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Original Article

Assessment of Maxillary Molar Tooth Changes Caused by Class III Elastics in Hybrid Hyrax-Mentoplate Treatments: A Pilot Study

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Main Points

- Dental extrusion occurs in the molar teeth, even with the use of skeletal anchorage.
- The transversal width is more at apical level than coronal due to elastic usage.
- Due to mesial tipping, the molar teeth move mesially despite the skeletal anchorage.

ABSTRACT

Objective: This study aimed to investigate the positional changes of maxillary first molars in patients treated with the hybrid hyrax-mentoplate and Cl III elastics combination using cone-beam computed tomography (CBCT).

Methods: Ten patients (7 females-3 males, mean age: 11.66±0.83 years) treated with hybrid hyrax-mentoplate at Marmara University Department of Orthodontics were included. Angular and linear measurements were taken from pre-treatment and post-treatment CBCT images, and changes in maxillary first molar teeth were examined using 3D SLICER version 5.0.2 (www.slicer.org). Statistical significance was set at $p \leq 0.05$.

Results: Significant increases were observed in all distance measurements except C16p-C26p in the coronal plane, and significant decreases were observed in angular measurements only at 16mb and 26mb ($p \leq 0.05$). All measurements in the sagittal plane significantly increased compared to the vertical and horizontal reference lines ($p \leq 0.001$). Angular measurements relative to the palatal reference line significantly increased only in P-16p, P-26mb, and P-26p ($p \leq 0.05$). In skeletal measurements, significant changes were observed only in V-A, V-ANS, H-PNS, and V-PNS measurements ($p \leq 0.05$). The expansion at the apical level was significantly higher than that at the coronal level ($p \leq 0.05$). Compared to the V line, more mesial movement was observed at the coronal level than at the apical level ($p \leq 0.001$).

Conclusion: The use of Class III elastics causes greater expansion at the apical level than the coronal. Molar teeth exhibit a mesial movement, but there could be multiple contributing factors. In molars connected to Class III elastics, extrusion occurs. When vertical control is important, appropriate safety measures are advised.

Keywords: Angle Class III, orthodontic appliances, orthodontic anchorage procedures

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INTRODUCTION

Different techniques are used during the different growth and development period for the orthopedic treatment of Class III malocclusions. While the facemask appliance, whose effectiveness has been proven, is utilized in conjunction with appliances supported by maxillary teeth, orthopedic therapy procedures utilizing various intra-oral anchorage units have also gained prominence due to technological advancements.[1,2] Appliances placed on the maxilla for anchorage can be tooth-borne, bone-borne, or tooth-bone-borne.[3-5] Particularly, tooth-borne appliances cause mesial movement in the maxillary dentition with the effect of orthopedic forces.[2] However, when bone-borne anchorage units are used, this effect is very minimal or non-existent.[6,7]

Maxillary expansion is a common method to increase the effectiveness of orthopedic forces.[2,8] The hybrid hyrax appliance can be used as a maxillary anchorage unit in Class III orthopedic treatments since it can expand and become a unit of anchorage.[1] Among publications in which hybrid hyrax was used as a maxillary anchorage unit in the orthopedic treatment of Class III malocclusions, only four publications investigating maxillary molar movements were found. These studies were not only specific to upper molar movements but also examined the general effects of the technique, and while some reported significant changes in the upper molars the orhers reported insignificant changes.[1,2,4,8] Three of the studies were conducted on lateral cephalometric X-rays.[2,4,8] Two-dimensional (2D) imaging has some disadvantages such as distortion in anatomical structures and inability to mark points accurately due to overlaps in images.[9] Moreover, in the another study that uses the intraoral models for examination, the movement of the roots in three-dimensional (3D) planes was neglected.[1] However, the movements of the maxillary molar teeth in 3 planes (coronal, sagittal, and horizontal) are important for both dental and skeletal effects that may occur during orthopedic treatment and also for the dental development that will continue afterward. To the best of our knowledge, there is no study in the literature examining the movements of maxillary molars in all three planes in which a hybrid hyrax appliance was used as a skeletal anchorage unit in the maxilla in the orthopedic treatment of Class III malocclusions. Therefore, the aim of this study was to examine the movements of the maxillary molars of patients treated with the hybrid hyrax-mentoplate and Class III elastic combination in 3D using cone-beam computed tomography (CBCT) data.

METHODS

Ethical Approval and Patient Selection

This retrospective study was approved by the Marmara University Faculty of Medicine Non-Drug and Medical Device Research Ethics Committee (approval no.: 09.2024.623, date: 08.07.2024). The inclusion criteria were as follows:

- Patients treated with hybrid hyrax-mentoplate for the orthopedic correction of Class III skeletal malocclusions,
- A concave profile,
- Dental Class III molar or canine relationship,
- Overjet ≤0,
- ANB angle ≤0,
- No skeletal unit failure during treatment,

The exclusion criteria were as follows:

- Craniofacial deformity, growth disorder, or hormonal disorder,
- Missing files, routine records, or CBCT data,
- Non-cooperative patients.

