applied sciences

MDPI

Article

Long-term CBCT evaluation of mandibular third molar changes after distalization in adolescents

Hye-Rim Hong [1], Nam-Ki Lee [2], Jae Hyun Park [3], Ja Hyeong Ku [4], Jaehyun Kim [4], Mohamed Bayome [5], Sung-Seo Mo. [6] and Yoon-Ah Kook [4,*]

[1] Graduate School of Clinical Dental Science, Catholic University of Korea, Seoul, Korea. asteria0402@naver.com
[2] Professor, Department of Orthodontics, Section of Dentistry, Seoul National University Bundang Hospital, Seongnam, Gyeonggi Province, Republic of Korea. ortho0328@naver.com
[3] Professor and chair, Postgraduate Orthodontic Program, Arizona School of Dentistry & Oral Health, A.T. Still University, Mesa, AZ, International Scholar, Graduate School of Dentistry, Kyung Hee University, Seoul, Korea, jpark@atsu.edu
[4] Resident, Department of Orthodontics, Seoul St. Mary's Hospital, College of Medicine, Catholic University of Korea, Seoul, Korea, ttcforlogan@gmail.com (J. H. K.); skiboy90@naver.com (J.K.); kook2002@catholic.ac.kr (Y.-A. K.)
[5] Department of Preventive Dentistry, College of Dentistry, King Faisal University, Alhufuf, Saudi Arabia, Department of Postgraduate Studies, Universidad Autonóma del Paraguay, Asunción, Paraguay, mac_kral@hotmail.com
[6] Professor, Department of Orthodontics, Yeouido St. Mary's Hospital, The Catholic University of Korea, Seoul, Korea, dmoss@catholic.ac.kr
* Correspondence: Yoon-Ah Kook, Kook, Department of Orthodontics, Seoul St. Mary's Hospital, Catholic University of Korea, 505 Banpo-Dong, Seocho-Gu, Seoul, 137-701, Korea; e-mail: kook2002@catholic.ac.kr; Tel: +82 2 2258 1776

Hong Hye-Rim and Nam-Ki Lee authors contributed equally to this work

Citation: Lastname, F.; Lastname, F.; Lastname, F. Title. *Appl. Sci.* **2021**, *11*, x. https://doi.org/10.3390/xxxxx

Academic Editor: Firstname Lastname

Received: date
Accepted: date
Published: date

Abstract: Introduction: This study aimed to evaluate the mandibular molar changes after distalization using Class III elastics and modified C-palatal plates (MCPPs) in the maxilla and to use CBCT to specifically analyze the third molar position after long-term retention in adolescents. Methods: The sample consisted of 65 mandibular third molars in 35 subjects divided into two groups. Twenty-six of third molars were in 14 adolescent Class I bimaxillary protrusion patients (mean age, 12.8 years) who had undergone bilateral maxillary distalization using an MCPP and mandibular distalization with Class III elastics by nonextraction treatment. For control group, 39 third molars in 21 Class I normal occlusion subjects were used. In treated group, CBCT images were taken before distalization (T1) after molar distalization (T2) and at a long-term observation point (6.1 ± 2.7 years) (T3). Repeated measures MANOVA and post hoc test with the Bonferroni correction were used to analyze significant differences in positions at the three points in time. Results: There were 2.3 and 1.7 mm of distal movement at the crown of mandibular first and second molars with distal tipping of 5.2° and 5.3° respectively and 3.0° of distal tipping of the third molars. Comparing the treated group with the control group at T3, there was a significant change in the angulation of the third molars ($P < 0.001$). In the long-term, third molars of treated group showed a downward and buccal position after distalization. Conclusions: In the long term, the developing mandibular third molar buds had downward and buccal positional changes after total arch distalization. These findings suggest the need for clinicians to consider the possibility of impaction of developing third molars after mandibular total arch distalization in adolescents.

Keywords : distalization; mandibular molars; temporary skeletal anchorage devices

1. Introduction

Bimaxillary dentoalveolar protrusion is characterized by flaring of the anterior teeth and facial convexity. The retraction of anterior teeth after premolar extractions has been the standard orthodontic approach to reduce facial convexity [1,2].

Currently, however, temporary skeletal anchorage devices (TSADs) have become an important modality of orthodontics, reducing the need for extraction while allowing for distalization of the maxillary dentition [3-5].

A promising nonextraction treatment modality to consider for correction of bimaxillary protrusion is molar distalization. To reduce bimaxillary protrusion, maxillary molar distalization should be performed concurrently with mandibular molar distalization.

Oh et al. [4] reported that with microimplant-aided sliding mechanics, crowding could be resolved while improving facial esthetics through retracting the lips with distalization of maxillary and mandibular posterior teeth without extraction. Chen et al. [6] demonstrated a novel technique to treat bimaxillary protrusion using miniscrews to extract just an impacted third molar without extraction of the premolars.

In other cases, miniplates, as well as miniscrews, were efficiently used for total mandibular arch distalization. Kook et al. [7] presented improved lip protrusion, and retroclination of the upper and lower incisors were achieved with nonextraction treatment using a modified C-palatal plate (MCPP) and intermaxillary elastics in a bimaxillary patient (Figure 1). Sugawara et al. [1] reported that the miniplate is an useful tool moving mandibular molars distally to correct anterior crossbite or mandibular anterior crowding.

