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Effectiveness of a miniscrew-assisted technique for protracting mandibular second molars: A prospective quasi-experimental study

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Abstract

Objective: This study assessed the effectiveness of a miniscrew-assisted rectangular loop technique for protracting mandibular second molars without using full-arch appliances.

Methods: This prospective pilot quasi-experimental study included 10 orthodontic patients (12 sites), aged 15–25 years, who had their mandibular first molars extracted at least three years earlier, and presented an interdental space of 4–7 mm between the second premolar and second molar. Two miniscrews were placed mesially and distally to the second premolar. Molar uprighting and protraction were performed using rectangular and T-loop mechanics. CBCT scans and study casts were obtained at baseline and after six months to measure primary and secondary outcomes. Primary outcome variables included crown- and root-level distances between the mandibular second premolar and second molar. Secondary outcomes included measurements of alveolar bone parameters (height, thickness, and density), second molar angulation, marginal ridge distance, and second molar first-order angulation. Data were analyzed using paired t-tests with a significance level of α = 0.05.

Results: Significant reductions were observed in crown-level (3.3 ± 1.45 mm, P=0.003) and root-level distances (4.39 ± 1.64 mm, P<0.001) between the second premolar and second molar. Second molar angulation relative to the mandibular plane increased significantly (5.56 ± 6.23°, P=0.01). Alveolar bone parameters showed no significant changes (P>0.05). Marginal ridge distance decreased significantly (3.06 ± 1.53 mm, P< 0.001), whereas second molar first-order angulation remained unchanged (P=0.828).

Conclusions: The miniscrew-assisted rectangular loop technique allows effective protraction of mandibular second molars, improving molar angulation, while minimally affecting the alveolar bone.

Keywords: Orthodontic anchorage, Orthodontic tooth movement, Orthodontics, Tooth movement techniques, X-ray computed tomography, Temporary anchorage devices

Introduction

Orthodontists frequently encounter patients with previously extracted mandibular first molars or cases in which the extraction of these teeth is indicated in the treatment plan (1). The resulting edentulous space can compromise arch integrity, occlusion, and long-term stability, making its management a significant challenge in orthodontic treatment planning. Extraction of first molars frequently leads to mesial tipping of the mandibular second molars into the edentulous space, resulting in loss of proper axial inclination and occlusal alignment (2, 3).

For patients with previously extracted first molars, treatment options include using fixed partial dentures, uprighting the second molars followed by implant placement, or closing the edentulous space by mesially moving the second molars (4, 5). Mesial movement of second molars is more challenging in the mandible than in the maxilla, due to its dense cortical bone and the relatively large root surface area of mandibular molars, which increases resistance to bodily tooth movement (6, 7). Achieving adequate anchorage for such movements frequently leads to unwanted tipping of adjacent teeth.

Additionally, conventional molar protraction methods, such as full-arch fixed appliances with sliding mechanics, often require prolonged treatment time and extensive anchorage control, which increases treatment complexity and limits their clinical efficiency.

The introduction of temporary anchorage devices (TADs), such as miniscrews, has transformed orthodontic treatment by providing stable anchorage and reducing complications associated with traditional methods (8, 9). When placed interdentally between

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adjacent teeth, miniscrews provide localized anchorage for molar protraction, allowing more direct and controlled force application compared with extra-alveolar anchorage sites (10-13).

A less invasive approach has been described in which two interradicular miniscrews are placed on the mesial and distal sides of the mandibular second premolar. These are combined with rectangular wires and T-loop mechanics to achieve controlled uprighting and protraction of the mandibular second molar, without the need for full-arch appliances (14). Although early case reports have demonstrated favorable clinical outcomes (15, 16). The effectiveness of this miniscrew-assisted approach has not been comprehensively evaluated. In addition, evidence is limited regarding its effects on the magnitude of tooth movement, molar angulation, and the surrounding alveolar bone.

This prospective pilot quasi-experimental study aimed to evaluate the effectiveness of a miniscrew-assisted technique, using interradicular miniscrews combined with loop mechanics, for protracting mandibular second molars. The objectives were to determine whether this approach could achieve controlled mesial tooth movement with minimal complications.