Considering these criteria, the data of 10 patients (7 females and 3 males, mean age: 11.66±0.83 years) were retrieved from the archive of Marmara University Faculty of Dentistry, Department of Orthodontics and included in the study. All included patients have an informed consent form in their files.

Treatment Protocol

Based on data gathered from patient files, two miniscrews with a diameter of 1.7 mm and a length of 8 mm (OrthoEasy® Pal Forestadent®, Bernhard Foerster GmbH, Pforzheim, Germany) were placed on both sides of the midpalatal suture, near the level of the third rugae.[10] To create a hybrid hyrax appliance, an alginate impression (Alginate, Tropicalgin, Zhermack, Rovigo, Italy) was taken following the insertion of two orthodontic bands for maxillary first molars and abutments for palatal screws. Two fixation screws were used to secure the hybrid hyrax appliance in the mouth. A mucoperiosteal flap was elevated to place the mentoplates (ANCOR Orthodontics, Ankara, Türkiye). The same surgeon positioned the mentoplates at the anterior symphysis while administering a local anesthetic and fastened them with three screws.

The parents or the legal guardians of the patients performed a week of rapid maxillary expansion (RME) using the hybrid hyrax appliance, turning the screws 0.5 mm each day (1/4 turn in the morning and 1/4 turn in the evening). After RME, bilateral intermaxillary Class III elastics with 200-250 grams on each side between the hooks of the mentoplates and the molar bands of the hybrid hyrax were used to obtain an orthopedic response. When a dental Class II canine relationship was achieved, positive overjet was gained, and the desired change in the profile was obtained, the active treatment was terminated (8.2±1.7 months on average) (Figure 1).

Data Collection and Method of Measurements

Lateral cephalograms were taken both before (T0) and after therapy (T1), based on the data obtained from the patient files. All lateral cephalograms were traced using the NemoStudio

Figure 1. Intraoral photos of one of the patients included in this study were taken from the archive. A) Initial right side. B) Initial frontal side. C) Initial left side. D) Final right side. E) Final frontal side. F) Final left side

NX-Pro software v.10.4.2 (Nemotec, Madrid, Spain) in order to assess the effectiveness of the treatment. With reference to each patient's Sella-Nasion length, the calibration of lateral cephalograms at the two time points was further established.

CBCT scans were performed both before the miniscrew and Mentoplate placement (T0) and after (T1) the active treatment by using an Imtec Iluma Imaging Machine (3M, Ardmore, OK, USA; X-ray tube voltage: 120 kV; X-ray tube current: 1-4 mA; scanning time: 40 seconds maximum and 7.8 seconds minimum; field of view: 14.2×21.1 cm; voxel size: 0.0936 mm; grayscale: 14 bit). During both imaging times, the patients were seated in an upright position with the Frankfurt horizontal plane parallel to the floor. The 3D SLICER version 5.0.2 program was used to examine skeletal and dental alterations (www.slicer.org).[11] All CBCT images were reoriented by arranging midsagittal, Frankfort horizontal, and transporionic planes to match with sagittal, axial, and coronal planes which were embedded in the software, respectively.[12] After head reorientation, 3D models were constructed, and on the CBCT slices and 3D models, bony and dental points were marked and verified (Table 1, Figure 2). The "Slicer CMF" extension was used to create midpoints and perform measurements, and the "Volume Rendering" tool was used to mark intraosseous landmarks.

Statistical Analysis

The IBM SPSS Statistics (version 23, IBM Corp, Armonk, NY) software was used for statistical analyses. To evaluate the overall power of the study, a post-hoc power analysis was carried out. The conformity of the parameters to normal distribution was determined using the Shapiro-Wilk test. The normally distributed data and the non-normally distributed data were compared between time points using paired samples t-tests and Wilcoxon signed-rank tests, respectively. To compare the mean values of two different measurement groups, Independent Samples t-test was used. Intra-examiner reliability was assessed based on the intraclass correlation coefficient (ICC). Statistical significance was set at $p<0.05$.