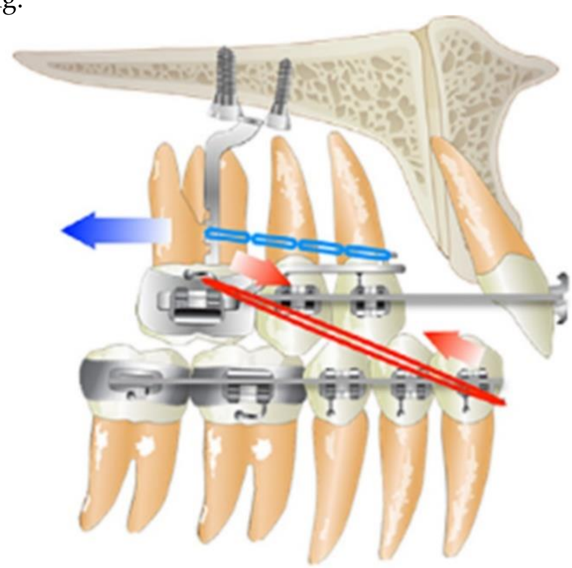


Figure 1. Schematic drawing of Class III elastics and a maxillary MCPP for total arch distalization.

Further, Yeon et al. [8] evaluated treatment effects between arch distalization using buccal miniscrews and ramal plates in the mandibular dentition. They suggested that ramal plates presented more molar distalization than what could be achieved with buccal miniscrews.

Traditionally, Class III elastics have been used to correct a protrusion of the mandibular dentition. This mechanic caused distal tipping of molars, incisor uprighting, and anticlockwise rotation of the occlusal plane, correcting protrusive lower lip [9,10], but causing extrusion and mesialization of the maxillary posterior teeth. To avoid this drawback, He et al. [11] successfully used the multiloop edgewise archwire technique and Class III elastics with mini-implants for compromised treatment of Class III malocclusion.

During distalization, third molars, which are more likely to become impacted in general, should be the primary concern of clinicians. The eruption space of third molar is affected by bone remodeling and orthodontic treatment. With the distalization of maxillary third molars, a germectomy has been proponed prior to applying a pendulum in growing patients [12], because nonextraction treatment is significantly associated with increased impaction rate of third molar [13,14].

When Park et al. [15] evaluated three-dimensional position of maxillary molars during retention using cone-beam computed tomography (CBCT), they concluded that second molars can fully erupt and third molars in both groups present a favorable position after distalization. Recently, Kang et al. [16] evaluated the long-term position of erupted third molars after maxillary total arch distalization using MCPPs in adolescents. They reported that maxillary third molars erupt spontaneously over time in spite of their position after distalization.

This is encouraging because prior to mandibular molar distalization, several studies recommended extraction of the third molar [4,6,17,18]. To the best of our knowledge, no long-term evaluations of the positional change of mandibular third molars have been reported. In addition, only a few studies have evaluated Class III effects in the mandible using maxillary TSADs as an indirect anchorage.

Therefore, this study aimed to evaluate the mandibular molar changes after distalization using Class III elastic and maxillary MCPPs as an indirect anchorage and to use CBCT to specifically analyze the third molar position after long-term retention in adolescents.

2. Materials and Methods

This retrospective study was approved by the Institutional Review Board at the Catholic University of Korea (IRB number KC21RISI0767).

The study sample was comprised of 65 third molars in 35 subjects divided into two groups. The treatment group included 26 third molars in 14 adolescent Class I bimaxillary protrusion patients (mean age, 12.8 years), who underwent bilateral maxillary distalization with a modified C-palatal plate (MCPP) and mandibular distalization with Class III elastics at the Department of Orthodontics, Seoul St. Mary's Hospital, The Catholic University of Korea. CBCT images were scanned at pre- and post- molar distalization (mean duration, 15.8 months) for evaluating during pre- and post-treatment. Long-term data (mean period, 6.1 years) was extracted from the CBCT images. In addition, there was 21 Class I subjects in the control group with 39 mandibular third molars of which CBCT images had been taken for purposes other than this research, such as periodontic treatment or pathologic disease(Table 1).

Table 1. Baseline characteristics of subjects in the treated and control groups

	Treated group (n=14) (26 third molars in 14 patients)			Control group (n=21) (39 third molars in 21 patients)
	Predistalization (T1)	Postdistalization (T2)	Retention (T3)	
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Age (y)	12.8 ± 1.2	14.4 ± 1.3	20.1 ± 1.4	21.3 ± 1.6
Gender		Male (n=7)		Male (n=11)
		Female (n=7)		Female (n=10)
CVM	T1	T2	T3	Control
	CS2 (n=5)	CS3 (n=6)	CS5 (n=3)	CS5 (n=4)
	CS3 (n=9)	CS4 (n=8)	CS6 (n=11)	(n=17)

*Control group was applied only for the comparison with third molar position at retention (T3) in treated group.

The inclusion criteria of the treated group for this study were (1) age range of 12 to 14 years (2) Class I molar with bimaxillary protrusion (3) unilateral or bilateral development of mandibular third molars (4) retention period of more than 4 years. For the comparison with the third molar position at retention (T3) in treated group, control group included 21 participants with normal occlusion, (1) mean age 21.3 ± 1.6 years (2) Class I occlusion with a normal overbite and overjet range of 1 to 3 mm (3) crowding ≤ 2 mm ; (4) no asymmetry and crossbite, (5) and the presence of third molars.

An i-CAT computed tomography scanner (Imaging Science International, Hatfield, PA), which had 120 kVp, 47.7 mA, a standard voxel size of 0.4 mm, 200 X 400 mm field of view, was used for all patients. An MCPP was used to distalize the maxillary dentition, while Class III elastics were applied to distalize the mandibular dentition.

