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Istanbul University Press
Official Publication of Istanbul University Faculty of Dentistry

Eur Oral Res 2025; 59(3): 179-185

Original research

Three-dimensional finite element analysis of the effects of different force vectors on tooth movement in miniscrew-assisted en masse retraction

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Purpose
This study evaluates the effects of different force directions on tooth movement in miniscrew-assisted en masse retraction using finite element analysis (FEA).

Materials and Methods
A three-dimensional (3D) finite element model was constructed to simulate en masse retraction in sliding mechanics. A retraction force of 200 g was applied from the anterior retraction hook (ARH) to a miniscrew, and force vectors were resolved along the X, Y, and Z axes. Six different configurations were analysed by varying the ARH (5 mm and 8 mm) and miniscrew heights (6 mm, 8 mm, and 12 mm). Displacement values of anterior and posterior teeth were examined to assess movement patterns in mesiodistal, buccopalatal, and vertical directions.

Results
The analysis revealed that increasing the retraction hook length enhanced mesiodistal tipping of anterior teeth, while higher miniscrew placement reduced mesiodistal tipping of posterior teeth. On the buccopalatal plane, anterior teeth exhibited greater palatal movement when the miniscrew height was reduced, whereas an increased retraction hook height intensified palatal tipping of anterior teeth. Posterior teeth displayed more palatal tipping with a low retraction hook, and greater miniscrew height increased posterior palatal tipping when the hook length remained constant. On the vertical plane, a higher retraction hook induced more intrusion in anterior teeth. Additionally, when a low retraction hook was used, an increase in miniscrew height further enhanced anterior intrusion.

Conclusion
The force direction in en masse retraction should be optimized based on the desired movement in vertical, horizontal, and buccopalatal dimensions. According to the FEA findings, the low hook–low miniscrew combination resulted in maximum palatal crown tipping, while a high miniscrew position was beneficial for torque control by reducing palatal tipping. The low hook–high miniscrew configuration generated significant anterior intrusion, making it a suitable strategy for deep bite correction.

Keywords: *Finite element analysis, en masse retraction, miniscrew, force direction, anterior retraction hook*

Introduction

The extraction of two maxillary premolars is often included in treatment plans for Class II patients with dentoalveolar protrusion or severe crowding. In these patients, the retraction of anterior teeth with maximum anchorage is required. Anchorage control has always been a critical issue, especially with sliding mechanics in en masse retraction.

In conventional en masse retraction, where the retraction force is applied between the retraction hook and the molar hook, extrusion is commonly observed in patients with vertical growth, deep bite, or a gummy

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Received: 9 May 2024
Revised: 25 July 2024
Accepted: 11 October 2024

DOI: 10.26650/eor.20251481061

How to cite: *Savkan I, Marsan G, Tagrikulu B. Three-dimensional finite element analysis of the effects of different force vectors on tooth movement in miniscrew-assisted en masse retraction. Eur Oral Res 2025; 59(3): 179-185.* DOI: 10.26650/eor.20251481061

smile, leading to unfavorable outcomes (1). Possible side effects of orthodontic treatment can only be eliminated through the three-dimensional control of tooth movement.

The use of orthodontic mini-implants not only enhances anchorage but also allows the application of force in various directions. Changing the height of the anterior retraction hook and/or the miniscrew can significantly alter biomechanics and influence the pattern of tooth movement (2, 3). The determination of an ideal force vector has gained significant interest in orthodontic literature; however, due to the limitations of clinical trials, finite element analysis (FEA) has emerged as an effective method for simulating various force vectors (2-6). FEA is a valuable research tool that has greatly contributed to the understanding of orthodontic mechanics. This method has revolutionized dental biomechanical research by enabling the application of various force systems in different directions and quantitatively analysing the resulting tooth movements (4, 5).

This study aims to evaluate the effects of different force directions in en masse retraction on the movement of anterior and posterior teeth using FEA. Specifically, it examines how variations in miniscrew and retraction hook heights influence displacement patterns in mesiodistal, buccopalatal, and vertical dimensions.

Materials and Methods

Creation of geometric model

In this study, finite element models of the teeth, periodontal ligament, alveolar bone, and orthodontic appliances (archwire, brackets, miniscrews, and hooks) were created separately using computer-based modeling.