Table 1. Definition of landmarks and measurements	
Abbreviation	Definition
	Reference Lines
H	Horizontal Reference Line: The line passing through the midpoint of Porions and midpoint of Orbitales
V	Vertical Reference Line: The line passing through the midpoint of Porions and bone projection on the superoinferior coordinate line according to the coordinate data of the midpoint of Porions
T	Transverse Reference Line: The line passing through the right and left Porions
P	Palatal Reference Line: The line passing through the ANS and PNS
	Dental Points
C	Coronal Points
A	Apical Points
C16db	Top of the distobuccal cusp of the maxillary right first molar
C16mb	Top of the mesiobuccal cusp of the maxillary right first molar
C16p	The projection of the midpoint of palatal cusps at palatal groove of the maxillary right first molar
A16db	Apex of distobuccal root of maxillary right first molar
A16mb	Apex of mesiobuccal root of maxillary right first molar
A16p	Apex of palatal root of maxillary right first molar
C26db	Top of the distobuccal cusp of the maxillary left first molar
C26mb	Top of the mesiobuccal cusp of the maxillary left first molar
C26p	The projection of the midpoint of palatal cusps at palatal groove of the maxillary left first molar
A26mb	Apex of mesiobuccal root of maxillary left first molar
A26db	Apex of distobuccal root of maxillary left first molar
A26p	Apex of palatal root of maxillary left first molar
	Measurements
C16db-C26db (mm)	3D distance between C16db and C26db
C16mb-C26mb (mm)	3D distance between C16mb and C26mb
C16p-C26p (mm)	3D distance between C16p and C26p
A16db-A26db (mm)	3D distance between A16db and C26db
A16mb-A26mb (mm)	3D distance between A16mb and C26mb
A16p-A26p (mm)	3D distance between A16p and C26p
16db (°)	The roll angle between the line that connects the A16db and C16db and the line and T line
16mb (°)	The roll angle between the line that connects the A16mb and C16mb and T line
16p (°)	The roll angle between the line that connects the A16p and C16p and T line
26db (°)	The roll angle between the line that connects theA26db and C26db and T line
26mb (°)	The roll angle between the line that connects theA26mb and C26mb and T line
26p (°)	The roll angle between the line that connects theA26p and C26p and T line
V-C16db (mm)	The anteroposterior component of the distance from the C16db to the V line
V-C16mb (mm)	The anteroposterior component of the distance from the C16mb to the V line
V-C16p (mm)	The anteroposterior component of the distance from the C16p to the V line
V-A16db (mm)	The anteroposterior component of the distance from the A16db to the V line
V-A16mb (mm)	The anteroposterior component of the distance from the A16mb to the V line
V-A16p (mm)	The anteroposterior component of the distance from the A16p to the V line
V-C26db (mm)	The anteroposterior component of the distance from the C26db to the V line
V-C26mb (mm)	The anteroposterior component of the distance from the C26mb to the V line
V-C26p (mm)	The anteroposterior component of the distance from the C26p to the V line
V-A26db (mm)	The anteroposterior component of the distance from the A26db to the V line
V-A26mb (mm)	The anteroposterior component of the distance from the C26mb to the V line

Table 1. Continued	
Abbreviation	**Definition**
	Measurements
V-A26p (mm)	The anteroposterior component of the distance from the C26p to the V line
V-16db (°)	The pitch angle between the V line and the line that connects the A16db and C16db
V-16mb (°)	The pitch angle between the V line and the line that connects the A16mb and C16mb
V-16p (°)	The pitch angle between the V line and the line that connects the A16p and C16p
V-26db (°)	The pitch angle between the V line and the line that connects the A26db and C26db
V-26mb (°)	The pitch angle between the V line and the line that connects the A26mb and C26mb
V-26p (°)	The pitch angle between the V line and the line that connects the A26p and C26p
H-C16db (mm)	The superoinferior component of the distance from the C16db to the H line
H-C16mb (mm)	The superoinferior component of the distance from the C16mb to the H line
H-C16p (mm)	The superoinferior component of the distance from the C16p to the H line
H-A16db (mm)	The superoinferior component of the distance from the A16db to the H line
H-A16mb (mm)	The superoinferior component of the distance from the A16mb to the H line
H-A16p (mm)	The superoinferior component of the distance from the A16p to the H line
H-C26db (mm)	The superoinferior component of the distance from the C26db to the H line
H-C26mb (mm)	The superoinferior component of the distance from the C26mb to the H line
H-C26p (mm)	The superoinferior component of the distance from the C26p to the H line
H-A26db (mm)	The superoinferior component of the distance from the A26db to the H line
H-A26mb (mm)	The superoinferior component of the distance from the A26mb to the H line
H-A26p (mm)	The superoinferior component of the distance from the A26p to the H line
P-16db (°)	The pitch angle between the P line and the line that connects the A16db and C16db
P-16mb (°)	The pitch angle between the P line and the line that connects the A16mb and C16mb
P-16p (°)	The pitch angle between the P line and the line that connects the A16p and C16p
P-26db (°)	The pitch angle between the P line and the line that connects the A26db and C26db
P-26mb (°)	The pitch angle between the P line and the line that connects the A26mb and C26mb
P-26p (°)	The pitch angle between the P line and the line that connects the A26p and A26p
H -A (mm)	The superoinferior component of the distance from the A point to the H line
V-A (mm)	The anteroposterior component of the distance from the A point to the V line
H-ANS (mm)	The superoinferior component of the distance from the ANS point to the H line
V-ANS (mm)	The anteroposterior component of the distance from the ANS point to the V line
H-PNS (mm)	The superoinferior component of the distance from the PNS point to the H line
V-PNS (mm)	The anteroposterior component of the distance from the PNS point to the V line
H-P (°)	The pitch angle between the H line and the P line

