Original Article

Three-dimensional changes after maxillary molar distalization with a miniscrew-anchored cantilever

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ABSTRACT

Objectives: To evaluate the changes after maxillary molar distalization in Class II malocclusion using the miniscrew-anchored cantilever with an extension arm.

Materials and Methods: The sample included 20 patients (9 male, 11 female; mean age 13.21 ± 1.54 years) with Class II malocclusion, treated with the miniscrew-anchored cantilever. Lateral cephalograms and dental models obtained before (T1) and after molar distalization (T2) were evaluated using Dolphin software and 3D Slicer. Superimposition of digital dental models using regions of interest on the palate was performed to evaluate three-dimensional displacement of maxillary teeth. Intragroup change comparisons were performed using dependent *t*-test and Wilcoxon test ($P < 0.05$).

Results: The maxillary first molars were distalized to overcorrected Class I. The mean distalization time was 0.43 ± 0.13 years. Cephalometric analysis demonstrated significant distal movement of the maxillary first premolar (–1.21 mm, 95% confidence interval [CI]: –0.45, –1.96) and maxillary first (–3.38 mm, 95% CI: –2.88, –3.87) and second molars (–2.12 mm, 95% CI: –1.53, –2.71). Distal movements increased progressively from the incisors to the molars. The first molar showed small intrusion (–0.72 mm, 95% CI: 0.49, –1.34). In the digital model analysis, the first and second molars showed a crown distal rotation of 19.31° ± 5.71° and 10.17° ± 3.84°, respectively. The increase in maxillary intermolar distance, evaluated at the mesiobuccal cusps, was 2.63 ± 1.56 mm.

Conclusions: The miniscrew-anchored cantilever was effective for maxillary molar distalization. Sagittal, lateral, and vertical movements were observed for all maxillary teeth. Distal movement was progressively greater from anterior to posterior teeth. (*Angle Orthod.* 2023;93:513–523.)

KEY WORDS: Malocclusion; Angle Class II; Cephalometry; Dental models; Three-dimensional imaging

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INTRODUCTION

Class II malocclusion is characterized by an inadequate sagittal relationship between the dental arches, with the mandibular teeth occluding distally in relation to the maxillary teeth and producing occlusal and facial impairment.[1] Class II malocclusion usually has a combination of skeletal and dental components. In cases of predominantly dental etiology, distalization of the maxillary molars is an effective treatment alternative to treat the sagittal discrepancy.[2,3] Different designs of intraoral distalizers have been commonly used for this purpose.[4]

Conventional intraoral distalizers often use dentoalveolar anchorage. This is associated with undesirable side effects such as anchorage loss (incisor labial tipping and protrusion), premolar mesialization, and molar distal tipping, among others.[3,5,6] To overcome these side effects, intraoral distalizers may be used with temporary anchorage devices (TADs) during molar distalization.[4] Previous studies presented different intraoral distalization systems with skeletal anchorage.[7–9] For this purpose, miniscrews are commonly used due to their simpler insertion and removal techniques.[10] While using TADs during distalization, anchorage loss can be controlled and molar distal tipping can be minimized.[11,12] Achieving bodily movement during distalization is challenging. Ideally, the line of action of the distal force should be placed close to the center of resistance of the molars.[11] Intraoral distalization associated with skeletal anchorage should allow the adjustment of force application in relation to the vertical position of the miniscrew. Therefore, it would be clinically important to develop distalizers with different designs to further reduce the undesirable side effects encountered during distalization.

Previous studies evaluated molar distalization by means of lateral cephalograms.[7,13,14] However, a few studies reported 3D analysis to evaluate maxillary molar distalization with superimposition of digital models. Recently, a method for superimposition of maxillary digital models using open-source software was reported to be reliable for tooth change evaluations.[15] Evaluating the effectiveness of skeletally anchored distalization alternatives may bring important insights for orthodontic clinical practice. Therefore, the purpose of this prospective clinical study was to evaluate the skeletal, dentoalveolar, and soft tissue changes after maxillary molar distalization in patients with Class II malocclusion using a miniscrew-anchored cantilever (MAC) with an extension arm, by means of cephalometric analysis and superimposition of digital dental models.

MATERIALS AND METHODS

This prospective study was approved by the Ethics in Research Committee of Bauru Dental School, University of São Paulo, Brazil (protocol No. 43930715.8.0000.5417). Informed consent was signed by all patients and their legal guardians. Sample size calculation was performed using an alpha error of 5%, test power of 90%, to detect a mean change of 1.75 mm of maxillary molar distalization, with a previously reported standard deviation of 1.5 mm.[3] A minimum of 12 patients was required.

The inclusion criteria were bilateral Class II malocclusion (minimum of ¼ cusp discrepancy), all permanent teeth up to the first molars erupted, no severe mandibular crowding, no previous orthodontic treatment, and no associated craniofacial anomalies or syndromes. Presence/absence of the third molar was not considered.