Surface models of the teeth were generated based on a dental study model (model-i21D-400G; Nissin Dental Products, Kyoto, Japan) with normal occlusion and flat Spee and Wilson curves. The first premolar was not included to simulate first premolar extraction.

To create surface models of the tooth crowns, the study model was scanned using the Next Engine 3D Laser Scanner (Next Engine, Inc., Santa Monica, CA, USA). The roots were then modelled in the Geomagic Design X program (Geomagic, Inc., Norrisville, NC, USA) using freeform modelling, based on root morphologies from the Sobotta Anatomical Atlas (7). These teeth were arranged in an ovoid arch form.

To approximate natural anatomy, the periodontal ligament was constructed using a parametric modeling method in the SolidWorks 3D CAD program (Dassault Systèmes, Vélizy-Villacoublay, France). The periodontal ligament was modelled as a linear elastic film with a 0.25 mm thickness surrounding the roots of all teeth. The periodontal ligament and teeth were modelled separately, allowing tooth movement within the ligament, simulating real anatomical conditions.

Subsequently, the alveolar bone was constructed 1 mm apical to the cemento-enamel junction. Periodontal ligament and the teeth were positioned within the alveolar bone. Although tooth movement within the alveolar bone was simulated, this study focused solely on the displacement values of teeth. Therefore, the alveolar bone served only to replicate the natural dental environment, and changes in the alveolar bone were not included in the study's results.

Following the construction of dental structures, brackets, archwires, retraction hooks, and miniscrews were modelled. All orthodontic appliances were designed using the SolidWorks program. To simulate sliding mechanics, brackets with a 0.022-inch slot size were modelled and positioned at the center of each tooth crown. Bracket bases were thickened according to the tip and torque values of 3M Unitek Gemini SWA brackets. The composite thickness between the tooth surface and bracket base was removed (Figure 1).

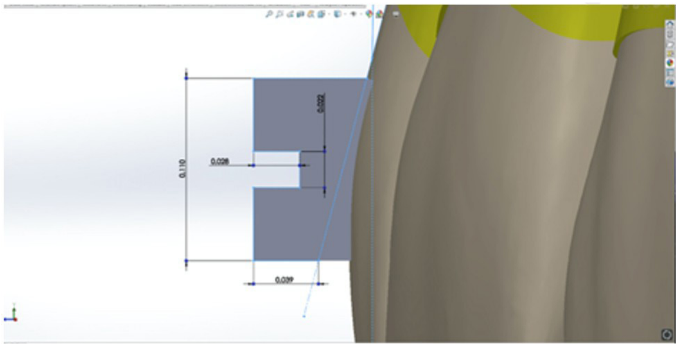

Figure 1. *Detailed modelling of the bracket base is made according to the tip and torque values of 3M Unitek Gemini SWA brackets.*

The main archwire was constructed using the SolidWorks 3D CAD program (Dassault Systèmes, Vélizy-Villacoublay, France). An archwire with dimensions of 0.019 × 0.025 inches was passively placed through the slot of each bracket. The archwire was positioned to make contact with the bottom surface of the bracket slots horizontally and the middle of the bracket slot vertically. This positioning allowed for the incorporation of the "play" between the archwire and the bracket slot into the model. As a result, when force was applied, angulation and inclination closely resembled those observed under clinical conditions (Figure 2).

Retraction hooks were modelled using SolidWorks 3D CAD (Dassault Systèmes, Vélizy-Villacoublay, France). The hooks were placed perpendicularly on the main archwire between the canine and lateral incisor. In this study, the height of the retraction hooks was set at 5 mm and 8 mm, measured from the main archwire.

The addition of miniscrews (1.6 mm diameter, 8 mm length) was the final step in completing the model. Miniscrews were also modelled using SolidWorks 3D CAD and positioned between the roots of the second premolar and first molar at three different heights from the main archwire (6 mm, 8 mm, and 12 mm). Detailed modelling of the miniscrews was not necessary, as they served only as maximum anchorage points. Simplifying the miniscrew design was also advantageous, as it minimized analysis time.