RESULTS

ICC values of all measurements were found to be close to 1.00 (range= 0.958-0.991), indicating that all the skeletal and dental measurements could be repeated with an insignificant error that had no bearing on the outcomes. Based on the variable V-C16db (mm), the post-hoc power calculation showed a 99% power of the sample to represent the population, as well as an effect size of d=1.6 at α=0.05.

When lateral cephalometric values were examined, significant increases in SNA, ANB, IMPA and overjet values and a significant decrease in SN-GoMe were observed (p=0.004, p=0.001, p=0.001, p=0.000 and p=0.029, respectively) (Table 2).

For molar movement evaluation on CBCT, the paired sample t-test showed significant increases in all linear measurements in the coronal plane (p<0.05), except for the C16p-C26p values (p=0.119) (Table 3). The angular measurements in the coronal plane showed significant decreases in the 16mb and 26mb values (p=0.043 and p=0.001, respectively) (Table 3). There were significant increases in the distances of the dental points to the vertical reference line (V line) and the horizontal

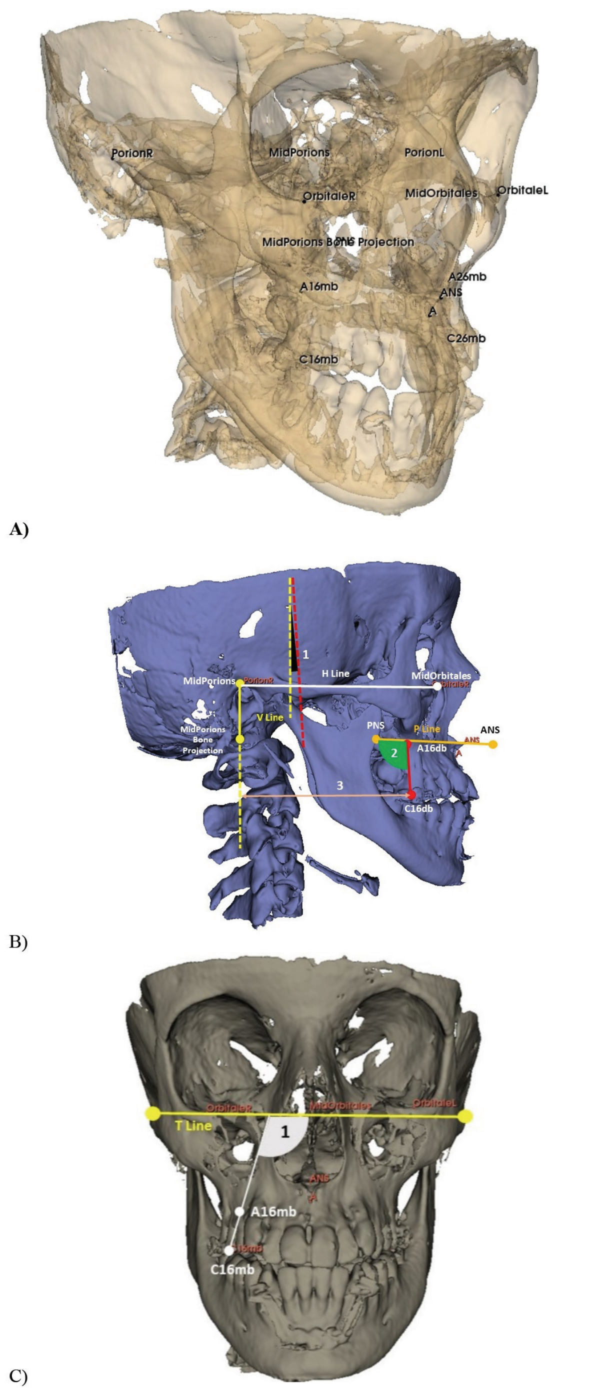

Figure 2. A) Points marked on the three dimensional head model B) Schematization of measurements and some reference lines. 1: V-16db (°), 2: P-16db (°), 3: V-C16db (mm). C) Schematization of measurements and T line from frontal view. 1: 16db (°)

reference line (H line) measured in millimeters in the sagittal plane (p≤0.001) (Table 3). Significant increases were found in all angular measurements made in the sagittal plane compared to the V line (p<0.05) (Table 3). In the angular measurements performed in the sagittal plane relative to the palatal reference line (P line), significant increases were observed in the P-16p, P-26mb, and P-26 p-values (p=0.002, p=0.007, and p=0.025, respectively) (Table 3). The skeletal measurement results showed significant increases in terms of the V-A, V-ANS, and V-PNS values (p=0.000, p=0.000, and p=0.005, respectively) (Table 3).