The sample consisted of 20 patients (9 male, 11 female; mean age 13.21 $\pm$ 1.54 years). Six patients presented ¼ cusp; 7, ½ cusp; 4, ¾ cusp; and 3, full cusp Class II molar relationships. All patients were treated with a MAC (Figure 1A,B). A miniscrew (8-mm length, 1.5-mm diameter; Morelli, Sorocaba, São Paulo, Brazil) was placed buccally, bilaterally, and between the maxillary first molars and second premolars (20°–30° angulation). Tooth crown references were considered for miniscrew insertion, and radiographs were taken before and after insertion as previously reported.[16] A cantilever formed with a 1.0-mm stainless steel wire was soldered into the round buccal tube of the maxillary first molar band. The appliance was cemented, and a NiTi closed coil spring with 200 g of force was placed from the miniscrew to the cantilever hook. The coil spring was activated once a month to maintain constant force during distalization. Reactivation was performed according to force measurement of distance extension of the closed coil springs. The mean distalization time was 0.43 $\pm$ 0.13 years, and the maxillary first molars were distalized until an overcorrection of the Class II molar relationship was observed (Figure 1C–E).

Cephalograms were obtained before (T1) and after molar distalization (T2). Cephalometric analysis was performed using Dolphin Imaging software (version 11.5, Dolphin Imaging and Management Solutions, Chatsworth, Calif). The magnification factor of the images was corrected. A total of 21 variables were measured to evaluate the skeletal, dentoalveolar, and soft tissue changes (Table 1; Figure 2A,B).

Dental models from T1 and T2 were scanned using an R700 3D scanner (3Shape A/S, Copenhagen, Denmark), stored as .STL files, and converted to .VTK files using 3D Slicer open-source software

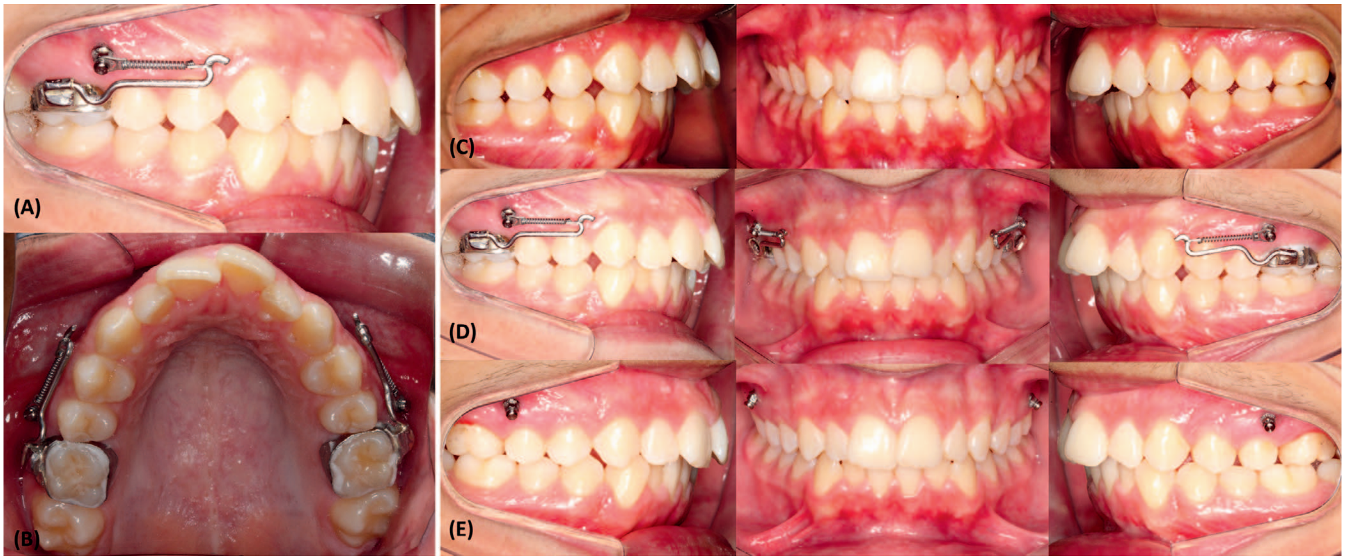

Figure 1. Miniscrew-anchored cantilever (MAC): (A) sagittal view; (B) occlusal view. Intraoral photographs of one patient of the sample: (C) before treatment; (D) installed miniscrew-anchored cantilever (MAC); (E) after distalization.

Table 1. Cephalometric Measurements

Designation and Unit	Description
Skeletal	
ANB, °	Angle formed by the intersection of NA line and NB line
FMA, °	Angle formed by the intersection of Frankfurt plane and Go-Me
Maxillary dentoalveolar	
Anteroposterior	
Mx1-PTV, mm	Linear distance from the tip of the maxillary central incisor perpendicular to the PTV
Mx4-PTV, mm	Linear distance from the centroid of the maxillary first premolar perpendicular to the PTV
Mx6-PTV, mm	Linear distance from the centroid of the maxillary first molar perpendicular to the PTV
Mx7-PTV, mm	Linear distance from the centroid of the maxillary second molar perpendicular to the PTV
Angulation	
Mx1.SN, °	Angle formed by the intersection of the long axis of the maxillary central incisor and the SN line
Mx4.SN, °	Angle formed by the intersection of the long axis of the maxillary first premolar and the SN line
Mx6.SN, °	Angle formed by the intersection of the long axis of the maxillary first molar and the SN line; the first molar long axis was determined by a line passing through the central point between the two root apices and the centroid point
Mx7.SN, °	Angle formed by the intersection of the long axis of the maxillary second molar and the SN line; the second molar long axis was determined by a line passing through the central point between the two root apices and the centroid point
Vertical	
Mx1-PP, mm	Perpendicular distance from the tip of the maxillary central incisor to the palatal plane
Mx4-PP, mm	Perpendicular distance from the centroid of the maxillary first premolar to the palatal plane
Mx6-PP, mm	Perpendicular distance from the centroid of the maxillary first molar to the palatal plane
Mx7-PP, mm	Perpendicular distance from the centroid of the maxillary second molar to the palatal plane
Mandibular dentoalveolar	
Anteroposterior	
Md6-PTV, mm	Linear distance from the centroid of the mandibular first molar perpendicular to the PTV
Angulation	
Md6.MP, °	Angle formed by the intersection of the long axis of the mandibular first molar and the mandibular plane; the first molar long axis was determined by a line passing through the central point between the two root apices and the centroid point
Interdental	
Overbite, mm	Linear vertical distance from incisal of maxillary incisor to incisal of mandibular incisor
Overjet, mm	Linear horizontal distance from incisal of maxillary incisor to incisal of mandibular incisor
Molar relationship, mm	Linear distance from the average of the most distal points of maxillary first molar crowns to the average of the most distal points of mandibular first molar crowns
Soft tissue	
NLA, °	Nasolabial angle, formed by the intersection of Cm-Sn and Sn-Ls
UL-Sline, mm	Distance from the upper lip to the S line (midpoint between subnasale and pronasale to soft tissue pogonion)