CBCT Reference planes and measurements

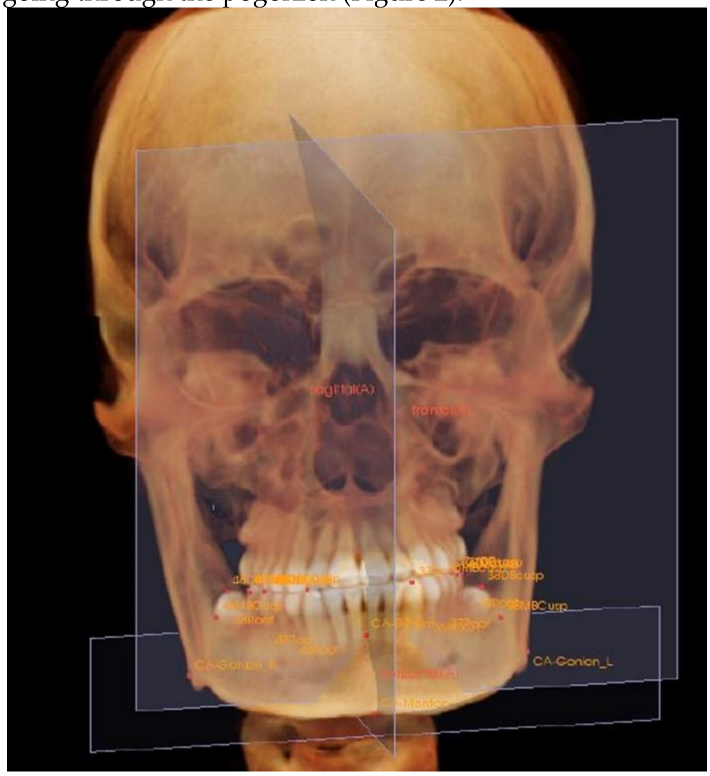
The CBCT imaging results were converted to the Digital Imaging and Communications in Medicine (DICOM) format. These DICOM data were three-dimensionally reconstruceted using InVivo software (version 5.3; Anatomage, San Jose, Calif) before analyzing. The orientation and measurements were performed by single examiner (K.J).

Repeated measurements were calculated to analyze the intraclass correlation coefficient (ICC). The ICC values showed intrarater reliability ranged from 0.92 to 0.95. Landmarks were additionally digitized; the mesiobuccal (MB) and distobuccal (DB) cusps, the distance from the MB cusp of mandibular molar to the horizontal, frontal, and sagittal planes were measured.

As X-axis, the horizontal plane was defined as the plane going through the menton and parallel to a plane extending through the right and left mental foramen and pogonion.

As Y-axis, the sagittal plane was defined as the plane perpendicular to the horizontal plane at the menton and passing through the B point.

As Z-axis, the frontal plane was defined as the plane perpendicular to both planes and going through the pogonion (Figure 2).



The horizontal plane (X-axis); the plane passing the menton and parallel to a plane extending through the right and left mental foramen and pogonion. The sagittal plane (Y-axis); perpendicular to the horizontal plane at the menton and passing through the B point. The frontal plane (Z-axis); perpendicular to both planes and passing through the pogonion

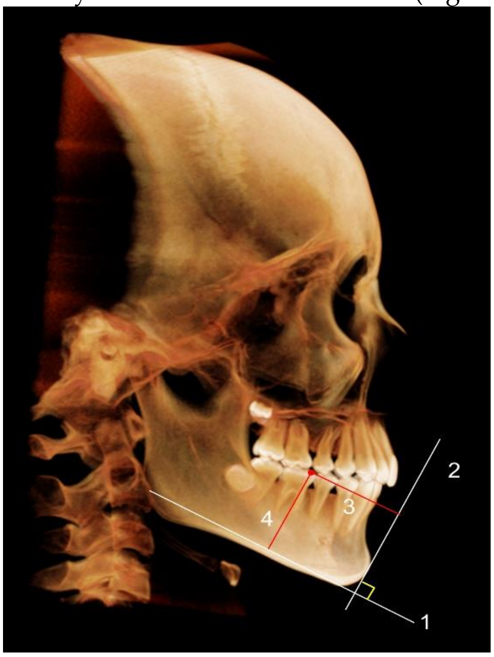
Figure 2. Reorientation of X, Y, Z reference planes using landmarks: menton; gonion; B point; pogonion; mental foramen.

The distances from the MB cusps of mandibular first, second, and third molars to horizontal, sagittal, and frontal planes were measured. The distances from the frontal plane to each MB cusp of the lower posterior teeth were measured parallel to reference line from pogonion to the superior point of mental foramen.

The positional changes on each plane were assessed by the distance differences pre-, post- distalization, and after long-term retention (Figure 3a).

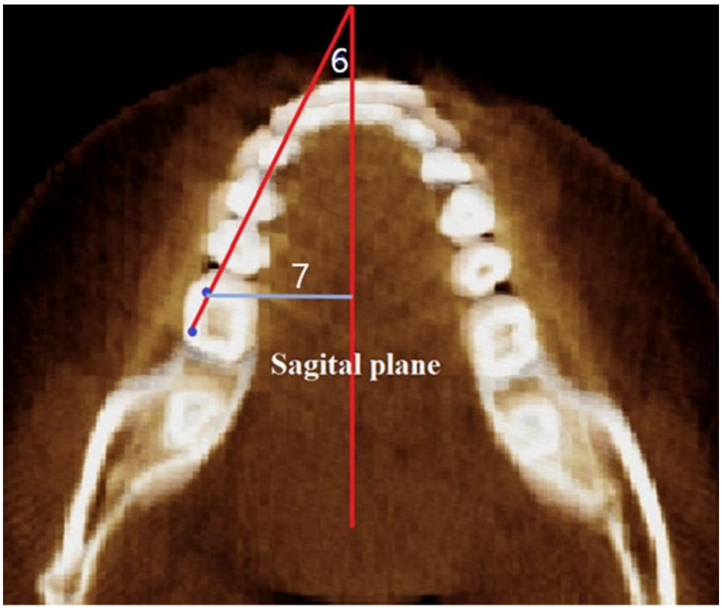
The angles between the horizontal plane and long axis of first and second molars, which were set as line from the MB cusp to the tip of mesial root, were calculated. The angulation of third molar was defined as the line from midpoint of the crown to that of developing root. The angulation changes of the posterior teeth were analyzed (Figure 3b).