To evaluate expansion difference at the coronal and apical level, an independent samples t-test was performed on the millimetric measurements made at the coronal plane. A significant difference was found between the values at the coronal level and those at the apical level, and higher values were found at the apical level (p=0.021) (Table 4). To interpret differences in sagittal movements at the coronal and apical levels, an independent samples t-test was performed between the V-C and V-A (mm) results, and there was a significant difference in favor of the C points (p=0.000) (Table 4). A paired samples t-test was applied to determine whether the movements at the apical and coronal levels relative to the H line were due to dental extrusion or skeletal movement (Table 4).

DISCUSSION

Mesialization of the maxillary posterior teeth and resultant incisor proclination, or lack of space for permanent canines, are among the most frequently encountered side effects of facemask treatment.[3] Class III orthopedic treatments using skeletal anchorage units are preferred particularly because they reduce dental side effects.[8] Although no clear consensus has been reached in the literature about the movement of maxillary molar teeth, the hybrid hyrax appliance is deemed safe for clinical usage because it is supposed to reduce these negative effects by keeping the maxillary molar teeth in their original positions. Therefore, our study aimed to examine the movement of maxillary molar teeth in patients treated with hybrid hyrax-Mentoplate appliances. There are not many publications in the literature discussing the movement of maxillary molar teeth and also most of these have been made based on intraoral models and lateral cephalometric X-rays.[1,2,4,8] CBCT data of patients were used in our study to examine the crown and root movements and minimize errors caused by superimposition or magnification in 2D images. Thus, this is the first study to examine the molar movement in 3D according to the authors' knowledge.

For the evaluation of the cephalometric analysis aimed for the efficiency of the treatment for individuals in the study group, SNA and ANB angles increased but the SNB angle remained same.[5,13-15] Once more, the overbite showed little change, but the overjet showed a notable increase.[5,13-15] These findings are consistent with related research in the literature. The SN-GoMe value decreased, while comparable investigations found no change in contrast to our findings.[5,13-15] This discrepancy could be caused by variations in study groups and methodologies. As reported in similar studies, no change was found UI-SN angle, but a significant increase was observed in IMPA in this study.[5,13-15] Şar et al.[16] explained this situation by the elimination of lip pressure by the hooks of the plates applied to the anterior mandible region.

Table 2. Cephalometric values of the study sample before and after treatment

	T0			T1			ΔT1-T0			
	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	p
SN-GoMe (°)	41.10	40.50	1.85	39.70	40.00	2.16	-1.40	-1.50	1.71	0.029^{a*}
SNA (°)	75.90	76.50	3.00	79.20	79.50	3.91	3.30	2.00	2.71	0.004^{a**}
SNB (°)	78.80	79.00	2.74	78.50	78.00	2.72	-0.30	-0.50	1.64	0.576^{a}
ANB (°)	-2.80	-2.00	1.99	0.50	0.50	2.01	3.30	3.00	2.06	0.001^{a**}
UI-SN (°)	107.40	108.00	4.58	109.50	109.00	5.42	2.10	1.00	5.30	0.242^{a}
IMPA (°)	80.00	80.00	5.16	87.20	88.00	3.01	7.20	7.00	4.89	0.001^{a**}
Overjet (mm)	-0.24	0.10	1.12	2.59	2.55	1.15	2.83	2.85	1.37	0.000^{a***}
Overbite (mm)	0.80	0.05	1.62	0.52	-0.05	1.56	-0.28	-0.15	0.97	0.327^{b}

$^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$; ^{a}Paired samples t-test, ^{b}Wilcoxon signed-rank tests
SD: Standard deviation