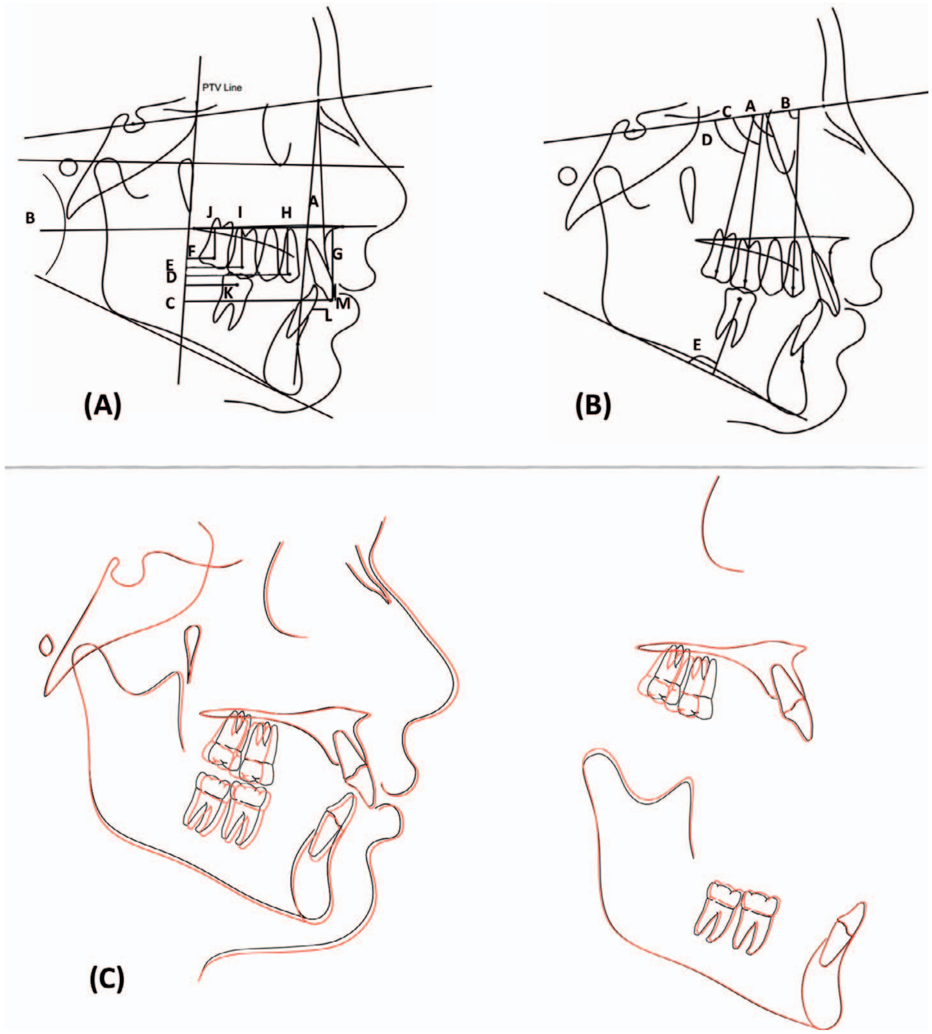

Figure 2. Upper images: Cephalometric variables. (A) A. SNA; B. FMA; C. Mx1-PTV; D. Mx4-PTV; E. Mx6-PTV; F. Mx7-PTV; G. Mx1-PP; H. Mx4-PP; I. Mx6-PP; J. Mx7-PP; K. Md6-PTV; L. overjet; M. overbite. (B) A. Mx1.SN; B. Mx4.SN; C. Mx6.SN; D. Mx7.SN; E. Md6.MP. Lower images: mean superimposition of the cephalometric tracings of all 20 patients. (C) Before treatment (black line) and after distalization (red line).