Materials and methods

Study design

This prospective pilot quasi-experimental study was conducted from May 2023 to October 2024, and involved 10 patients (12 sites). The patients were referred to the Orthodontic Department of Mashhad Dental School, Mashhad University of Medical Sciences, Mashhad, Iran.

The sample size was determined based on the pilot nature of the study and the lack of previous trials with similar objectives. A total of 10 participants (12 intervention sites) was considered sufficient to generate preliminary data for planning future randomized controlled trials.

The study protocol and consent form were approved by the ethics committee of Mashhad University of Medical Sciences (IR.MUMS.DENTISTRY.REC.1402.014). The study was conducted in accordance with the principles of the Declaration of Helsinki. The trial was prospectively registered in the Iranian Registry of Clinical Trials (IRCT20230407057841N1). All participants signed informed consent forms after receiving a detailed explanation of the study procedures, risks, and benefits.

Eligibility criteria

The study included patients aged 15–25 years with previously extracted permanent mandibular first molars and mesially tipped second molars. The second molars exhibited a tipping angle of 30–45° relative to the mandibular border, as confirmed by orthopantomographic (OPG) imaging. All patients had lost their first molars at least three years before the study and required mesial protraction of the second molars. The interdental space between the second premolar and second molar was 4–7 mm, and the buccolingual bone thickness in the edentulous area was at least two-thirds that of the mesial root of the second molar. The exclusion criteria were as follows:

- Patients with poor cooperation during treatment or follow-up
- Patients who experienced mini-screw failure, defined as loosening or dislodgement
- Patients with severe malocclusions or periodontal disease requiring complex orthodontic or periodontal treatment
- Patients with contraindications to mini-screw placement, such as inadequate bone density or proximity to vital anatomical structures
- Patients undergoing concurrent active orthodontic treatment
- patients with systemic conditions affecting bone metabolism
- Patients with a history of smoking or those taking medications known to affect bone turnover

Clinical procedures

This clinical pilot study included 10 orthodontic patients, comprising a total of 12 treatment sites, as two patients required bilateral treatment. All orthodontic and surgical procedures were performed by a single experienced orthodontist (FF) with more than ten years of experience in the use of TADs.

At the initial visit, an alginate impression of the mandible (Alginoplast, Kulzer GmbH, Hanau, Germany) was obtained to produce pre-treatment study casts.

Patients were subsequently referred for standard orthodontic records and cone-beam computed tomography (CBCT) imaging for comprehensive evaluation and baseline documentation. Following review of the radiographic data and confirmation of eligibility, orthodontic treatment was initiated.

The intervention began with the insertion of mini-screws. Before the surgical procedure, patients were instructed to rinse with 0.2% chlorhexidine mouthwash (Behsa Co., Tehran, Iran) for oral disinfection. Local anesthesia was administered by infiltration of 1.8 mL of 2% lidocaine with 1:100,000 epinephrine (Daru Pakhsh, Tehran, Iran) at the target site.

Two mini-screws (Jeil G2 dual-top, 1.4 × 8 mm; Jeil Medical, Seoul, South Korea) were inserted mesial and distal to the second premolar at the coronal level of the mucogingival junction using a screwdriver (111-010 model; Jeil Medical). The screw slots were aligned to achieve parallel orientation.

After mini-screw placement, a molar band (MBT 22; Dentaurum, Ispringen, Germany) was fitted to the mandibular second molar using a band seater and band pusher (Dentaurum). The band was then cemented with a self-curing glass ionomer cement (GC Fuji I; GC Corporation, Tokyo, Japan).

Fixed appliances (MBT prescription; 0.022-inch slot) were selectively used in patients with crowding or those requiring alignment, independent of the molar protraction segment. In such cases, bonding was performed at the initial visit, and alignment was achieved using standard archwire sequences. The molar protraction mechanics were applied as a separate segment and were not directly integrated into the full-arch appliance system.

A one-month healing period was allowed to ensure primary stability of the mini-screws. At the follow-up visit, stability was confirmed by the absence of mobility, inflammation, or infection. Occlusal interferences were selectively adjusted as needed to prevent unwanted contacts during tooth movement.