Table 3. Changes in measured parameters over time

		T0			T1			Δ T1-T0		
		n	Mean	SD	n	Mean	SD	Mean	SD	p
CORONAL PLANE	C16db -C26db (mm)	10	53.24	2.46	10	55.45	2.87	1.03	1.25	0.000***†
	C16mb-C26mb (mm)	10	50.32	2.16	10	51.35	2.72	2.21	1.04	0.029*†
	C16p-C26p (mm)	10	42.26	2.8	10	43.8	2.89	1.53	2.82	0.119†
	A16db-A26db (mm)	10	49.65	3.3	10	52.13	3.95	2.49	1.38	0.000***†
	A16mb-A26mb (mm)	10	47.29	3.53	10	49.73	3.73	2.44	1.21	0.000***†
	A16p-A26p (mm)	10	32.02	3.06	10	34.84	3.16	2.82	1.4	0.000***†
	16db (°)	10	93.66	6.02	10	92.96	7.36	-0.71	2.67	0.425†
	16mb (°)	10	93.18	7.15	10	90.68	5.66	-2.5	3.36	0.043*†
	16p (°)	10	103.49	6.22	10	102.71	4.38	-0.78	3.31	0.473†
	26db (°)	10	97.92	6.58	10	97.34	7.59	-0.59	2.62	0.495†
	26mb (°)	10	96.93	5.98	10	94.79	5.99	-2.14	1.29	0.001***†
	26p (°)	10	106.51	5.31	10	105.29	6.56	-1.21	3.3	0.275†
SAGITTAL PLANE	V-C16db (mm)	10	53.64	3.34	10	59.67	4.63	6.04	3.75	0.001***†
	V-C16mb (mm)	10	58	3.45	10	64.14	4.62	6.14	3.41	0.000***†
	V-C16p (mm)	10	51.86	3.57	10	58.88	4.58	7.02	3.17	0.000***†
	V-A16db (mm)	10	56.94	3.7	10	61.24	3.46	4.3	1.82	0.000***†
	V-A16mb (mm)	10	59.41	3.56	10	63.81	3.26	4.4	1.75	0.000***†
	V-A16p (mm)	10	54.59	3.99	10	58.74	3.63	4.15	1.92	0.000***†
	V-C26db (mm)	10	54.07	3.36	10	59.68	4.14	5.61	3.06	0.000***†
	V-C26mb (mm)	10	58.37	3.43	10	64.07	4.56	5.7	2.85	0.000***†
	V-C26p (mm)	10	52.31	3.35	10	58.6	4.59	6.29	3.26	0.000***†
	V-A26db (mm)	10	57.19	4.26	10	61.17	3.8	3.98	1.89	0.000***†
	V-A26mb (mm)	10	59.85	3.96	10	63.93	3.78	4.07	1.93	0.000***†
	V-A26p (mm)	10	55.1	4.07	10	59.19	3.35	4.09	1.79	0.000***†
	V -16db (°)	10	-10.23	5.55	10	-4.85	6.95	5.38	6.81	0.034*†
	V-16mb (°)	10	-4.6	5.97	10	0.62	6.86	5.22	6.05	0.023*†
	V-16p (°)	10	-8.53	6.37	10	0.19	7.44	8.73	5.65	0.001***†
	V-26db (°)	10	-9.8	4.98	10	-4.61	5.75	5.19	6.57	0.034*†
	V-26mb (°)	10	-4.49	6.61	10	0.41	8.34	4.91	5.68	0.023*†
	V-26p (°)	10	-8.85	3.01	10	-1.98	6.8	6.88	6.6	0.009**†

Table 3. Continued

		T0			T1			Δ T1-T0		
		n	Mean	SD	n	Mean	SD	Mean	SD	p
SAGITTAL PLANE	H -C16db (mm)	10	40.68	1.87	10	43.51	2.16	2.83	1.94	0.001***†
	H-C16mb (mm)	10	41.55	1.69	10	43.89	1.9	2.34	1.54	0.001***†
	H-C16p (mm)	10	40.94	1.54	10	43.9	2.04	2.95	1.19	0.000***†
	H-A16db (mm)	10	22.18	2.12	10	24.63	2.62	2.44	1.61	0.001***†
	H-A16mb (mm)	10	22.76	1.88	10	24.82	2.12	2.06	1.26	0.001***†
	H-A16p (mm)	10	22.37	1.91	10	25.1	2.59	2.73	1.52	0.000***†
	H-C26db (mm)	10	40.07	1.53	10	42.51	2.26	2.43	0.98	0.000***†
	H-C26mb (mm)	10	41.15	1.56	10	43.13	1.93	1.98	0.92	0.000***†
	H-C26p (mm)	10	40.45	1.65	10	42.63	2.3	2.18	1.35	0.001***†
	H-A26db (mm)	10	21.84	2.32	10	23.9	3.06	2.06	1.28	0.001***†
	H-A26mb (mm)	10	22.69	2.16	10	24.59	2.61	1.89	0.96	0.000***†
	H-A26p (mm)	10	22.35	2.57	10	24.54	2.97	2.18	1.48	0.001***†
	P -16db (°)	10	81.78	4.29	10	85.73	5.74	3.95	6.41	0.74‡
	P-16mb (°)	10	87.41	4.66	10	91.49	5.43	4.09	5.74	0.051†
	P-16p (°)	10	83.47	4.86	10	91	6.18	7.53	5.38	0.002**†
	P-26db (°)	10	82.22	4.95	10	85.52	3.68	3.29	5.19	0.076†
	P-26mb (°)	10	85.31	4.84	10	90.92	6.93	5.61	5.11	0.007**†
	P-26p (°)	10	83.15	2.76	10	88.34	5.09	5.19	6.11	0.025*†
SKELETAL MEASUREMENTS	H -A (mm)	10	27.9	1.39	10	27.86	1.57	-0.04	1.52	0.93†
	V-A (mm)	10	83.09	4.27	10	86.42	4.19	3.33	1.55	0.000***†
	H-ANS (mm)	10	20.63	2.13	10	20.77	2.36	0.14	0.79	0.584†
	V-ANS (mm)	10	88.08	4.01	10	90.83	4.68	2.75	1.15	0.000***†
	H-PNS (mm)	10	19.38	1.44	10	20.54	1.81	1.16	1.32	0.022*†
	V-PNS (mm)	10	39.17	4.8	10	41.04	4.43	1.87	1.26	0.005‡
	H-P (°)	10	1.54	1.88	10	0.23	2.63	-1.31	1.9	0.057†