(version 4.10.2; https://www.slicer.org). The image analysis followed the steps reported by a previously validated method[15] (Figure 3A–C):

1. Orientation: The T1 dental models were oriented using the midpalatal raphe, the occlusal plane (defined as passing from the first molars to the central incisors), and the incisal line, in the occlusal (axial), lateral (sagittal), and frontal (coronal) views, respectively.
2. Approximation: The T2 models were approximated to the oriented T1 model using corresponding landmarks placed at the tip of the buccal cusps of the first premolars and at the middle of the incisal edge of the central incisors, on both sides.
3. Superimposition (registration): A total of nine landmarks were placed at the posterior limit of the incisive papilla, at the medial edges of the second palatal rugae, at the medial and lateral edges of the third rugae, and at 10-mm distal to the medial edge of third rugae. In addition, regions of interest (20-mm diameter, each) were defined around the landmarks placed at the middle edge of the second and third palatal rugae and around the most posterior landmarks. These procedures were performed for the oriented T1 model and for the approximated T2 model. Subsequently, the software superimposed the T2 model to the oriented T1 model by matching the corresponding regions of interest.
4. Quantitative 3D assessment: Landmarks were placed in the oriented T1 and registered T2 models at the tip of the mesiobuccal and distobuccal cusps of the second molars; mesiobuccal, distobuccal, and mesiopalatal cusps of the first molars; buccal cusp of the first and second premolars; and the

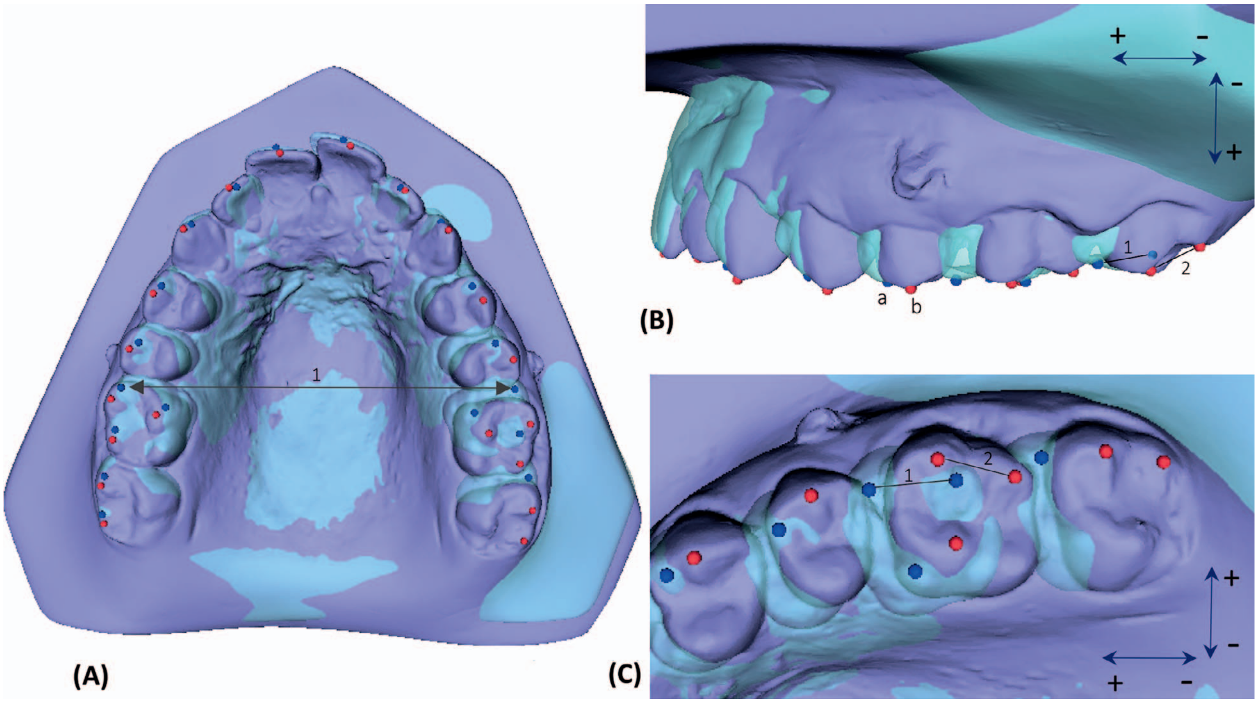

Figure 3. Superimposed models and representation of the measurements. Before treatment (blue point), after distalization (red point). (A) Occlusal view. Intermolar distance evaluated at the mesiobuccal cusps (line 1). (B) Sagittal view. Linear displacements were calculated three-dimensionally by distances between point a (before treatment) and point b (after distalization) for all teeth. Molar distal angulation was calculated by the angle formed between line 1 and line 2 in the vertical plane for the first and second molars. (C) Occlusal view. First molar rotation was calculated by the angle between line 1 and line 2 in the transverse plane.

cusp of canines and at the middle of the incisal edge of lateral and central incisors, bilaterally. Finally, displacements (mm) in the coordinates X (right-left), Y (anteroposterior), and Z (superior-inferior) as well as the three-dimensional (3D) displacement between T1 and T2, were measured by the Q3DC tool. Anterior, inferior, and lateral displacements had positive values. Posterior, superior, and medial displacements had negative values. Lines connecting landmarks placed at the mesiobuccal and distobuccal cusps of the molars were defined at T1 and T2. The angles between the two lines were calculated to evaluate the rotation (yaw) and the mesiodistal angulation (pitch) of the first and second molars. In addition, the inter–first molar distance was calculated using landmarks placed at the mesiobuccal cusps of the first molars, individually, at T1 and T2.

Error Study

Lateral cephalograms and dental models of 50% of the sample were randomly selected, and the measurements were repeated by the same examiner (LV) after 15 days. Intraobserver reproducibility was evaluated with the intraclass correlation coefficient (ICC) and Bland-Altman plots.