Conversion of the geometric model to the finite element model

The geometric model was converted into a finite element model using the ANSYS 19.2 program (Swanson Analysis System, Canonsburg, PA, USA). Ten-node tetrahedral elements were used to generate the mesh structure (Figure 3). The study model consisted of 476,358 nodes and 243,915 elements.

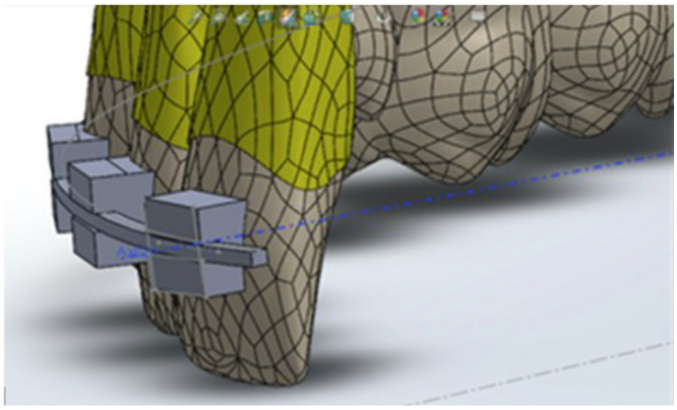

Figure 2. *The main archwire is constructed on Solidworks program, and positioned to contact the bottom surface of the bracket slots horizontally, and vertically in the middle of the bracket slot as in real environment.*

Material parameters and contact relations

Material parameters, such as Poisson's ratio and Young's modulus, used in this study were obtained from the studies of Tominaga *et al.* (8,9), Kojima *et al.* (10), and Parashar *et al.* (11). The values are listed in Table 1. To simplify the model and reduce analysis time, the same material properties (Young's modulus and Poisson's ratio) were assigned to the archwire, power arm, and brackets, as in previous studies (8-11). Structures such as the teeth, periodontal ligament, and alveolar bone were modeled as homogeneous and isotropic materials. Additionally, stiffness and longitudinal damping values were defined for the nickel-titanium coil. The stiffness value was set at 5×10^{-3} N/mm, and the longitudinal damping was 1×10^{-2} Ns/mm.

Application of forces and boundary conditions

In this study, six different force directions were simulated by altering the vertical heights of the retraction hook and the miniscrew. A retraction force of 200 g was applied in each scenario. The force applications were as follows: Model 1.1 involved a retraction hook at 5 mm height with a miniscrew at 6 mm height; Model 1.2 had a 5 mm retraction hook with an 8 mm miniscrew; and Model 1.3 used a 5 mm retraction hook with a 12 mm miniscrew. Similarly, Model 2.1 included a retraction hook at 8 mm with a 6 mm miniscrew; Model 2.2 had an 8 mm retraction hook with an 8 mm miniscrew; and Model 2.3 used an 8 mm retraction hook with a 12 mm miniscrew. Figure 4 illustrates all force directions with varying retraction hook and miniscrew heights.

The boundary conditions were defined to simulate the constraints of the model and to prevent unrestricted bodily movement. To avoid sliding displacement of the entire model, the bottom of the alveolar bone was restrained in six degrees of freedom. Additionally, a contact boundary surface was applied to each interproximal surface to ensure proper interaction between teeth. A "no separation" contact type was used between each tooth and the periodontal ligament, allowing realistic force transmission within the system.

Analysis protocol

FEA was performed using ANSYS software (Swanson Analysis System Inc., Canonsburg, USA), and tooth displacements in three-dimensional space were calculated. The results are represented in the X, Y, and Z coordinates, with axes set for each tooth. The X-axis represents mesiodistal movement, the Y-axis corresponds to bucco palatal movement, and the Z-axis indicates superior-inferior movement. Positive and negative displacement values indicate directionality. Positive values denote distal movement along the X-axis, palatal movement along the Y-axis, and apical movement along the Z-axis. Displacement values were measured from designated reference points on the teeth. Root tips, incisal edges, and tubercle cusps were marked within the program, and specific displacement values were obtained from these points.