†Paired samples t-test, ‡Wilcoxon signed-rank tests, *p≤0.05, **p≤0.01, ***p≤0.001
SD, standard deviation; mm, millimeters; °, degree

Table 4. Evaluation of alterations at the coronal and apical level

		Mean	SD	p
Expansion	A	2.58	1.29	0.021*
	C	1.59	1.88	
V-mm	A	3.60	2.10	0.000**
	C	6.13	3.16	
H-mm	A	2.23	1.34	0.246
	C	2.45	1.35	

p-values for Independent Samples t-test
*p≤0.05, **p≤0.001
SD: Standard deviation, mm: millimeters

When molar movements are examined via CBCT, except for the C16p-C26 p-values, there were significant increases in all distance measurements as a result of 1 week of RME. 2.58 mm of increase at the apical level and 1.59 mm of increase at the coronal level were observed, with a significant difference between them. Consistent with these results, all angular measurements on the coronal plane decreased, although this decrease was statistically significant for only two of these measurements. Contrary to studies in the literature examining the amount of expansion at the apical and coronal levels, in this study, the amount of expansion at the apical level was found to be greater than that at the coronal level.[17,18] Since it is known that RME can affect the circummaxillary and midpalatal sutures, the palatal bone halves may have been inclined inwardly by the Class III elastic force vector that was applied throughout the time needed for the recalcification of the sutures following expansion.[19] This can also explain the reduction in angular measurements examined in the coronal plane. Further research is necessary to determine why this change is greater at the apical level than at the coronal level.

There are a limited number of studies in the literature examining maxillary molar movement after force application in the orthopedic treatment of Class III malocclusions with skeletal anchorage support. In our study, the angles of the maxillary first molars relative to the V line for each cusp were found to be significantly increased after the treatment. Compared to the V line, the amount of mesial movement increased significantly at both the coronal and apical levels, while the degree of increase was higher at the coronal level. Therefore, an increase in angles compared to the V line is expected. In this study, considering the 3.33 mm forward movement of point A relative to the V line, the degree of maxillary molar movement was found to be 2.8 mm at the coronal level and 0.27 mm at the apical level. The angles measured relative to the P line, a significant change was observed in some measurements, but not in all of them. It was found that the P line made a slight anterior rotation compared to the H line, although this change was not significant. In light of all this information, the increase in angular measurements and the almost complete absence of mesial movement at the apical level can be attributed to two reasons: the slight anterior rotation in the palatal line may have masked the mesial movement of the molar at the apical level, or as stated in previous studies, the wire may have been bent due to elastic forces.[2]

Wilmes et al.[1] examined the mesial movement of maxillary molar teeth on intraoral models of 10 patients to whom hybrid hyrax-facemasks were applied. They reported that during the facemask treatment, mesial movements of 0.4 mm for the maxillary first right molar and 0.3 mm for the maxillary first left occurred.[1] Although there were individuals with a similar mean age and similar characteristics to those in our study, variations in treatment methods or intermaxillary elastic strengths could account for the difference between the study conducted by Wilmes et al.[1] and this study. Wilmes et al.[1] used 5 oz 1/4 inch elastics during treatment. Over time, the decrease in the strength of elastics as the maxilla comes forward may have caused a decrease in the mesial movement of the molar teeth. Tarraf et al.[5] also examined individuals treated with the same technique as in this study, reported mesial tipping in the maxillary molars, and attributed the result to bending in the wire.