Statistical Analyses

Normal distribution of the variables was evaluated with Shapiro-Wilk tests. Interphase changes were compared using dependent *t*-tests or Wilcoxon tests. For dental model measurements, right and left sides were averaged and descriptive statistics were reported. All statistical analyses were performed with the SPSS software (version 25.0; IBM, Armonk, NY) and the results were considered significant at $P < .05$.

RESULTS

The ICC ranged from 0.819 to 0.992 for all cephalometric variables and ranged from 0.821 to 0.997 for the digital dental model assessment, showing good to excellent reproducibility. Bland-Altman plots confirmed the intrarater agreement (Figures 4 and 5).

The maxillary first premolar and maxillary first and second molars showed distal movement (1.21, 3.38, and 2.12 mm, respectively) and distal angulation (4.29°, 6.82°, and 8.30°, respectively; Figure 2C; Table 2). The maxillary first molar showed intrusion (0.92 mm), the overjet decreased (0.32 mm), and the molar relationship improved (4.69 mm). Results were statistically significant ($P < .05$).

Transverse changes involved lateral displacement of all maxillary teeth (range: 0.10–1.58 mm; Figure 3;

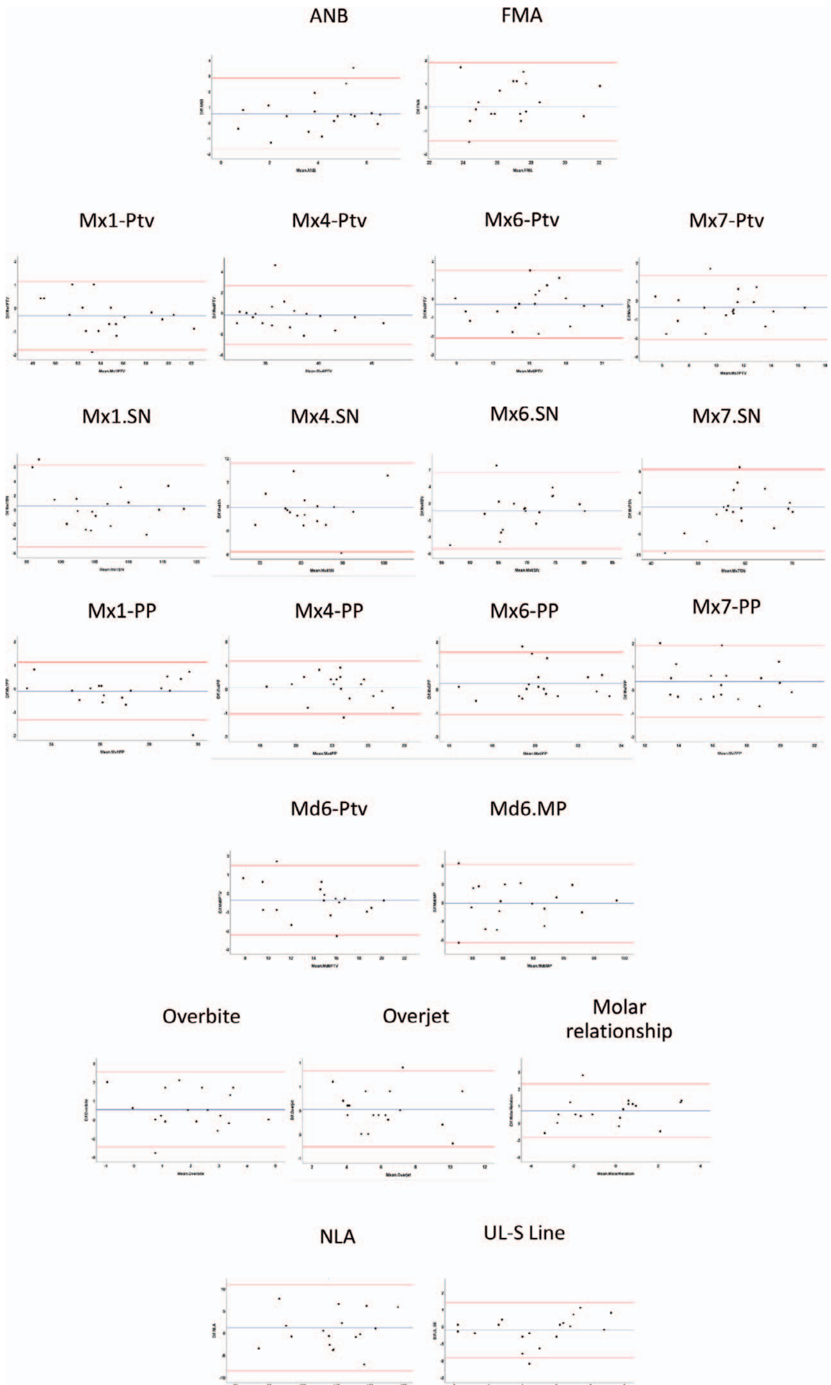

Figure 4. Bland-Altman plots for the cephalometric variables.

Table 3). The distal tooth movement was progressively greater from the lateral incisor to the molars (0.08 to 4.54 mm, respectively). First molar distalization measured at the mesiobuccal cusp was greater than the distalization measured at the mesiopalatal cusp (4.54 vs 2.61 mm). The first molar showed small intrusion (0.12 mm) when the mesiopalatal cusp was considered. The 3D movements were progressively greater from the anterior to the posterior teeth (0.91 to 4.93 mm).