The angles were analyzed between sagittal plane projected on horizontal plane and the crown axis of molars, a line tangent to the MB and DB cusps. The change in rotation of maxillary molars was also measured (Figures 3c and 4).



(A)

(B)



(C)

Figure 3. A, Position of the mandibular right first molar: (1) Horizontal plane, (2); Frontal plane, (3); the distance from the mesiobuccal cusp to the frontal plane (Z), (4); the distance from the mesiobuccal cusp to the horizontal plane (X) B, Angulation of the mandibular first molar: (5) the angle between the long axis of the first molar (mesiobuccal cusp-mesial root tip) and the horizontal plane (X). C, Rotation of the mandibular first molar: (6) the angle between the crown axis of the first molar (mesiobuccal cusp-distobuccal cusp) and sagittal (Y) plane projected on the horizontal (X) plane, (7); the distance from the mesiobuccal cusp to the sagittal (Y) plane.

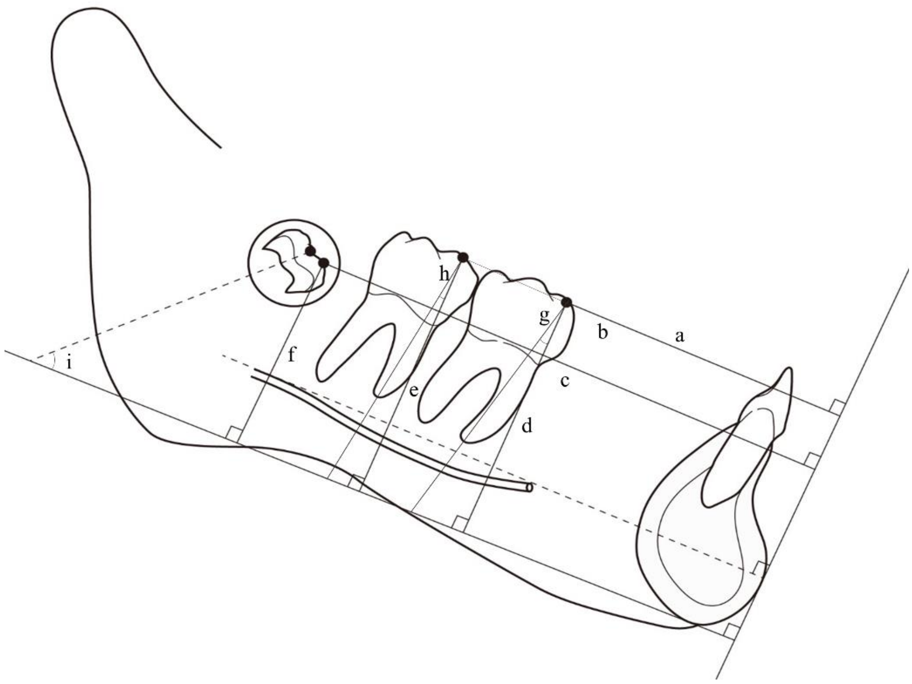


Figure 4. Schematic illustration of the measurements. a-c) Distance between the MB cusp of each tooth to the frontal plane; d-f) Distance between the MB cusp of each tooth to the horizontal plane; g-i) Angulation of each teeth to the horizontal plane. The first and second molar axis was defined as extending through the MB cusp and apex of the mesial root. The third molar axis was defined and extended through the midpoint of the crown and developing root.

Sample size estimation

The total sample size for proper statistical power in this study was calculated with statistical power analysis software (G*Power 3.1.9.4, Heinrich-Heine-Universität Düsseldorf, Germany).

Statistical analysis

With IBM SPSS software, Version 26.0 (SPSS Inc., Chicago, Ill), post-hoc repeated measured MANOVA analysis with Bonferroni corrections was used to evaluate the significance between pretreatment with posttreatment (P1), between pretreatment and after retention (P2), and between posttreatment and after retention (P3). MANOVA was used to compare variables between (T3) and the control group for analysis. Differences with probabilities of less than 5% ($P<0.05$) were considered statistically significant.

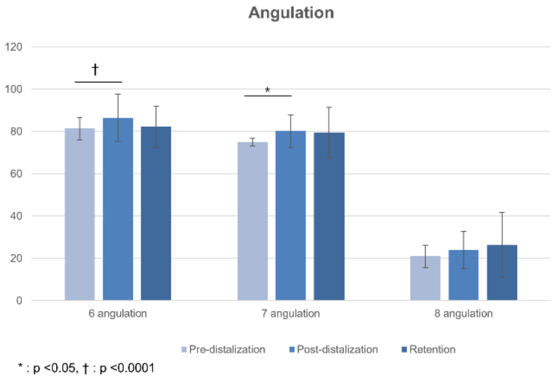
Table 2. Measurements of predistalization, postdistalization and long-term retention treated group

