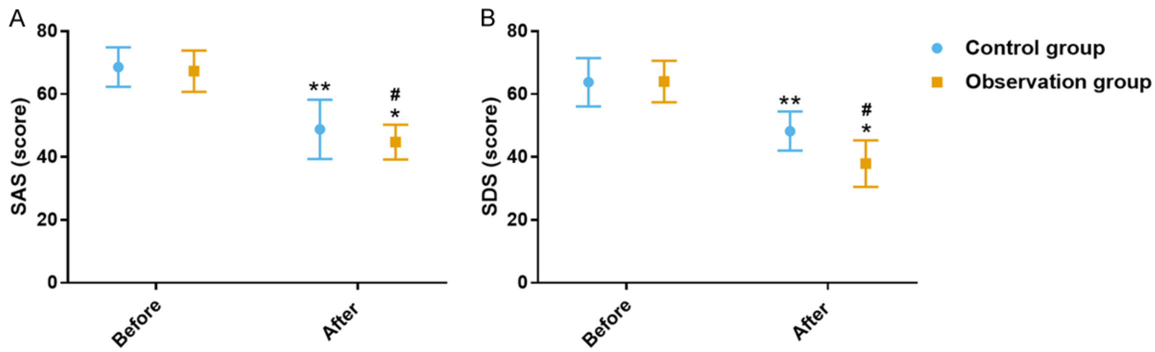

Figure 6. Psychological assessments in two groups. A. Self-Rating Anxiety Scale (SAS) score changes pre- and post-intervention. B. Self-Rating Depression Scale (SDS) score changes pre- and post-intervention. Note: *P<0.05, **P<0.01 vs. baseline; #P<0.05 vs. control group.

Table 4. Comparative patient satisfaction analysis

Satisfaction	Control group (n=45)	Observation group (n=47)	χ^2	P
Highly satisfied	22 (48.89)	26 (55.32)		
Satisfied	12 (26.67)	17 (36.17)		
Dissatisfied	11 (24.44)	4 (8.51)		
Total satisfaction	34 (75.56)	43 (91.49)	4.278	0.039

MIA has also been shown to promote faster tooth movement while exerting minimal influence on craniofacial and soft tissue relationships in adults requiring bilateral maxillary premolar extraction [27], corroborating the findings of this study.

Furthermore, MIA resulted in significantly attenuated elevation of inflammatory mediators (MMP-2, MMP-9, TNF-α, and ICAM-1) and superior improvements in periodontal parameters (SBI, GI, and PLI) compared to conventional orthodontic approaches. Zhao et al. [28] reported that MIA therapy in Class II malocclusion patients promotes orthodontic outcomes by facilitating buccal tubercle displacement and adjusting soft and hard tissue positions. Additionally, it significantly reduces inflammatory markers like MMP-2 and ICAM-1, which aligns with the findings of this research. Liang et al. [29] also demonstrated that MIA, in combination with guided tissue regeneration in periodontitis patients, contributes to anti-inflammatory effects (reducing IL-6, MMP-8, and TGF-β expression) and significant improvements in periodontal health (ameliorated SBI, GI, and PLI), similar to the outcomes observed in this study.

From a safety perspective, the safety profile analysis demonstrated a significant superiority of MIA, with the observation group exhibiting a markedly lower incidence of treatment-related adverse events compared to conventional approaches. One possible explanation is that MIA involves smaller implants, which reduce intraoral irritation, minimize discomfort, and allow for faster healing of the puncture holes post-removal, thus lowering complication risks [30]. Xu et al. [31] further corroborated this finding, showing that MIA yielded comparable outcomes in complication rates relative to the adjunctive use of cefaclor.

Additionally, psychological evaluations revealed significantly greater improvements in anxiety and depression scores in the observation group, likely attributable to the higher treatment efficiency of micro-implants, which not only enhance periodontal health but also reduce negative impacts from potential complications. The superior patient satisfaction scores further validate the advantages of micro-implants in both comfort and aesthetic acceptability. Supporting these findings, Hou et al. [32] reported that MIA in pediatric orthodontics demonstrated pronounced clinical superiority over traditional methods in enhancing periodontal health and dental structure, achieving significantly higher treatment efficacy and patient satisfaction, closely aligning with our results.