A rectangular loop was then fabricated from 0.017 × 0.025-inch titanium molybdenum alloy (TMA) wire (Ortho Technology, West Columbia, USA) using a loop-forming orthodontic plier (139 plier; Dentaurum, Ispringen, Germany). The loop was inserted into the mini-screw slots and extended posteriorly into the main tube of the mandibular second molar to achieve molar uprighting over a period of one to three months.

After uprighting the second molar to an angulation of less than 10° relative to the mandibular plane, molar protraction was initiated using a T-loop or boot loop (depending on vestibular depth). The loop was fabricated from 0.017 × 0.025-inch TMA wire (Ortho Technology) using a standardized bending guide to ensure consistent loop dimensions and activation angles (Figure 1).

The guide was designed to allow precise control of T-loop angulation. Each T-loop incorporated a 40° β-bend and a 30° anti-rotation bend. Activation was achieved by increasing the inter-arm distance by 2 mm at monthly intervals. Adjustments were performed at each visit to maintain consistent force application and to monitor treatment progress.

The treatment was considered complete upon achieving complete or near-complete space closure between the mandibular second premolar and second molar, defined clinically by contact of the marginal ridges and radiographically by approximation of the crown and root structures. Post-treatment records were obtained after molar protraction (approximately six months after initial T-loop activation), including alginate impressions, OPG imaging, and CBCT scans.

A labial fixed retainer was bonded in patients in whom complete space closure was achieved, and both first- and second-order corrections were completed (Figure 2). Pre- and post-treatment changes were then assessed using study casts and CBCT images.

Outcome measurements

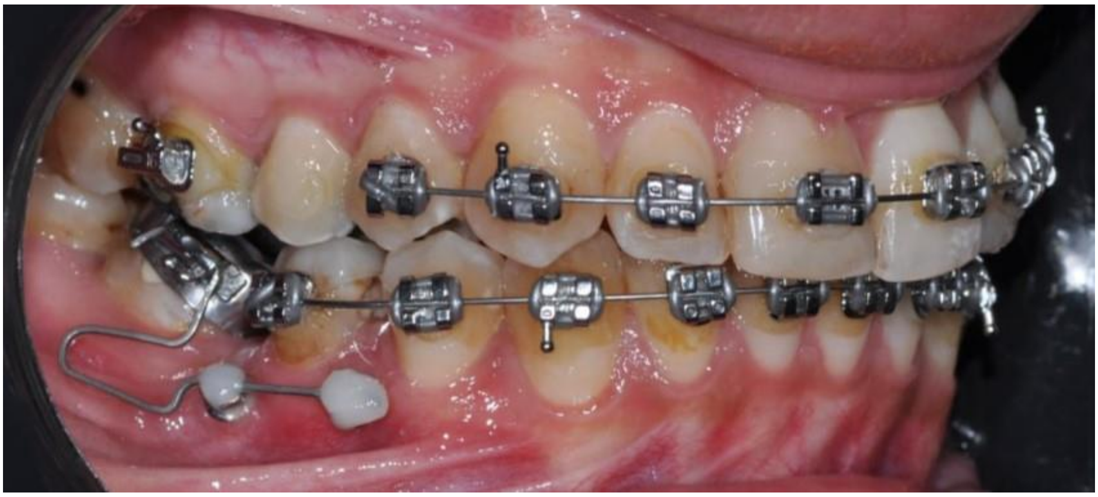

Figure 1. Boot loop (0.017 × 0.025-inch TMA wire) inserted into miniscrew slots for mandibular second molar protraction Note: The appliances used in this study were designed to address crowding according to the MBT system and were independent of the space-closure segment.