	Predistalization		Postdistalization		Retention	
	Mean	SD	Mean	SD	Mean	SD
Angulation (°)						
6 angulation	81.45	5.36	86.60	1.88	82.15	5.44
7 angulation	74.90	11.18	80.18	7.77	79.37	8.87
8 angulation	20.95	9.72	23.93	11.93	26.33	15.31
Rotation (°)						
6 rotation	72.13	10.11	71.12	19.48	73.08	11.97
7 rotation	49.54	22.40	54.72	22.23	53.71	21.94
8 rotation	37.91	16.42	40.77	10.05	36.34	21.86
Position (mm)						
6 MB cusp to frontal plane(mm)	31.13	2.21	33.4	2.61	32.25	2.52
6 MB cusp to horizontal (mm)	27.36	2.66	28.61	2.79	30.03	2.49
6 MB cusp to midsagittal (mm)	26.33	3.13	25.60	2.83	26.36	3.86
7 MB cusp to frontal (mm)	41.88	2.48	43.6	3.4	42.34	3.15
7 MB cusp to horizontal (mm)	24.95	2.90	25.58	3.20	27.61	3.14
7 MB cusp to midsagittal (mm)	29.26	4.43	28.62	2.71	29.28	5.11
8 MB cusp to frontal (mm)	47.74	2.43	47.58	2.37	46.31	2.58
8 MB cusp to horizontal (mm)	16.99	3.07	17.51	3.45	19.68	3.92
8 MB cusp to midsagittal (mm)	40.66	2.31	40.69	2.10	39.02	4.08
Width (mm)						
Mandibular intercanine width	28.25	2.76	28.35	2.47	28.01	1.90
Mandibular intermolar width	52.66	5.90	51.23	5.17	52.75	7.68

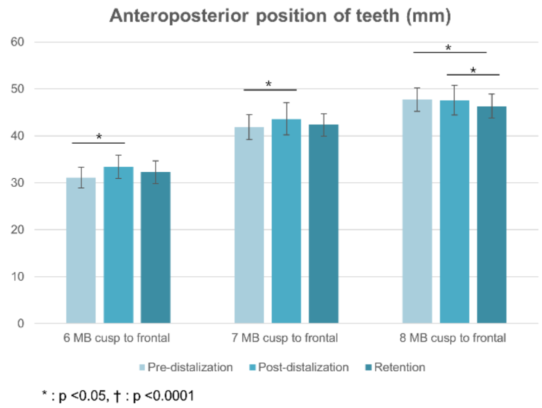
3. Results

Table 2 shows the measurements of each posterior tooth's angulation, rotation, position, and width at predistalization, postdistalization, and postretention in the treatment group.

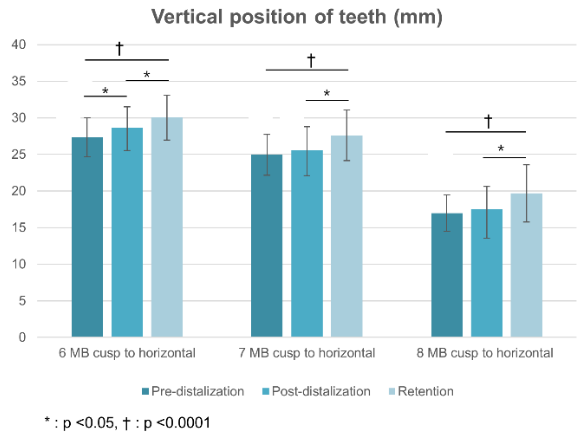
The mandibular first and second molars showed a significant distal movement of 2.3 and 1.7 mm ($P<0.05$), with distal crown tipping of 5.2° and 5.3° and extrusion of 1.3 and 0.6 mm respectively after total arch distalization. Notably, there were no significant changes in the distal tipping of the third molars (Figure 5).



(A)



(B)



(C)

Figure 5. Bar graphs of angulation, frontal and horizontal positional change at predistalization, post-distalization, and long-term retention in the treated group. A, Angulation. B, Frontal positional change. C, Horizontal positional change.

The mandibular first and second molars moved insignificantly mesially by 1.1 and 1.3 mm during the retention period. The first molars showed mesial tipping of 4.5° (P = 0.001) (Table 3).

Table 3. Changes in post-distalization and long-term retention of the treated group

Variables	T1-T2		T2-T3		T1-T3		Post Hoc Analysis Bonferroni		
	Mean	SD	Mean	SD	Mean	SD	P1	P2	P3
6 angulation	-5.16	4.85	4.45	5.75	-0.71	5.82	<0.0001	0.001	1.000
7 angulation	-5.28	10.63	0.81	9.11	-4.47	10.54	0.042	1.000	0.112
8 angulation	-2.97	6.78	-2.40	16.17	-5.38	15.23	0.084	1.000	0.218
6 rotation	1.01	17.39	-1.96	16.26	-0.95	10.90	1.000	1.000	1.000
7 rotation	-5.18	23.56	1.01	24.39	-4.17	26.91	0.763	1.000	1.000
8 rotation	-2.86	13.78	4.43	20.94	1.57	23.74	0.847	0.819	1.000
6 MB cusp to frontal (mm)	-2.26	2.43	1.14	3.51	-1.12	3.03	0.012	0.737	0.571
6 MB cusp to horizontal (mm)	-1.25	1.83	-1.42	2.03	-2.67	2.04	0.004	0.003	<0.0001
6 MB cusp to midsagittal (mm)	0.72	2.69	-0.76	3.35	-0.03	3.66	0.498	0.724	1.000
7 MB cusp to frontal (mm)	-1.72	2.1	1.26	3.96	-0.46	3.32	0.027	0.761	1
7 MB cusp to horizontal (mm)	-0.63	2.78	-2.02	2.99	-2.65	2.41	0.720	0.004	<0.0001
7 MB cusp to midsagittal (mm)	0.64	4.42	-0.66	5.43	-0.02	4.93	1.000	1.000	1.000
8 MB cusp to frontal (mm)	0.16	1.1	1.27	1.64	1.43	1.88	1	0.038	0.042
8 MB cusp to horizontal (mm)	-0.52	1.66	-2.16	2.89	-2.69	3.15	0.321	0.001	<0.0001
8 MB cusp to midsagittal (mm)	-0.03	1.95	1.67	3.89	1.64	4.18	1.000	0.095	0.143
Mandibular intercanine width	-0.10	3.35	0.34	2.22	0.24	2.13	1.000	1.000	1.000
Mandibular intermolar width	1.43	4.79	-1.52	6.32	-0.09	6.78	0.851	1.000	1.000