Table 1. *Material properties (see main text for references).*

	Young Modulus	Poisson Ratio
Tooth	20000	0,3
Periodontal Ligament	0,05	0,49
Cortical Bone	2000	0,3
Trabecular Bone	200	0,3
Bracket	200000	0,3
Archwire	200000	0,3
Miniscrew and coil	110000	0,35

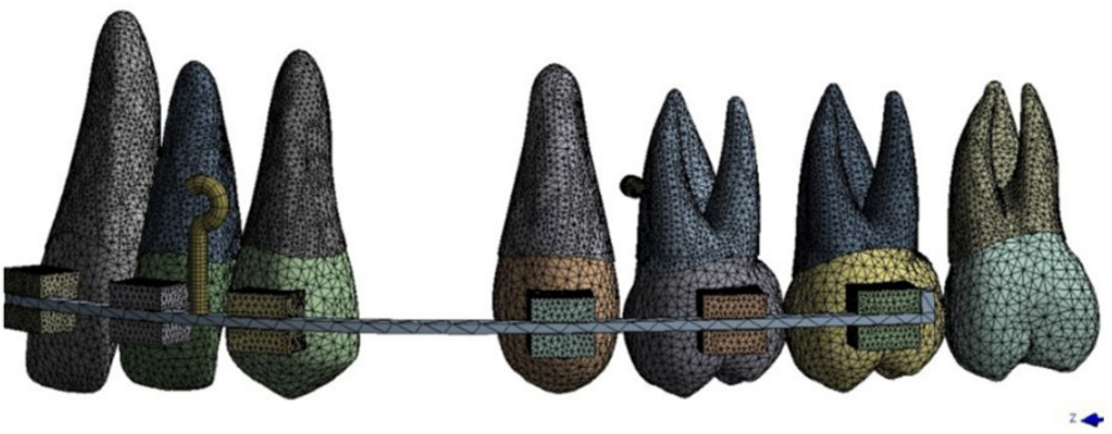

Figure 3. *Finite elements model which is created by using ANSYS software.*

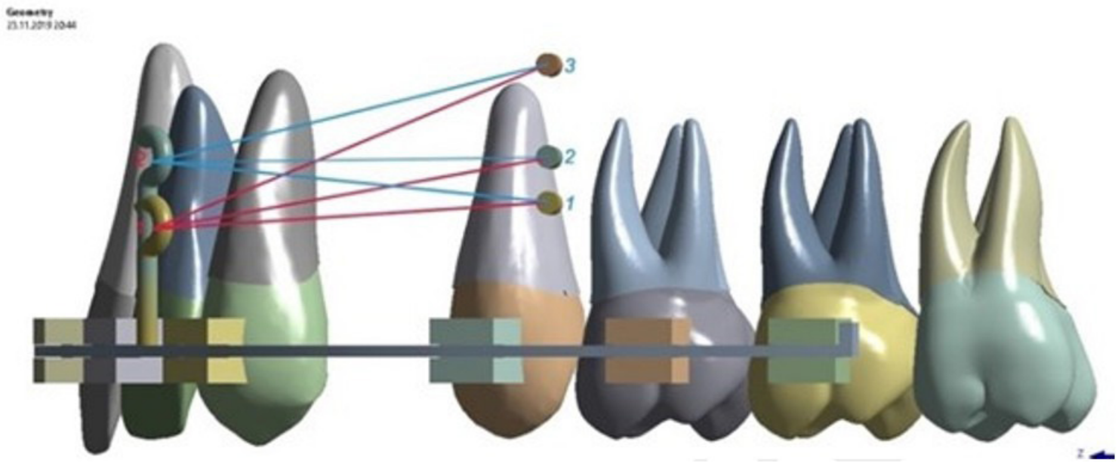

Figure 4. *Representation of the force directions.*

Results

The initial displacement values are provided in Table 2. Displacement values are presented across three different planes and compared between models with varying hook and screw heights. The values in Table 2 represent the initial displacements occurring under the designated force directions, measured in millimetres (unit × 10^{-2}). Positive and negative values indicate displacement direction, as described in the Materials and Methods section.

Model comparisons

In this study, different force directions were analyzed by varying the height of the anterior retraction hook (ARH) and the miniscrew. Comparisons between models revealed distinct movement patterns in the mesiodistal, buccopalatal, and vertical planes.