Figure 2. Fixed retainer placement following the completion of the active treatment

The primary aim of this study was to assess pre- and post-treatment changes in tooth movement by measuring the positions of the height of contour and root apex between the second premolar and second molar using CBCT panoramic reconstructions. The secondary aim was to evaluate changes in dental and skeletal parameters before and after treatment, including linear and angular tooth movements, as well as alveolar bone characteristics (height, thickness, and density) in the region between the mandibular second premolar and second molar. These parameters were assessed using CBCT imaging and study casts. The outcome variables were as follows:

Primary outcomes

1. Height of contour distance (mm): The horizontal distance between the height of contour points of the mandibular second premolar and second molar, representing crown-level tooth movement (Figure 3; green line)

2. Apical distance (mm): The horizontal distance between the root apices of the mandibular second premolar and second molar, representing root-level tooth movement (Figure 3; yellow line)

Secondary outcomes (CBCT-based)

3. Alveolar bone height (mm): the perpendicular distance from the alveolar crest mesial to the second molar and distal to the second premolar to the superior border of the inferior alveolar canal (Figure 3; red line)

4. Alveolar bone density (Hounsfield units; HU): Bone density was measured within a standardized region of interest in the edentulous area between the mandibular second premolar and second molar (Figure 3; purple

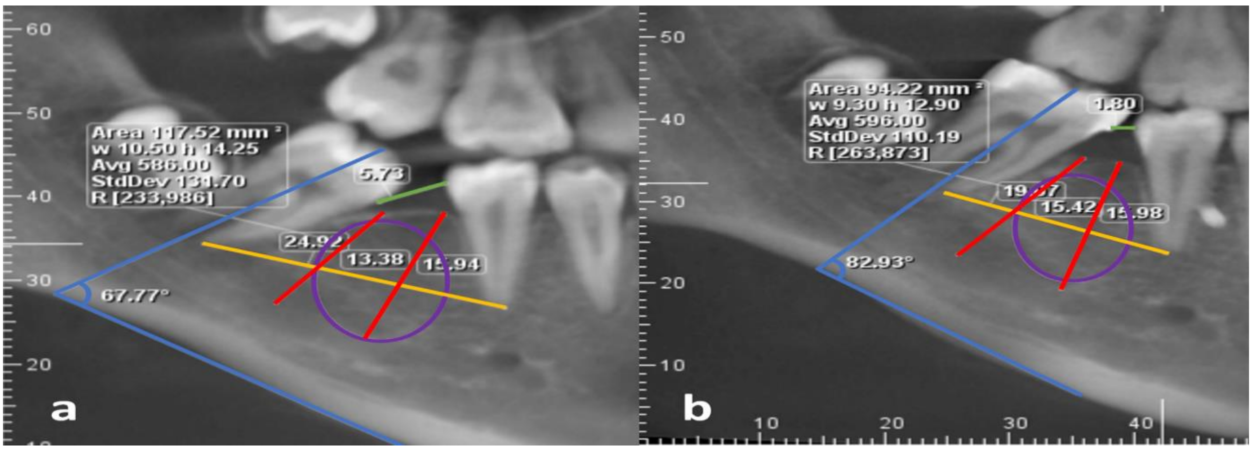

Figure 3. Panoramic view of CBCT used for measurements; (a) Pre-treatment image and (b) post-treatment image. Green lines represent the height-of-contour distance; yellow lines indicate the apical distance; red lines denote alveolar bone height mesial to the second molar and distal to the second premolar; the purple circle indicates the region of interest for bone density measurement; and blue lines illustrate the angulation of the second molar.

circle). The region extended from 3 mm apical to the cementoenamel junction (CEJ) of the second premolar (upper boundary) to the superior border of the inferior alveolar canal (lower boundary). The mesial boundary was set 2 mm from the periodontal ligament (PDL) space of the second premolar, and the distal boundary was defined as 2 mm from the PDL of the second molar.

5. Second molar angulation (°): The angle between the long axis of the mandibular second molar and the mandibular plane (Figure 3; blue line)

6. Alveolar bone thickness (mm): The maximum buccolingual thickness of the alveolar bone mesial to the second molar (Figure 4)

Secondary outcomes (study cast-based)

7. Marginal ridge distance (mm): The horizontal distance between the marginal ridges of the mandibular second premolar and second molar

8. Second molar first-order angulation (°): The buccolingual inclination of the mandibular second molar, defined as the angle between a line connecting the buccal cusps of the second molar and the posterior occlusal plane (Figure 5)

For CBCT-based measurements, Romexis software (version 6.4.5; Planmeca, Helsinki, Finland) was used. Study cast measurements were performed using a digital caliper (1108-150; INSIZE Inc., Suzhou, China), and first-order angulation was measured using a transparent protractor.