Nienkemper et al.[8] examined the effects of a hybrid hyrax-facemask combination on 16 individuals with a mean age of 9.5 on lateral cephalometric X-rays and reported a statistically insignificant mesial movement of 0.4 mm relative to point A in the maxillary molar teeth. Although the treatment period was shorter than the one in this study, the predominance of the skeletal effect of the orthopedic forces (400 gr on each side) due to the younger mean age may be the reason for the lack of a significant movement in the molars.[3]

Ngan et al.[2] reported 0.6 mm of mesial movement in maxillary molars in individuals with a mean age of 9.8 years, whom they treated with hybrid hyrax-facemasks, and they attributed the result to the bending in the wire. It is thought that the results of other studies were lower than those in our study due to the dominance of the skeletal effect brought about by the mean ages of the included patients.[3,8]

Miranda et al.[4] performed skeletal Class III orthopedic treatments with hybrid hyrax with Miniscrew Anchored Maxillary Protraction (MAMP) protocol, and they reported 1.96 mm of mesial movement in the maxillary molars. The fact that the elastic forces in this study were smaller than those in similar studies mentioned before, and the mean age of the patients in this study was smaller than the aforementioned previous study may be the reason for the differences in our results.[4]

Considering the results of the aforementioned studies and the results we obtained in our study, factors such as age and orthopedic strength may affect the sagittal movement of molar teeth. To minimize this effect, we recommend the use of more rigid appliances, and since there are some publications regarding the drift of miniscrews under orthodontic and orthopedic forces, the effects of miniscrews under orthopedic force should also be examined.[20-22] Without analyzing miniscrew movements, it is impossible to pinpoint the exact reason for this, even though bending in the appliance or palatal plane rotation may contribute to concealing it.

While the results of the present study did not show a significant change at point A relative to the H line, the Independent Samples t-test showed a significant extrusion at both the apical (2.23 mm) and coronal (2.45 mm) levels in all teeth. In a previous study of Yıldırım et al.[13], they also reported a significant extrusion in maxillary molar teeth, and the degree of this extrusion was higher than that in this study. The small number of patients in that study may be the cause of the higher degree of molar extrusion.[13] Kamel et al.[23] applied the MAMP with Alternate RME and Constriction protocol to individuals with a mean age of 11 and reported 1.43 mm of extrusion, which was smaller than the value in our results. Methodological differences and the fact that the elastic force used by the authors was smaller than that in this study may be the reason for this difference. In light of these findings, even if there is skeletal anchorage support, the bending in the wire of the anchorage device, the movements of the miniscrews, and in addition to these, the vector of the elastic force should be taken into consideration. In cases where extrusion is undesirable, precautions may need to be taken for vertical control.

In the skeletal measurements, no significant change was observed in the H-P values. The fact that there was no change at point A in the supero-inferior direction according to the H-A measurements supported this result. Upon reviewing research with a similar methodology to that in this study, although Yıldırım et al.[13] and the study conducted by Willman et al.[15] revealed results supporting this study, Katyal et al.[14] reported a statistically significant but clinically insignificant anterior rotation of 0.8°. In terms of the sagittal movement of point A, Willmann et al.[15] reported a forward movement value of 2.67 mm, and Tarraf et al.[5] found a value of 4.06 mm. Even though the age group covered by Willmann et al.[15] was younger than the one in this study, the elastic force in their study was smaller, explaining why they reported less movement than that in this study. The reason why Tarraf et al.[5] reported more sagittal movement than us at point A may be the longer treatment duration in their study compared to the one in this study.

Study Limitations

The lack of a control group, small sample size, and the inability to evaluate changes after the long-term follow-up of treated patients can be considered as limitations. In addition, the increased vertical growth direction of the individuals in this study group can be considered as a limitation. It is thought that the inclusion of individuals with different vertical growth patterns and a control group with long-term follow-up results in future studies may also contribute to the literature.

CONCLUSION

According to the results of the present study, the use of Class III intermaxillary elastics may affect the transverse width of the maxilla at both the coronal and apical levels, in favor of the apical level due to immature bone in the midpalatal suture after expansion. Examined on the sagittal plane, the molar teeth exhibit clear mesial movement due to mesial tipping. In this treatment technique, dental extrusion occurs in the molar teeth despite the usage of skeletal anchorage. However, considering that this study is a pilot study, caution should be taken in interpreting the results.

Ethics

Ethics Committee Approval: The study was approved by the Marmara University Faculty of Medicine Non-Drug and Medical Device Research Ethics Committee (approval no.: 09.2024.623, date: 08.07.2024).

Informed Consent: All included patients have an informed consent form in their files.

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Footnotes

Author Contributions: Concept - G.Y., E.O.O.; Design - G.Y., E.O.O.; Data Collecting and Processing - G.Y.; Analysis or Interpretation - G.Y., E.O.O.; Literature Search - G.Y., E.O.O.; Writing - G.Y., E.O.O.

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