When comparing Model 1.3 and Model 2.3, where the miniscrew height was constant at 12 mm, increasing the ARH height resulted in greater distal tipping of the anterior dentition and mesial tipping of the posterior dentition. Buccopalatally, the low traction group exhibited more pronounced palatal crown tipping in the anterior region, whereas the posterior region showed greater buccal crown and root movement. In the vertical plane, anterior teeth exhibited intrusive movement regardless of ARH height, while posterior teeth underwent extrusion, which was more pronounced in the low traction group.

In the comparison between Model 1.2 and Model 2.2, with a fixed miniscrew height of 8 mm, a high ARH resulted in increased distal tipping of the anterior dentition. In contrast, in the posterior region, a low ARH led to greater mesial tipping of the premolars. Along the buccopalatal axis, anterior teeth exhibited more significant palatal crown movement when the ARH height was set at 8 mm. Posterior teeth showed both crown and root displacement in the buccal direction, with greater movement in the 5 mm hook group. Vertically, the entire dentition displayed intrusive movement, with the anterior region experiencing greater intrusion in the 5 mm hook group, whereas the posterior region showed the highest intrusion in the 8 mm ARH group.

For Model 1.1 and Model 2.1, where the miniscrew height remained at 6 mm, incisors exhibited distal crown tipping, with the displacement being more significant at an 8 mm ARH height. Posterior teeth displayed a stronger mesiodistal tipping tendency when a lower ARH was used. At this screw height, the coronal region tipped mesially while the apex tipped distally. Along the buccopalatal axis, increasing the retraction height altered the movement pattern from lingual crown tipping to lingual root tipping, with the low traction group exhibiting a greater buccolingual inclination tendency for the entire dentition. Vertically, incisors displayed extrusion at an 8 mm ARH height and intrusion at a 5 mm height, while posterior dentition showed intrusion, which was more pronounced in the 5 mm ARH group.

When miniscrew height varied while maintaining a constant 5 mm ARH height, as in Model 1.1, Model 1.2, and Model 1.3, greater distal movement of the anterior region was observed with a 12 mm miniscrew. In the posterior dentition, mesial movement decreased as the miniscrew height increased. The extent of palatal crown tipping in the anterior region diminished as the miniscrew height increased, while the posterior dentition exhibited buccal movement, which intensified with increasing miniscrew height. Vertically, a higher miniscrew height was associated with an increased intrusion tendency.

For Model 2.1, Model 2.2, and Model 2.3, where the ARH was consistently set at 8 mm, increasing miniscrew height influenced movement along all three axes. In the mesiodistal plane, distal movement and distal crown tipping of the anterior dentition increased with higher miniscrew placement. In the posterior dentition, increasing the miniscrew height reduced mesial displacement and tipping. Buccopalatally, anterior teeth exhibited palatal displacement, with minimal tipping at 6 mm miniscrew height and maximum movement at 8 mm. Posterior dentition showed buccal movement, with greater displacement occurring at higher miniscrew heights. Vertically, anterior teeth displayed extrusion at a 6 mm miniscrew height, while intrusion occurred at 8 mm and 12 mm miniscrew heights. The posterior dentition exhibited intrusion at 6 mm and 8 mm heights, whereas extrusion was observed at 12 mm.

These findings demonstrate that variations in ARH and miniscrew height significantly influence tooth movement in en masse retraction. Understanding these effects is critical for optimizing force direction to achieve the desired orthodontic outcomes.