Several limitations exist in this research that should be acknowledged. First, the study did not analyze sleep quality, quality of life, or facial aesthetics. Incorporating these factors could expand the potential clinical advantages of MIA in orthodontics. Second, no long-term follow-up analysis was conducted; a 5-year follow-up would provide valuable insights into the sustained efficacy of MIA. Third, critical factors influencing treatment success were not explored; identifying these factors in future studies is essential to further optimize orthodontic therapy and related management processes, ultimately improving orthodontic outcomes. Finally, although an orthodontic satisfaction scale was specifically developed for this study, its broader applicability depends on further reliability and validity assessments in larger cohorts.

In conclusion, MIA offers comprehensive clinical benefits over conventional methods, including superior treatment precision and efficiency, enhanced improvements in dental and periodontal health, reduced inflammatory burden, favorable safety profile, diminished psychological distress, and greater patient acceptance.

Disclosure of conflict of interest

None.

Address correspondence to: Yang Wu, Department of Oral and Maxillofacial Surgery, School and Hospital of Stomatology, Wuhan University, Wuhan 430079, Hubei, China. Tel: +86-027-87686387; E-mail: wuyang83@whu.edu.cn

References

[1] Alam MK, Abutayyem H, Kanwal B and A L Shayeb M. Future of orthodontics-a systematic review and meta-analysis on the emerging trends in this field. J Clin Med 2023; 12: 532.

[2] Abu-Arqub S, Ahmida A, Da Cunha Godoy L, Kuo CL, Upadhyay M and Yadav S. Insight into clear aligner therapy protocols and preferences among members of the American Association of Orthodontists in the United States and Canada. Angle Orthod 2023; 93: 417-426.

[3] Luchian I, Surlari Z, Goriuc A, Ioanid N, Zetu I, Butnaru O, Scutariu MM, Tatarciuc M and Budala DG. The influence of orthodontic treatment on periodontal health between challenge and synergy: a narrative review. Dent J (Basel) 2024; 12: 112.

[4] Coppola G, Christopoulou I, Gkantidis N, Verna C, Pandis N and Kanavakis G. The effect of orthodontic treatment on smile attractiveness: a systematic review. Prog Orthod 2023; 24: 4.

[5] Mathew R, Sathasivam HP, Mohamednor L and Yugaraj P. Knowledge, attitude and practice of patients towards orthodontic treatment. BMC Oral Health 2023; 23: 132.

[6] Schwarz L, Ossmann V, Ritschl V, Stamm T, Jonke E and Bekes K. Influence of malocclusion on OHRQoL in adolescents in initial orthodontic treatment phase. Clin Oral Investig 2024; 28: 286.

[7] Erbe C, Heger S, Kasaj A, Berres M and Wehrbein H. Orthodontic treatment in periodontally compromised patients: a systematic review. Clin Oral Investig 2023; 27: 79-89.

[8] Umalkar SS, Jadhav VV, Paul P and Reche A. Modern anchorage systems in orthodontics. Cureus 2022; 14: e31476.

[9] Xu Y and Xie J. Comparison of the effects of mini-implant and traditional anchorage on patients with maxillary dentoalveolar protrusion. Angle Orthod 2017; 87: 320-327.

[10] Tseng YC, Hsieh CH, Chen CH, Shen YS, Huang IY and Chen CM. The application of mini-implants for orthodontic anchorage. Int J Oral Maxillofac Surg 2006; 35: 704-707.

[11] Sahoo SK, Chekka M, Chawla R, Nehal Naimatullah M, Kumar Misra K, Kandikatla P and Prashant MC. Comparative study of mini-implants versus standard implants in orthodontic anchorage for space closure. J Pharm Bioallied Sci 2024; 16: S2458-S2460.

[12] Hong VTT, Lien TTK, Tuan PA and Viet H. Superior effect of mini-implant anchorage in the