All measurements were performed by a single trained and calibrated orthodontist (LD). Intra-examiner reliability was assessed by re-measuring 20% of the samples after a two-week interval, with intra-class correlation coefficient (ICC) values ranging from 0.85 to 0.95.

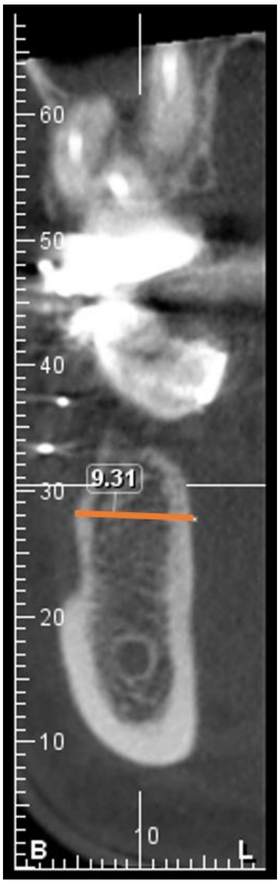

Figure 4. Sagittal CBCT view illustrating the measurement of alveolar bone thickness. The orange line indicates the maximum buccolingual thickness within the defined region of interest.s

Statistical analysis

The Shapiro–Wilk test was used to assess the normality of data distribution ($P > 0.05$). Accordingly, paired t-tests were applied to compare pre-treatment and post-treatment values for each variable. Statistical analyses were performed using IBM SPSS Statistics for

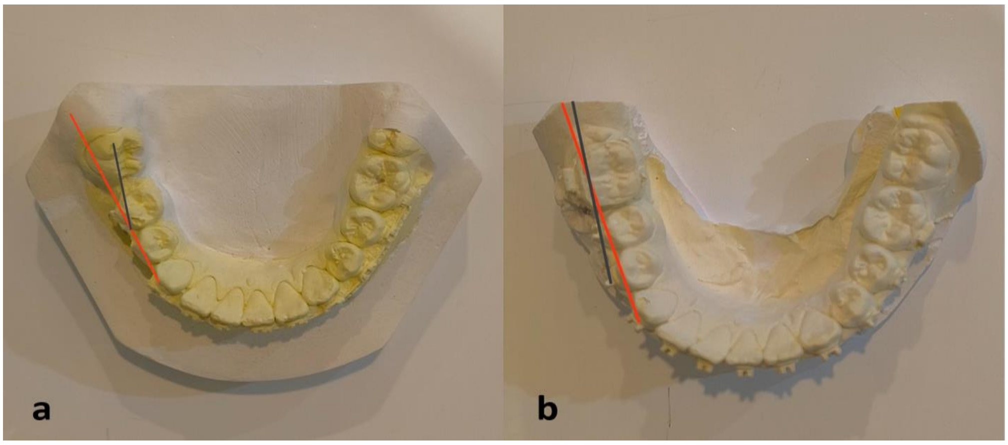

Figure 5. Study cast used for measurement of the second molar first-order angulation; (a) Pre-treatment study cast and (b) post-treatment study cast. Red lines indicate the posterior line of occlusion, and black lines connect the buccal cusps of the mandibular second molar.

Windows (version 25; IBM Corp., Armonk, NY, USA). A significance level of P < 0.05 was set for all tests.

Results

The pre-treatment, post-treatment, and change (Δ) values for the primary and secondary outcomes are presented in Table 1. Paired t-test analysis showed significant reductions in both the height of contour distance and apical distance. The height of contour distance decreased by 3.3 ± 1.45 mm (P = 0.003), while the apical distance decreased by 4.39 ± 1.64 mm (P < 0.001).

Regarding alveolar bone measurements, no significant changes were observed in bone height either mesial to the second molar, which increased by 0.23 ± 1.35 mm (P = 0.555), or distal to the second premolar, which increased by 0.27 ± 1.19 mm (P = 0.450). Similarly, alveolar bone density within the predefined region of interest did not change significantly, with a mean variation of 32.08 ± 198.35 Hounsfield units (P = 0.586).