Table 2. *Displacement values obtained from finite element analysis.*

MODEL	HOOK**	SCREW***	DIRECTION	U1 incisal	U1 apical	U2 incisal	U2 apical	U3 incisal	U3 apical	U5 incisal	U5 apical	U6 mesial tub	U6 MB root
1.1.	5 mm	6 mm	X	10.9	9.71	9.64	10.2	8.08	10.2	-5.52	4.54	-4.68	0,94
			Y	6.48	-3.04	7.60	-3.58	13.6	-4.52	-7.50	-2.30	-6.47	-2.02
			Z	0,45	0.93	0.14	1.57	2.42	4.01	1.28	2.66	0.45	1.0
1.2.	5 mm	8 mm	X	10.9	1.21	10.8	2.69	9.07	1.84	-4.27	0.31	-4.65	-0.678
			Y	5.86	0.648	6.21	0.48	10.17	0.046	-7.79	-0.22	-6.16	-0.97
			Z	0.92	-0.08	0.08	0.73	1.92	1.34	-0.16	0.35	0.02	0.14
1.3.	5 mm	12 mm	X	8.80	1.19	10.1	2.78	7.90	1.94	-3.98	0.36	-4.12	-0.54
			Y	5.80	0.65	6.30	0.46	10.1	0.16	-7.66	-0.15	-6.25	-1.04
			Z	2.01	0.51	0.86	1.24	2.86	1.86	-0.95	-0.16	-0.55	-0.37
2.1.	8 mm	6 mm	X	12.9	1.19	11.3	2.42	10.1	1.60	-4.25	0.13	-5.00	-0.77
			Y	5.00	0.58	5.82	0.47	12.1	-0.15	-7.42	-0.42	-5.64	-1.13
			Z	-0.48	-0.63	-0.80	0.072	0.26	0.51	1.13	0.98	0.74	0.70
2.2.	8 mm	8 mm	X	12.2	1.20	11.2	2.52	9.83	1.69	-4.20	0.031	-4.85	-0.77
			Y	6.01	0.61	6.05	0.45	12.1	-0.10	-7.64	-0.43	-5.89	-1.27
			Z	0.073	-0.41	-0.41	0.29	0.90	0.90	0.76	0.75	-0.45	0.37
2.3.	8 mm	12 mm	X	10.5	1.29	10.7	2.74	8.79	1.86	-4.12	0.24	-4.49	-0.64
			Y	5.46	0.64	6.34	0.46	11.6	0.051	-7.75	-0.26	-6.21	-1.14
			Z	1.24	0.24	0.29	0.84	2.07	1.48	-0.35	0.21	-0.17	-0.07

* Displacement values are given in mm (unit * 10^-2 mm)
** Hook: Height of the retraction hook in millimetres
*** Screw: Height of the miniscrew height in millimetres
**** U1: Maxillary first incisor, U2: Maxillary lateral incisor, U3: Maxillary canine, U5: Maxillary second premolar, U6: Maxillary first molar
***** Positive and negative values indicate direction. Positive values indicate distal movement in x axis, palatal movement in y axis and apical movement in z axis.

Discussion

The results obtained in finite element analysis (FEA) are directly related to the quality of the model created. A model that closely resembles reality in various aspects is essential for achieving accurate results (8). Thus, modelling is the most critical phase in FEA. As FEA is based on mechanical principles, factors such as saliva and masticatory forces in the oral cavity are not considered, and results should always be interpreted with this limitation in mind (1). Despite these, FEA allows for the simulation of different force vectors and the analysis of the dentition's response in a three-dimensional environment. This method enables researchers to modify force direction and intensity to replicate clinical scenarios, facilitating a more precise evaluation of the effects of different forces on tooth movement (8).

In miniscrew-supported sliding mechanics, although the miniscrew eliminates anchorage loss and allows for the retraction of the anterior teeth as a unit, the applied force exerts an external influence on the system, potentially causing rotations in the dentition. Therefore, selecting the appropriate force vector is crucial for achieving the desired tooth movement (9). The height of the anterior retraction hook (ARH) plays a key role in preventing torque loss due to lingual tipping of the anterior teeth (10). By adjusting the vertical height of retraction hooks, various movement patterns, including lingual tipping, bodily movement, and labial tipping, can be achieved. Similarly, modifying the vertical position of the miniscrew alters the direction of force application, allowing better control over the relationship between the centre of resistance and force direction, thereby optimizing the management of rotational movements in the dentition (11-13).

Several authors have examined the impact of miniscrew height and ARH alterations on tooth movement. Keluskar *et al.* (14) and Parashar *et al.* (11) investigated the effects of different miniscrew heights, while Tominaga *et al.* (8) and Ozaki *et al.* (15) focused on changes in ARH height in miniscrew-assisted en masse retraction cases. However, only a limited number of studies have analysed both variables simultaneously (14).