The first and second molars showed distal rotation of the crown of 19.31° (±5.71°) and 10.17° (±3.84°), respectively (Table 4). Distal angulation of the maxillary first and second molar crowns was 8.80° (±3.79°) and 6.46° (±3.30°), respectively. The intermolar distance, evaluated at the mesiobuccal cusps, showed an increase of 2.63 (±1.56) mm.

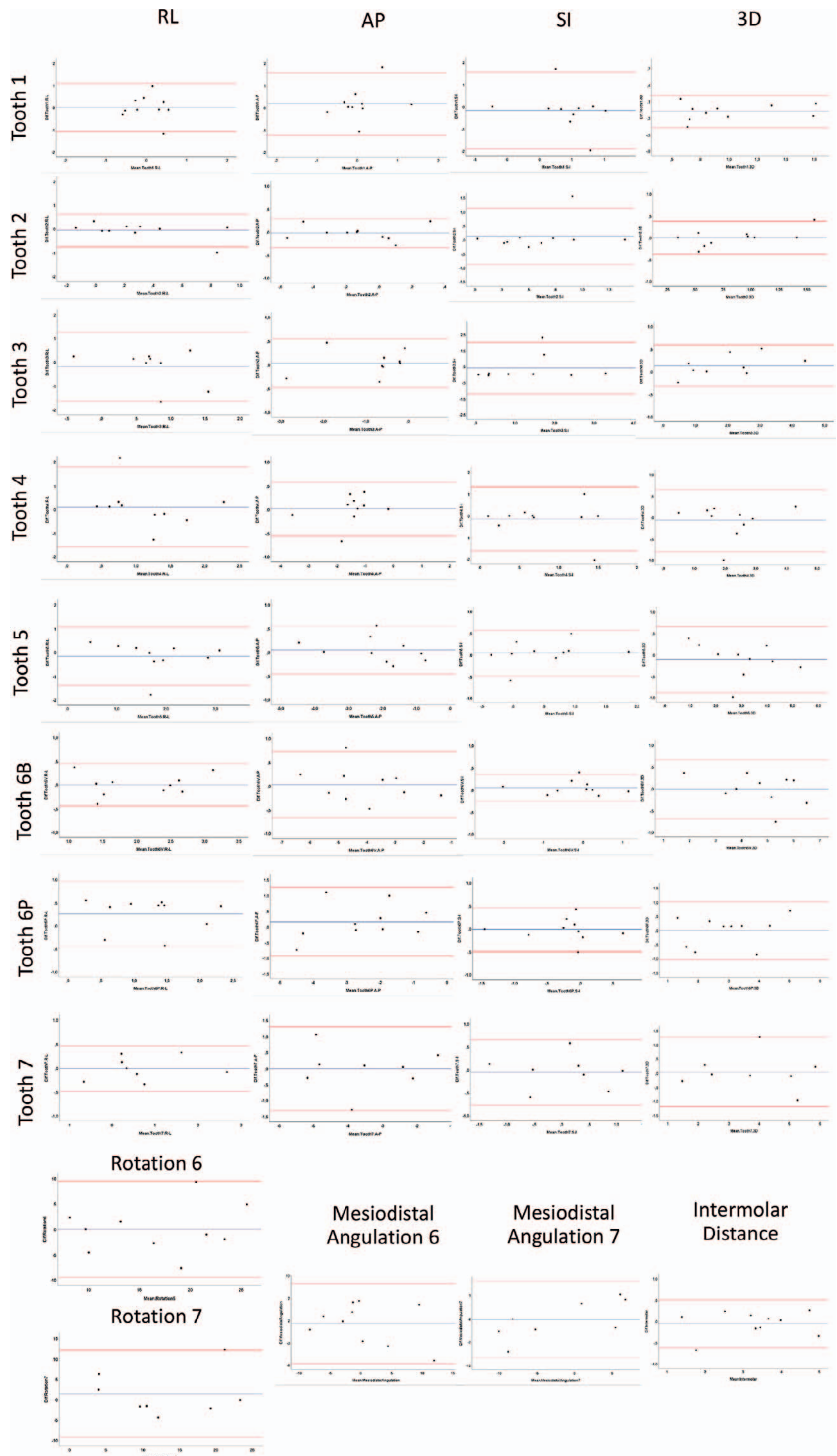

Figure 5. Bland-Altman plots for the dental model variables.

DISCUSSION

This study assessed the isolated distalization effects of the MAC and the potential movements that occurred in all teeth with no interference of other orthodontic forces. Cephalometric analysis evidenced a statistically significant distal movement of maxillary first premolars (1.21 mm), first molars (3.38 mm), and second molars (2.12 mm), without anchorage loss at the incisors (Table 2). These distalization amounts were similar to previous studies that also performed distalization with TADs, highlighting the effectiveness of this

Table 2. Initial (T1), Postdistalization (T2), and Changes (T2–T1) in Cephalometric Variables (Dependent *t*-Test or Wilcoxon Test)