Alveolar bone thickness mesial to the second molar also remained stable, with a minimal increase of 0.09 ± 0.61 mm (P = 0.814). The second molar angulation relative to the mandibular plane increased significantly by 5.56 ± 6.23° (P = 0.01).

Regarding study cast measurements, the marginal ridge distance significantly decreased by 3.06 ± 1.53 mm from pre- to post-treatment (P < 0.001). The second molar first-order angulation did not change significantly, with a decrease of 0.79 ± 12.32° (P = 0.828).

Discussion

The present prospective pilot quasi-experimental study evaluated a segmented miniscrew-assisted approach for mandibular second molar protraction in 10 patients (12 sites). Unlike conventional full-arch mechanics or miniscrew-assisted systems integrated into continuous archwires, this technique employed two interradicular miniscrews placed adjacent to the second premolar, combined with rectangular-wire uprighting and T-loop/boot-loop mechanics, to achieve controlled tooth movement as an independent segment.

Significant changes were observed in dental measurements. The crown-level (height of contour) distance between the mandibular second premolar and second molar decreased by 3.3 ± 1.45 mm, the root-level (apical) distance decreased by 4.39 ± 1.64 mm, and the marginal ridge distance decreased by 3.06 ± 1.53 mm; all of these were statistically significant. In addition, the angulation of the mandibular second molar relative to the mandibular plane increased by 5.56° ± 6.23, indicating effective molar uprighting. These findings suggest that the miniscrew-assisted approach allows controlled tooth movement with simultaneous space closure and molar uprighting.

In the present study, alveolar bone height showed slight, non-significant increases of 0.23 ± 1.35 mm mesial to the mandibular second molar and 0.27 ± 1.19 mm distal to the second premolar. Similarly, bone density within the defined region of interest between these teeth, as well as alveolar bone thickness mesial to the second molar, did not show significant changes between pre- and post-treatment values. These findings suggest that miniscrew-assisted mechanics enable controlled tooth movement, while their effects on

Table 1. Summary of pre-treatment, post-treatment, and Δ values (changes between pre-treatment and post-treatment) for CBCT and study cast variables in patients treated with the miniscrew-assisted technique (n = 12).

Measurements		pre-treatment	post-treatment	Δ value	P-value
		Mean ± SD	Mean ± SD	Mean ± SD	
Height of contour distance (mm)		5.40 ± 1.96	2.10 ± 1.06	-3.3 ± 1.45	0.003*
Apical distance (mm)		21.27 ± 2.96	16.88 ± 2.61	-4.39 ± 1.64	< 0.001*
Alveolar bone height (mm)	L7	15.46 ± 3.64	15.70 ± 3.52	0.23 ± 1.35	0.555
	L5	16.57 ± 3.05	16.84 ± 3.19	0.27 ± 1.19	0.450
Alveolar bone density (HU)		686.58 ± 173.51	718.72 ± 205.43	32.08 ± 198.35	0.586
Second molar angulation (°)		73.15 ± 9.22	78.72 ± 6.61	5.56 ± 6.23	0.010*
Alveolar bone thickness (mm)		8.4 ± 1.1	8.5 ± 1.2	0.09 ± 0.61	0.814
Marginal ridge distance (mm)		3.55 ± 1.3	0.483 ± 0.735	-3.06 ± 1.53	< 0.001*
Second molar first order angulation (°)		6.79 ± 10.8	6 ± 9.2	-0.79 ± 12.32	0.828

* indicates statistically significance difference between pre-treatment and post-treatment values at P < 0.05.

alveolar bone structure appear minimal and are not clinically significant. Therefore, the use of miniscrews provides a reliable and efficient option for mandibular second molar protraction in cases with extracted mandibular first molars.