This study evaluates the vertical modifications of both miniscrew and ARH height. Tominaga *et al.* (8) analysed the effects of different force directions on the movement of a single tooth, whereas Ozaki *et al.* (15) focused solely on anterior tooth movement. The present study contributes to the literature by examining the movement of both anterior and posterior teeth together.

In previous studies, tooth movement was often assessed in a single plane, either X, Y, or Z. This study compares the movement of teeth under different force vectors across all three spatial dimensions, providing comprehensive data on the displacement of each tooth in the maxillary arch. Tominaga *et al.* (8) investigated how alterations in ARH height affected central incisor movement, using ARH heights of 0, 2, 4, 6, 8, 10, and 12 mm. Their results demonstrated that increasing ARH height shifted movement direction from lingual crown tipping to lingual root tipping, findings that align with Ozaki *et al.* (15) and are consistent with our study, particularly for the 6 mm miniscrew group.

Other studies have maintained a constant ARH height while modifying miniscrew height to alter force direction (11,13). It has been observed that as miniscrew height increases, the superior movement of anterior teeth also increases. Additionally, in the buccopalatal axis, lingual tipping slightly decreases as miniscrew height increases. Our results align with those of Chetan *et al.* (14) and Parashar *et al.* (11), confirming similar trends in tooth movement.

Kojima *et al.* (10) conducted an FEA study simulating long-term tooth movement, incorporating sequential remodeling based on stress distribution in the periodontal ligament. Their findings indicated that increasing ARH height reduces palatal movement of the incisal edge and decreases vertical intrusive movement. Furthermore, they reported that when miniscrew height was fixed at 6 mm, posterior intrusive movement decreased as ARH height increased.

Although clinical conclusions cannot be drawn solely from FEA studies, the findings of this study offer insights into potential treatment strategies that should be validated through clinical research. Based on our results, a miniscrew positioned 6 mm above the main archwire combined with an 8 mm ARH may be effective in Class II Division 2 cases, as it promotes palatal root movement in the anterior region. In contrast, for Class II Division 1 cases, a 6 mm miniscrew with a 5 mm ARH may be more beneficial, as it facilitates buccal movement of the anterior tooth roots along with intrusion. This force vector could aid in the correction of deep bite by inducing buccal movement of anterior tooth roots.

In addition to measuring displacement values, FEA can also compute stress and strain distributions within tissues. However, since the present study focused solely on initial tooth displacement, stress and strain values were not included in the analysis.

While FEA is a valuable tool for simulating tooth movement, results should be interpreted with caution, as the complex anatomical and biomechanical properties of human tissues cannot be fully replicated in a computational environment. In finite element studies, oral tissues are often assumed to have homogeneous and isotropic properties, whereas in reality, structures such as bone exhibit heterogeneous characteristics. Due to these inherent limitations, FEA findings should serve as guidelines that require validation through clinical trials (16).

In this study, significant effort was made to construct a realistic model using an anatomical atlas and dental study models. However, future studies could enhance accuracy by incorporating CBCT data to improve model fidelity. Additionally, since tooth movement is a continuous process, future research should focus on simulating long-term tooth movement in a computational environment. Further investigations should explore different force vectors to determine the optimal hook and miniscrew heights and examine potential sagittal position changes in miniscrew and ARH placement. All findings should ultimately be reinforced through clinical research.

Conclusion

This study demonstrates that the direction of force application in miniscrew-assisted en masse retraction significantly influences tooth movement in all three spatial planes. The findings indicate that a low hook–low miniscrew combination leads to maximum palatal crown tipping, while a high miniscrew position helps control torque by reducing palatal tipping. Additionally, a low hook–high miniscrew configuration enhances anterior intrusion, making it a suitable approach for deep bite correction. These results emphasize the importance of selecting the appropriate force vector based on desired tooth movement outcomes. While FEA provides valuable insights into orthodontic biomechanics, clinical validation remains essential. Future research should explore the long-term effects of different force vectors and assess their clinical relevance in diverse patient cases to further refine treatment strategies.