Variable	T1		T2		T2-T1		95% CI		*P*
	Mean	SD	Mean	SD	Mean	SD	Lower	Upper	
Skeletal									
ANB	4.21	2.20	4.47	2.07	0.26	0.80	−0.12	0.64	.163[a]
FMA	25.81	5.14	25.25	5.22	−0.57	1.62	−1.32	0.19	.136[a]
Maxillary dentoalveolar									
Anteroposterior									
Mx1-Ptv	54.26	4.85	54.21	5.36	−0.05	1.49	−0.75	0.65	.717[b]
Mx4-Ptv	36.14	3.74	34.94	4.19	−1.21	1.61	−1.96	−0.45	.003[a,*]
Mx6-Ptv	16.29	3.50	12.91	3.51	−3.38	1.05	−3.87	−2.88	<.001[a,*]
Mx7-Ptv	11.79	2.77	9.67	2.83	−2.12	1.26	−2.71	−1.53	<.001[a,*]
Angulation									
Mx1.SN	107.38	7.72	106.37	7.94	−1.02	2.55	−2.21	0.18	.070[b]
Mx4.SN	80.45	5.21	76.16	7.10	−4.29	4.71	−6.49	−2.09	.001[a,*]
Mx6.SN	72.55	7.02	65.73	8.22	−6.82	2.93	−8.19	−5.44	<.001[a,*]
Mx7.SN	63.14	7.25	54.84	8.36	−8.30	5.88	−11.05	−5.54	<.001[a,*]
Vertical									
Mx1-PP	26.63	2.42	26.93	2.40	0.31	0.65	0.00	0.61	.049[a]
Mx4-PP	22.54	2.30	22.78	2.42	0.25	0.79	−0.13	0.62	.184[a]
Mx6-PP	20.44	2.41	19.53	2.35	−0.92	0.92	−1.34	−0.49	<.001[a,*]
Mx7-PP	15.58	3.88	15.67	3.89	0.09	1.56	−0.65	0.82	.810[a]
Mandibular dentoalveolar									
Anteroposterior									
Md6-Ptv	13.66	3.97	14.16	3.85	0.50	1.41	−0.16	1.15	.133[a]
Angulation									
Md6.MP	92.12	3.52	93.20	4.69	1.08	4.16	−0.87	3.03	.260[a]
Interdental									
Overbite	2.25	1.45	1.94	1.57	−0.31	0.91	−0.73	0.12	.151[†]
Overjet	5.79	2.05	5.47	1.85	−0.32	0.60	−0.60	−0.04	.028[†*]
Molar relationship	1.75	1.61	−2.94	1.69	−4.69	1.29	−5.29	−4.08	<.001[†*]
Soft tissue									
NLA	107.07	8.30	105.68	9.67	−1.40	5.41	−3.93	1.14	.263[a]
UL-Sline	1.19	1.25	0.95	1.64	−0.24	0.92	−0.67	0.19	.260[a]

[a] Dependent *t*-test.
[b] Wilcoxon test.
* Statistically significant at $P < .05$.

type of mechanics.[9,14,17] It could be speculated that, if greater amounts of distalization are required, the association of distalizing appliances with miniplates could be suggested for greater anchorage reinforcement and predictability.[18]

In the digital models, the first molars distalized 4.54 mm and 2.61 mm on average when the mesiobuccal and mesiopalatal cusps were used as references, respectively (Table 3). Smaller amounts of distalization were observed when the mesiopalatal cusps were considered. This was expected since this reference is less affected by the rotational effects of distalization compared with the mesiobuccal cusp, as previously suggested.[17,19] Therefore, it could be argued that part of

Table 3. Three-Dimensional Linear Displacements of Maxillary Teeth Obtained by Superimposition of Digital Dental Models[a]

Tooth	R-L				A-P				S-I				3D			
	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD
1	−0.50	0.75	0.10	0.29	−0.84	1.35	0.01	0.54	−0.69	1.17	0.50	0.47	0.38	2.07	0.98	0.41
2	−0.60	0.75	0.20	0.30	−0.55	1.34	−0.08	0.45	−0.34	1.41	0.54	0.43	0.31	1.65	0.91	0.37
3	−0.31	1.52	0.47	0.41	−2.23	0.66	−0.72	0.76	−0.07	3.36	1.31	0.95	0.51	4.11	1.81	0.99
4	0.26	2.16	1.18	0.58	−3.39	−0.05	−1.48	0.69	−0.16	1.54	0.73	0.45	1.11	4.06	2.19	0.70
5	0.55	3.03	1.58	0.72	−3.98	−0.89	−2.15	0.91	−0.47	1.95	0.51	0.58	1.29	4.83	2.87	1.06
6B	−0.66	2.44	1.29	0.83	−6.73	−2.62	−4.54	1.23	−1.94	1.44	0.15	0.75	3.17	6.79	4.93	1.12
6P	−0.97	1.89	0.62	0.85	−4.83	−0.58	−2.61	1.04	−1.30	1.08	−0.12	0.54	1.12	4.84	2.97	0.99
7	−0.98	1.70	0.53	0.86	−4.86	−2.25	−3.57	0.90	−1.66	1.53	0.22	0.79	2.42	5.24	3.81	0.94

[a] R-L indicates transversal displacement; A-P, anteroposterior displacement; S-I, vertical displacement; 1, central incisor; 2, lateral incisor; 3, canines; 4, first premolars; 5, second premolars; 6B, first molars using mesiobuccal cusps; 6P, first molars using mesiopalatal cusps; 7, second molars.

Table 4. Molar Rotation, Molar Angulation, and Intermolar Changes Observed in Superimposition of Maxillary Digital Dental Models[a]

	Min	Max	Mean	SD
Rotation				
6	9.56	32.22	19.31	5.71
7	4.59	17.04	10.17	3.84
Mesiodistal angulation				
6	−15.48	−2.96	−8.80	3.79
7	−13.21	1.17	−6.46	3.30
Intermolar distances				
6-6 T1	45.91	55.34	50.87	2.51
6-6 T2	46.86	57.97	53.50	2.69
6-6 Change	−0.31	4.87	2.63	1.56

[a] 6 indicates first molars; 7, second molars.

the overall distalization using the MAC appliance was related to molar distal rotation. In addition, the 3D changes in all teeth were mostly influenced by movement in the anteroposterior plane, as expected, because of the molar distalization force.