Regarding tooth movement, the reductions in height of contour distance (3.3 ± 1.45 mm), apical distance (4.39 ± 1.64 mm), and marginal ridge distance (3.06 ± 1.53 mm) observed in the present study indicate moderate but clinically meaningful molar protraction over the study period. These findings are consistent with the study of Kim et al. (17), who reported 4.97 mm of crown movement and 8.64 mm of root movement using miniscrew-assisted mechanics. The greater displacement reported in their study may be attributed to longer treatment duration, differences in force systems, and measurement methods. For example, panoramic radiographs were used in their study, which may overestimate linear changes compared with CBCT imaging.

Some case reports indicated substantial molar protraction using skeletal anchorage. Baik et al. (15) reported extensive mandibular molar protraction of approximately 11 mm, while Katta et al. (16) achieved up to 10 mm of space closure using miniscrews and power-arm mechanics. However, these larger movements were obtained over extended treatment periods and under highly controlled conditions, often involving full-arch mechanics and additional anchorage strategies. The magnitude of tooth movement observed in the present study is smaller, which may be explained by the shorter observation period, the use of a localized miniscrew-assisted technique without full-arch appliances, and the focus on controlled uprighting combined with protraction rather than extensive space closure. Therefore, the present findings suggest that this approach provides effective and controlled tooth movement within a limited timeframe, rather than maximizing total displacement.

The present findings are consistent with previous studies reporting minimal changes in alveolar bone parameters following miniscrew-assisted mandibular molar protraction. Janakiraman et al. (18) also found no significant changes in alveolar bone measurements, while reporting a reduced overall treatment time with miniscrew-supported mechanics, suggesting more efficient space closure and tooth movement. Using finite element analysis, Nihara et al. (19) demonstrated that the stresses generated during miniscrew-assisted molar movement create localized areas of compression and tension in the alveolar bone, leading to physiological bone remodeling without significant changes in overall bone height. This is in agreement with the present study, in which only minor and statistically nonsignificant changes in bone structure were observed. Likewise, Rivis et al. (20) reported no significant changes in alveolar bone height in the mesial region of the mandibular second molar and the distal region of the second premolar during molar protraction. These findings are consistent with the slight, non-significant increases in alveolar bone height observed in the present study.

Collectively, these studies suggest that, while miniscrew-assisted mechanics allow effective and controlled tooth movement, the associated alveolar bone response appears to be limited to physiological remodeling without clinically significant structural changes.

In contrast to the findings of this study, Kim et al. (17) reported a significant reduction in alveolar bone height (0.56 mm) following miniscrew-assisted mandibular second molar protraction. This difference may be related to variations in treatment mechanics and duration, as greater or prolonged force application during extensive tooth movement may increase the risk of localized bone remodeling or resorption. Differences in imaging methods and measurement protocols may also have contributed to this discrepancy.

Certain limitations of the present study should be noted. Root resorption, a potential complication of orthodontic treatment, was not assessed in the protracted second molars. In addition, the lack of a control group and long-term follow-up limits the generalizability of the findings. Future studies should include larger sample sizes, control groups treated with conventional methods, and randomized clinical trial designs with extended follow-up periods to evaluate relapse and long-term outcomes.

Conclusion

The findings of this study indicate that the segmented miniscrew-assisted approach enables effective and controlled protraction of mandibular second molars, achieving efficient space closure with minimal impact on alveolar bone structure. This approach may represent a viable and less complex alternative to conventional methods, particularly in cases where shorter treatment duration and simplified mechanics are desired.

Acknowledgments

None.

Conflict of interest

The authors declare no conflict of interest.

Author contributions

F.F. designed and supervised the study, collected the data, and revised the manuscript. M.G. contributed to manuscript drafting, statistical analysis, and data interpretation. H.S. contributed to data collection, manuscript revision, and technical support. L.D. contributed to study design, data collection and interpretation, and manuscript drafting and revision. All authors read and approved the final manuscript.

Ethical considerations

The study protocol and consent form were approved by the ethics committee of Mashhad University of Medical Sciences (IR.MUMS.DENTISTRY.REC.1402.014). The study was conducted in accordance with the principles of the Declaration of Helsinki. The trial was prospectively registered in the Iranian Registry of Clinical Trials (IRCT20230407057841N1). All participants signed informed consent forms after receiving a detailed explanation of the study procedures, risks, and benefits.

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