Comparing the treated group with the control group at postretention, there was no significant difference in the position of the first and second molars in either group. However, the difference was significantly observed in the angulation of third molars between treated and control groups, 26.3° and 71.4° respectively ($P < 0.001$) (Table 4).

Table 4. Comparison of the measurements among long-term retention and the control group

Variables	T3		Control		P-value
	Average	SD	Average	SD	
6 angulation	82.15	5.44	83.03	4.95	0.492
7 angulation	79.37	8.87	78.36	7.56	0.614
8 angulation	26.33	15.31	71.37	10.30	<0.001
6 rotation	73.08	11.97	72.90	12.13	0.952
7 rotation	53.71	21.94	46.51	25.43	0.229
8 rotation	36.34	21.86	31.37	17.38	0.301
6 MB cusp to frontal (mm)	32.25	2.51	32.95	2.8	0.456
6 MB cusp to horizontal (mm)	30.03	2.49	29.65	3.68	0.639
6 MB cusp to midsagittal (mm)	26.36	3.86	25.15	2.06	0.098
7 MB cusp to frontal (mm)	42.34	3.15	42.68	2.99	0.748
7 MB cusp to horizontal (mm)	27.61	3.14	27.35	2.95	0.729
7 MB cusp to midsagittal (mm)	29.28	5.11	27.72	3.41	0.135
8 MB cusp to frontal (mm)	46.31	2.58	49.88	3.28	0.002
8 MB cusp to horizontal (mm)	19.68	3.92	22.74	3.84	0.002
8 MB cusp to midsagittal (mm)	39.02	4.08	35.07	4.62	0.001
Mandibular intercanine width	28.01	1.90	26.93	1.27	0.043
Mandibular intermolar width	52.75	7.68	50.62	2.72	0.203

Regarding the vertical position of third molars, treatment group showed a more downward position than that in control group, 19.7 mm versus 22.7 mm, respectively ($P = 0.002$). Also, regarding the evaluation of the transverse position, treated group had a more buccal position than that in control group, 39.0 mm versus 35.1 mm ($P = 0.001$).

Regarding the mandibular intercanine width, treated group presented a significant increase compared to control group, 28.0 mm versus 26.9 mm ($P < 0.05$).

4. Discussion

Total arch distalization of the mandible in Class I bimaxillary protrusion cases could cause posterior crowding, which in turn could change the position of developing third molars in adolescents [19]. Until now, there is no previous study using CBCT to analyze positional changes of molars after the distalization of mandibular dentition. In this study, mandibular third molar positions were evaluated in Class III patients treated with elastics and maxillary MCPPs for total arch distalization.

The mandibular first molars of the treated group in our study showed 2.3 mm of distalization with distal crown tipping of 5.2° and extrusion of 1.3 mm in patients distalized using Class III elastics. Nakamura et al. [20] demonstrated 3.0 mm distal movement with 6.2° distal tipping with TSADs. Also, Yu et al. [21] reported 3.2 mm distal movement and 4.6° distal tipping with a ramal plate. Our results showed less distal movement compared to the results in other reports because we used Class III elastics instead of TSADs in the mandible.

After postdistalization in this study, samples consisted of adolescents aged 14.4 ± 1.3 with a cervical vertebral maturation stage (CVMS) of CS3 and CS4 (Table I). Gu et al. [22] found the peak increase in mandibular length occurs during this stage. Another report showed continued accelerated craniofacial growth can be anticipated in the CS4 stage [23]. Interestingly, both the treated and control groups had the same CVMS of CS5 and CS6 at post retention, as seen in Table 1.

Orthodontic appliances that produce posterior movement of the mandibular dentition either by the tipping of individual tooth or translation of the dentition may restrict the space for second and third molars, which can cause impaction of third molars [24-27].

It was known for the third molars to show the mesioangular and unfavorable position in long-term. Kinzinger et al. [12] evaluated the treatment outcomes on maxillary third molars during distalization by modified pendulum. Tooth buds of third molars acted as a fulcrum, causing the second molars to tip approximately 8° to palatal plane after 2.6 mm distalization. In addition, Kang et al. [28] demonstrated this effect by three-dimensional finite element method. The presence or absence of third molar follicles did not significantly affect the movement of first molar.

Several studies reported that premolar extractions treatment might produce the posterior space and reduce the potential of third molar impaction [29,30]. Regarding vertical and horizontal positions in our case, the lower third molars in treatment group showed a more downward and mesial position compared to those in control group. Accordingly, the potential for third molar impaction could be high. On the other hand, Kang et al. [16] demonstrated that maxillary third molars show spontaneous eruption over time despite their position after distalization.

With the regard to the positional changes of third molar after distalizing, the great amount of 8.9° was observed in the treated group. To reduce this distinct tipping of second molars during molar distalization, a surgical extraction of third molar bud was recommended due to fulcrum action [12]. Unfortunately, their study has a limted evaluation immediately after distalization with a few patients in germectomy group and only used two-dimensional images.