Some discrepancies between the cephalometric and digital model findings were observed. These differences were already expected due to the different reference points used to perform the measurements. In the lateral cephalograms, the cranial base (CB) and the pterygoid vertical line (Ptv) were used to evaluate distalization, as in previous studies,[2,3] while the palatal rugae was used as reference in the digital model assessment. Slight differences in the horizontal movements relative to the molars and premolars were observed in another study that compared dentoalveolar maxillary measurements superimposed on the CB and the maxilla.[20] Using the CB could underestimate the amount of molar distalization because of the forward movement of the maxilla that occurs with growth.[20,21]

The second premolars moved distally 2.15 mm (±0.91) following first molar distalization even in the presence of a miniscrew on the mesial side of the first molar. This distalization effect of the second premolars was reported in other distalizing appliances when these teeth were excluded from the anchorage unit.[8,17] The transeptal fibers can be considered the primary factor responsible for this beneficial effect during distalization mechanics.[5,22]

During distalization, a molar distal tipping of 6.82° (±2.93°) was observed (Table 2). This was also expected because the line of action of the force was not at the center of resistance of the molar but below. Distal tipping varying from 3° to 12° has been reported after distalization with skeletal anchorage.[4] A previous study used buccal distalizing forces without orthodontic fixed appliances and reported 6.4° (±5.4°) of distal molar angulation in cephalometric analysis,[18] similar to the present study. Even when buccal distalizing forces are delivered using miniscrews associated with fixed appliances, distal angulation between 4.8° and 7.2° was reported in the literature.[23,24] Different designs of distalizing appliances with force lines of action closer the center of resistance of the molar could reduce the amount of molar distal tipping.[22] Some minimal discrepancies in the angulation assessment of the maxillary molars between cephalometrics and dental models were observed, as expected, because different references to evaluate distal angulation were used in each analysis.

The distal tipping of the molar displaced the distal cusp upward, resulting in a slight intrusion of the molar (Tables 2 and 3). Mild molar intrusion ranging from 0.3 to 0.7 mm during distalization mechanics is commonly reported in the literature.[9,18,24] With the MAC appliance, this intrusive effect could be expected because the line of action of the force was below the center of resistance of the molar and had an apical direction after activation in some patients. Indeed, Duran et al.[25] suggested that the slight changes in the molar vertical perspective were probably a result of the distalization force direction and appliance stiffness.

Concerning the molar rotation, distalizing appliances with force application on the buccal aspect commonly cause a distal crown rotation.[5,6] That was the case for the MAC appliance, which caused 19.31° (±5.71°) of first molar distal crown rotation (Table 4). Even though rotation could be considered a side effect in some cases, most Class II malocclusion patients present with the molars mesially rotated.[1] From this perspective, distal rotation associated with buccal distalization forces can be useful for Class II correction. On the other hand, if the maxillary molars already have acceptable rotation, a buccal distalization force could worsen the molar intercuspation. In these cases, distalizing appliances with palatal or buccopalatal distalization forces could be recommended.[5,17,22]

The intermolar distance, evaluated at the mesiobuccal cusps, showed an increase of 2.63 ± 1.56 mm (Table 4). Possibly, the intermolar width increased due to the line of action of the force applied, which had a buccal force component.[14] Likewise, the distal crown rotation of the molar during distalization was partially responsible for that intermolar width increase. This effect was favorable to maintain proper transverse relationships between the maxillary and mandibular dental arches. Previous studies also found increases in dental arch width after molar distalization.[13,14] It should be pointed out that palatal distalizing appliances may exhibit less effects concerning the intermolar distance.[3,5]

The MAC appliance was significantly effective to correct the Class II molar relationship. An improvement of 4.69 (±1.29) mm was observed (Table 2). It is worth mentioning that this Class II correction was influenced minimally by growth because of the age of the patients. The mean maxillomandibular differential growth in this sample was 0.5 mm (CoGn-CoA). In addition, there was no significant correlation between the dentoalveolar anteroposterior severity and first molar distalization, angulation, and rotation ($P > .05$).

Clinically, during the distalization phase, 3 out of 40 miniscrews (7.5%) were loose; in these cases, a second miniscrew was inserted within 30 days. Overall, the appliance is simple, can be fabricated easily by the orthodontist, has a low cost, and can be adjusted to deliver a constant distalization force. However, distal angulation and distal rotation of the first molar were observed. The system allowed these movements since the vertical arm extension was not apical enough. Thus, the line of action of the force application was below the center of resistance of the tooth and had a buccal component. A transpalatal arch might be needed to counteract these effects, when necessary. This should be considered when planning molar distalization mechanics.

The lack of a control group was a limitation of the present study. Further controlled studies should be performed to confirm the results and to evaluate comprehensive treatment and stability after Class II malocclusion correction with this appliance.

CONCLUSIONS

- The miniscrew-anchored cantilever was effective for maxillary molar distalization.
- Lateral, anteroposterior, and vertical movements were observed for all maxillary teeth.
- Greater changes were observed for the anteroposterior displacement of the maxillary molars.
- Distal movement increased progressively from anterior to posterior teeth.
- The distalization system tested allowed distal angulation and rotation of the maxillary molars.

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