treatment of skeletal class II malocclusion. J Orthod Sci 2024; 13: 44.
[13] Garbo D, Aimetti M, Bongiovanni L, Vidotto C, Mariani GM, Baima G and Romano F. Periodontal and orthodontic synergy in the management of stage IV periodontitis: challenges, indications and limits. Life (Basel) 2022; 12: 2131.
[14] Papadimitriou A, Mousoulea S, Gkantidis N and Kloukos D. Clinical effectiveness of Invisalign(R) orthodontic treatment: a systematic review. Prog Orthod 2018; 19: 37.
[15] Yu JH, Nguyen T, Kim YI, Hwang S, Kim KH and Chung CJ. Morphologic changes of the incisive canal and its proximity to maxillary incisor roots after anterior tooth movement. Am J Orthod Dentofacial Orthop 2022; 161: 396-403, e1.
[16] He W, Zhu H and Liu C. Profiles of inflammation factors and inflammatory pathways around the peri-miniscrew implant. Histol Histopathol 2021; 36: 899-906.
[17] Liu Y, Shi X, Lin G and Guo N. Effects of periodontal initial therapy combined with orthodontic treatment on anterior tooth function and inflammatory factors in gingival crevicular fluid in patients with periodontal disease induced anterior tooth displacement. Pak J Med Sci 2023; 39: 1620-1625.
[18] AlMoharib HS, AlAskar MH, AlShabib AN, Almadhoon HW and AlMohareb TS. The effectiveness of dental water jet in reducing dental plaque and gingival bleeding in orthodontic patients: a systematic review and meta-analysis of randomized clinical trials. Int J Dent Hyg 2024; 22: 56-64
[19] Chang J and Li X. Multivariate analysis of oral mucosal ulcers during orthodontic treatment. World J Clin Cases 2024; 12: 5868-5876.
[20] Xu Y, Ying K, Lang X and Xu C. Micro-implant anchorage in adolescent orthodontics: a promising and advantageous option. Am J Transl Res 2025; 17: 1882-1891.
[21] Sripathi SP, Peddu R, Talapaneni AK, Mallavarapu K, Dokku A, Lanka D, Pichai S, Bellam S, Asma Bhanu S and Kalyani L. Effect of second and third molar eruption stages on first molar and maxillary arch distalization with modified palatal anchorage plate and beneslider: A 3D finite element analysis. Cureus 2024; 16: e61403.
[22] Panaite T, Balcos C, Savin C, Olteanu ND, Karvelas N, Romanec C, Vieriu RM, Chehab A and Zetu I. Exploring the use, perceptions, and challenges of mini-implants in orthodontic practice: a survey study. Front Oral Health 2024; 5: 1483068.
[23] Selvaraj S, Tandon A, Chandrasekaran D, Purushothaman D, Katepogu P, Mohan R and Angrish N. Anchorage and stability of orthodontic mini implants in relation to length and types of implants. Cureus 2024; 16: e73056.
[24] Shi Y, Mi L, Liu J, Liu X and Hao Y. Therapeutic effect of micro-implant anchorage in orthodontics. Pak J Med Sci 2024; 40: 2293-2298.
[25] Jia-Mahasap W, Rungsiyakull C, Bumrungsiri W, Sirisereephap N and Rungsiyakull P. Effect of number and location on stress distribution of mini dental implant-assisted mandibular kennedy class i removable partial denture: three-dimensional finite element analysis. Int J Dent 2022; 2022: 4825177.
[26] Ji L, Li B and Wu X. Evaluation of biomechanics using different traction devices in distalization of maxillary molar with clear aligners: a finite element study. Comput Methods Biomech Biomed Engin 2023; 26: 559-567.
[27] Liu X, Yu J and Liu K. Retrospective analysis of mini-implant assisted micro-osteoperforation for accelerating canine movement in adult orthodontics. BMC Oral Health 2025; 25: 695.
[28] Zhao H, Sun R, Cao S and Han J. Treatment of class II malocclusion with orthodontic microimplant anchorage. Int Dent J 2024; 74: 536-542.
[29] Liang Y, Zou J and Meng X. Clinical efficacy analysis of guided tissue regeneration combined with microscrew implant anchorage technique in the treatment of periodontitis with malocclusion. J Invest Surg 2025; 38: 2507233.
[30] Wang K, Fan H, Yang H, Li J and Xie W. Efficacy and safety of micro-implant anchorage in Angle class II malocclusion orthodontic treatment: a protocol for systematic review and meta-analysis. Medicine (Baltimore) 2020; 99: e23221.
[31] Xu F. Application of cefaclor in orthodontics through micro-implant anchorage in patients with periodontitis. Ann Ital Chir 2024; 95: 374-381.
[32] Hou Z, Qu X, Hou L and Ren F. Comparison between effects of mini-implant anchorage and face-bow anchorage in orthodontics for children. J Clin Pediatr Dent 2024; 48: 198-203.