In our study, stable structures were applied in the mandible to evaluate the positional changes in the three stages (pre- and postdistalization and retention). Oh et al. [31] evaluated the mandibular and dentoalveolar change using functional appliances based on the mandibular reference plane with Björk's structural method on a 2-dimensional cephalometric radiograph, while we used CBCT images to analyze a 3-dimensional determination of stable structures in the mandible as seen in Figure 4. Adams et al. [32] showed that a 3-dimensional evaluation is more precise and accurate than a 2-dimensional approach. Nguyen et al. [33] demonstrated that the anterior contour of bony chin at pogonion showed no remodeling, while Chen et al. [34] showed that as a stable structure in the mandible, the mental foramen can be used for regional superimposition in a 3-dimensional mandibular evaluation of growing patients. In our study with CBCT images, we use a reference line from pogonion to the superior point of mental foramen as stable structures to evaluate the anterioposterior movement of the lower posterior teeth.

Regarding maxillary third molars, distalization of posterior teeth can occur in adolescents having retained third molars [28]. Molar distalization has no significant impact on normal eruption of maxillary third molars, which suggests that a surgical removal may not be required prior to distalizing maxillary molars in adolescents with developing third molars [16,35].

Additionally, in the mandible, Chen et al. [36] reported that the increased posterior available space was mainly due to bony resorption on the anterior border of ramus in growing patients. They also found that the average available spaces increased by 1.2 mm in female under age 16 and by 1.5 mm in male under age 17 per side annually. Our study found that mandibular third molars showed a downward and buccal position after distalization in the long-term than in the control group. This means that clinically, there is a possibility that third molars could be impacted after distalizing mandibular dentition in adolescents.

One limitation of our study was that control group comprised adult patients who had CBCT data obtained for purposes other than this research, like as periodontic treatment or pathologic diseases; the longitudinal sample was limited for ethical reasons. Therefore, the positional changes of third molars cannot be evaluated at each treatment stage as was possible with the treated group. In the future, a study needs to evaluate longitudinal positions in adolescents to demonstrate the treatment effect after distalization using TSADs in the mandible.

5. Conclusions

We evaluated the mandibular molar changes after molar distalization and used CBCT to specifically analyze the third molar position after long-term retention in adolescents.

- The first and second molars exhibited a distal movement of 2.3 and 1.7 mm, respectively, with distal crown tipping after distalization. There was no significant change in the angulation of the third molars.
- The treated group showed a downward and buccal position of the third molars after distalization in the long-term compared to the control group.

These findings suggest that clinicians should consider the possibility of impacted third molars after mandibular distalization in adolescents.

Author Contributions: Conceptualization, Nam-Ki Lee and Jae Hyun Park; Data curation, Hye-Rim Hong and Ja Hyeong Ku; Formal analysis, Jaehyun Kim; Investigation, Ja Hyeong Ku and Jaehyun Kim; Methodology, Jae Hyun Park; Software, Mohamed Bayome; Supervision, Yoon-Ah Kook; Validation, Sung-Seo Mo; Visualization, Mohamed Bayome; Writing – original draft, Hye-Rim Hong and Nam-Ki Lee; Writing – review & editing, Sung-Seo Mo and Yoon-Ah Kook.

Acknowledgments: The authors would like to express their gratitude to Dr. Jiyoung Oh (Resident, Department of Orthodontics, Seoul St. Mary's Hospital, The Catholic University of Korea, Seoul, Korea) for her invaluable contribution to this study.