Türkçe öz: *Minivida destekli en masse retraksiyon uygulamalarinda farkli kuvvet doğrultularinin diş hareketi üzerine etkilerinin sonlu elemanlar analizi ile incelenmesi. Amaç: Çalışmamızın amacı, mini vidalardan destek alınarak yapılan en masse retraksiyon uygulamalarında farklı kuvvet doğrultularının diş hareketi üzerindeki etkilerinin FEM analizi ile incelenmesidir. Gereç ve yöntem: Çalışmamızda anterior bölgenin kütlesel retraksiyonunun sağlanması amacıyla, retraksiyon çengelleri ile, mini vidalar arasında kapatıcı yaylar vasıtasıyla 200 gr şiddetinde kuvvet uygulanması simüle edilmiştir. Farklı kuvvet vektörlerinin simüle edilmesi amacıyla, ark telinden itibaren 5 mm ve 8 mm olmak üzere iki farklı yükseklikte retraksiyon çengeli ile; 6, 8 ve 12 mm olmak üzere üç farklı yükseklikte mini vidanın yerleştirildiği altı analiz modeli oluşturulmuştur. Ön ve arka dişlerde meydana gelen yer değiştirmeler FEM analiziyle incelenmiştir. Bulgular: Analiz sonucunda, retraksiyon çengeli yüksekliğinin artması ile kesiciler bölgesinde meziodistal yönde meydana gelen devrilme miktarında artış gözlenmiştir, posterior bölgede ise vida yüksekliğinin artması ile birlikte meziodistal yönlü devrilme miktarında azalma gözlenmiştir. Bukkopalatinal yönde alçak retraksiyon çengeli kullanıldığında, vida yüksekliğinin artması ile birlikte palatinal yönlü devrilme hareketi azalırken, yüksek retraksiyon çengeli kullanıldığında, vida yüksekliği arttıkça palatinal yönlü devrilme miktarının da arttığı görülmüştür. Posterior bölgede ise, vida yüksekliğinden bağımsız olarak alçak retraksiyon çengeli bukkal yönde daha fazla devrilmeye yol açmıştır. Vida yüksekliğinin artması ile ise bukkal yöndeki devrilme miktarı artmıştır. Vertikal yönde anterior bölgede, retraksiyon çengeli yüksekliği arttıkça, meydana gelen intrüzyon miktarı artmıştır, posterior bölgede ise ekstrüzyon meydana gelmiş olup, hareket miktarı hook yüksekliğinin artması ile artmıştır. Alçak retraksiyon çengelinin kullanıldığı durumda, anterior bölgede vida yüksekliğindeki artış intrüzyon miktarını arttırmıştır. Sonuç: En masse retraksiyon uygulamalarında, kuvvet doğrultusu retraksiyon sağlamanın yanısıra düzeltilmek istenen diğer problemleri de çözecek şekilde seçilmelidir. Bu çalışmanın Sonlu elemanlar analizi bulgularına göre, alçak retraksiyon çengeli- alçak minivida kombinasyonunda maksimum palatal kuron devrilmesi ortaya çıkmaktadır. Yüksek minivida pozisyonu ile ise palatal devrilme azalmaktadır. Alçak retraksiyon çengeli- yüksek minivida kombinasyonu ile anterior dentisyonda intrüzyon hareketi sağlanmaktadır Anahtar Kelimeler: sonlu elemanlar analizi, en masse retraksiyon, mini vida, kuvvet vektörleri, anterior retraksiyon çengeli*

Ethics Committee Approval: Not required.

Informed Consent: Not required.

Peer-review: Externally peer-reviewed.

Author contributions: IS, GM, BT participated in designing the study. IS, GM, BT participated in generating the data for the study. IS, GM, BT participated in gathering the data for the study. IS, GM, BT participated in the analysis of the data. IS, GM, BT wrote the majority of the original draft of the paper. IS, GM, BT participated in writing the paper. IS, GM, BT has had access to all of the raw data of the study. IS, GM, BT has reviewed the pertinent raw data on which the results and conclusions of this study are based. IS, GM, BT have approved the final version of this paper. IS, GM, BT guarantees that all individuals who meet the Journal's authorship criteria are included as authors of this paper.

Conflict of Interest: The authors declared that they have no conflict of interest.

Financial Disclosure: The authors declared that they have received no financial support.

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