References

1. Sugawara J, Daimaruya T, Umemori M, Nagasaka H, Takahashi I, Kawamura H et al. Distal movement of mandibular molars in adult patients with the skeletal anchorage system. Am J Orthod Dentofacial Orthop 2004 Feb;125:130-38.
2. Kook YA, Park JH, Bayome M, Sa'aed NL. Correction of severe bimaxillary protrusion with first premolar extractions and total arch distalization with palatal anchorage plates. Am J Orthod Dentofacial Orthop 2015 Aug;148:310-20.
3. Kook YA, Bayome M, Trang VT, Kim HJ, Park JH, Kim KB, et al. Treatment effects of a modified palatal anchorage plate for distalization evaluated with cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2014;146:47-54.
4. Oh YH, Park HS, Kwon TG. Treatment effects of microimplant-aided sliding mechanics on distal retraction of posterior teeth. Am J Orthod Dentofacial Orthop 2011;139:470–81
5. Baccetti T, Franchi L, Stahl F. Comparison of 2 comprehensive Class II treatment protocols including the bonded Herbst and headgear appliances: a double-blind study of consecutively treated patients at puberty. Am J Orthod Dentofacial Orthop 2009; 135 (698e1–10)
6. Chen G, Teng F, Xu TM. Distalization of the maxillary and mandibular dentitions with miniscrew anchorage in a patient with moderate Class I bimaxillary dentoalveolar protrusion. Am J Orthod Dentofacial Orthop 2016;149:401-10.
7. Kook YA, Park JH, Kim Y, Ahn CS, Bayome M. Sagittal correction of adolescent patients with modified palatal anchorage plate appliances. Am J Orthod Dentofacial Orthop 2015;148:674-84.
8. Yeon BM, Lee NK, Park JH, Kim JM, Kim SH, Kook YA. Comparison of treatment effects after total mandibular arch distalization with miniscrews vs. ramal plates in Class III patients. Am J Orthod Dentofacial Orthop In press.
9. Le_on-Salazar V, Janson G, de Freitas MR, de Almeida RR, Le_on- Salazar R. Nonextraction treatment of a skeletal Class III malocclusion. Am J Orthod Dentofacial Orthop 2009;136:736-45.
10. Lin J, Gu Y. Preliminary investigation of nonsurgical treatment of severe skeletal Class III malocclusion in the permanent dentition. Angle Orthod 2003;73:401-10.
11. He S, Gao J, Wamalwa P, Wang Y, Zou S, Chen S. Camouflage treatment of skeletal Class III malocclusion with multiloop edgewise archwire and modified Class III elastics by maxillary mini-implant anchorage. Angle Orthod 2013;83:630-40.
12. Kinzinger GSM, Fritz UB, Sander FG, Diedrich PR. Efficiency of a pendulum appliance for molar distalization related to second and third molar eruption stage. Am J Orthod Dentofacial Orthop 2004;125:8–23.
13. Ricketts RM. A Principle of Arcial Growth of the Mandible. Angle Orthod 1972;42:368–86.
14. Kaplan RG. Some Factors Related to Mandibular Third Molar Impaction. Angle Orthod 1975;45:153–8.
15. Park JH, Kim Y, Park JH, Lee NK, Kim SH, Kook YA. Long-term evaluation of maxillary molar position after distalization with and without second molar eruption. Am J Orthod Dentofacial Orthop, In press.
16. Kang H, Lee NK, Kim J, Park JH, Kim Y, Kook YA. Factors associated with the maxillary third molar position after total arch distalization using a modified C-palatal plate in adolescents. Orthod Craniofac Res 2021;24 Suppl 1:31-8.
17. Kook YA, Park JH, Bayome M, Kim S, Han E, Kim CH. Distalization of the mandibular dentition with a ramal plate for skeletal Class III malocclusion correction. Am J Orthod Dentofacial Orthop 2016;150:364-77.
18. Tai K. Park J.H. Tatamiya M. et al. Distal movement of the mandibular dentition with temporary skeletal anchorage devices to correct a Class III malocclusion. Am J Orthod Dentofacial Orthop 2013; 144: 715-25
19. Kook YA, Park JH, Kim Y, Ahn CS, Bayome M. Sagittal correction of adolescent patients with modified palatal anchorage plate appliances. Am J Orthod Dentofacial Orthop 2015;148:674-84.
20. Nakamura M, Kawanabe N, Kataoka T, Murakami T, Yamashiro T, Kamioka H. Comparative evaluation of treatment outcomes between temporary anchorage devices and Class III elastics in Class III malocclusions. Am J Orthod Dentofacial Orthop 2017;151:1116-24.
21. Yu J, Park JH, Bayome M, Kim S, Kook YA, Kim Y, et al. Treatment effects of mandibular total arch distalization using a ramal plate. Korean J Orthod 2016;46:212-21.
22. Gu Y, McNamara JA. Mandibular growth changes and cervical vertebral maturation: a cephalometric implant study Angle Orthod 2007;77:947–53.
23. McNamara JA, Franchi L. The cervical vertebral maturation method: a user’s guide. Angle Orthod 2018;88:133–43.
24. Bishara, S.E., Andreasen, G. Third molars: a review. American Journal of Orthodontics 1983;83, 131–37.
25. Vaden JL, Kiser HE. Straight talk about extraction and nonextraction: a differential diagnostic decision. Am J Orthod Dentofacial Orthop 1996;109:445-52.
26. Richardson ME. The etiology and prediction of mandibular third molar impaction. Angle Orthod 1977;47:165-72.
27. Kim SJ, Choi TH, Baik HS, Park YC, Lee KJ. Mandibular posterior anatomic limit for molar distalization. Am J Orthod Dentofacial Orthop 2014;146:190-17.
28. Kang JM, Park JH, Bayome M, Oh M, Park CO, Kook YA, et al. A three-dimensional finite element analysis of molar distalization with a palatal plate, pendulum, and headgear according to molar eruption stage. Korean J Orthod 2016;46:290–300.
29. Richardson ME, Richardson A. Lower third molar development subsequent to second molar extraction. Am J Orthod Dentofacial Orthop 1993;104:566–74.
30. Behbehani F, Artun J, Thalib L. Prediction of mandibular third-molar impaction in adolescent orthodontic patients. Am J Orthod Dentofacial Orthop 2006;130:47-55.
31. Oh E, Ahn SJ, Sonnesen L. Evaluation of growth changes induced by functional appliances in children with Class II malocclusion: Superimposition of lateral cephalograms on stable structures. Korean J Orthod 2020;50:170-80.

32. Adams GL, Gansky SA, Miller AJ, Harrell WE Jr, Hatcher DC. Comparison between traditional 2-dimensional cephalometry and a 3-dimensional approach on human dry skulls. Am J Orthod Dentofacial Orthop 2004;126:397-409.
33. Nguyen T, Cevidanes L, Franchi L, Ruellas A, Jackson T. Three-dimensional mandibular regional superimposition in growing patients. Am J Orthod Dentofacial Orthop 2018;153:747-54.
34. Chen G, Al Awadi M, Chambers DW, Lagravère-Vich MO, Xu T, Oh H. The three-dimensional stable mandibular landmarks in patients between the ages of 12.5 and 17.1 years. BMC Oral Health 2020;20:153.
35. Lee YJ, Kook YA, Park JH, Park J, Bayome M, Vaid NR, et al. Short-term cone-beam computed tomography evaluation of maxillary third molar changes after total arch distalization in adolescents. Am J Orthod Dentofacial Orthop 2019;155:191–7.
36. Chen LL, Xu TM, Jiang JH, Zhang XZ, Lin JX. Longitudinal changes in mandibular arch posterior space in adolescents with normal occlusion. Am J Orthod Dentofacial Orthop 2010;137:187-93.