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Long-term evaluation of maxillary molar position after distalization using modified C-palatal plates in patients with and without second molar eruption

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Introduction: The purpose of this study was to analyze the treatment effects after molar distalization using modified C-palatal plates with and without second molar eruption and to evaluate the three-dimensional position of the molars during long-term retention using cone-beam computed tomography. **Methods:** The study sample comprised 74 third molars in 42 patients. Twenty-seven adolescent patients (mean age, 12.6 years) having 48 maxillary third molars were divided into 2 groups according to the eruption of their second molars: 15 patients with second molar eruption (group 1) and 12 patients without second molar eruption (group 2). Pretreatment, posttreatment, and long-term data (mean, 5.2 years) from cone-beam computed tomography were scanned and compared with control groups. **Results:** There was less tipping movement of the first and second molars (0.94° and 3.22°) and distal tipping movement of the third molars (8.91°) in group 1 than in group 2 (4.36°, 7.39°, and 3.08°, respectively), but the treatment time was shorter and the positional change of the third molars was insignificant in group 2. In the long-term, the second molars fully erupted after distalization in group 2, and there was no difference in the third molar position between group 1, group 2, and the control group, except for the vertical position of the third molars in group 1. **Conclusions:** In the long-term, the second molars fully erupted after distalization, and the third molars were in a favorable position. Therefore, these findings suggest that clinicians do not need to extract developing third molars before distalization in adolescents. (Am J Orthod Dentofacial Orthop 2021;160:853-61)

Nonextraction treatment with molar distalization is now feasible using temporary skeletal anchorage devices in patients with Class II malocclusion.[1-3] To overcome tipping and extrusion problems common with conventional distalization methods, temporary skeletal anchorage devices allow for greater distalization with less distal tipping of the first molars.[4]

However, distalization before the eruption of second molars is a challenge considering the potential for a delayed eruption of the second and third molars. Regarding the probability of eruption disturbances of the molars associated with distalization in the absence or presence of the maxillary second molars, Rubin et al[5] suggested patients be carefully monitored to prevent impaction of the second molars when orthodontic appliances are used to maintain the mandibular arch perimeter in the mixed dentition.

For efficient molar distalization, Shpack et al[6] have recommended headgear treatment be started before the eruption of the maxillary second molars. In growing patients, a germectomy of the third molars has been suggested before the application of a pendulum,[7] and some researchers have found that nonextraction therapy is associated with a significant increase in the frequency

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of third molar impaction.[8,9] However, recently, Kang et al[10] found no significant effect on the molar distalization of a third molar tooth follicle when temporary anchorage devices were used. Considering the possible difficulties and trauma relative to surgical extraction of impacted third molars in adolescent patients, the relation between the eruption stage and molar distalization needs to be clarified.

Treatment timing remains controversial. Previous studies assessed the distal movement of maxillary molars relative to the eruption state.[6-15] Several of them suggested that the optimal treatment timing for maxillary arch distalization is before the eruption of the maxillary second molars,[6,8,9] but other studies have reported that the eruption stage has only limited or negligible impact on distalization.[13-15]

Clinicians have expressed concern about the delayed eruption of second molars, which can result in insufficient space for the third molars and can lengthen treatment time. Maxillary third molar impaction can be predicted in adolescents on the basis of the size of the retromolar space measured as the distance from the first molar to the pterygoid vertical along the occlusal plane.[16] The high impaction rate of maxillary third molars may be explained by insufficient periosteal apposition at the posterior outline of the maxillary tuberosity.[17,18] Lee et al[19] observed an insignificant difference in the posttreatment volume of maxillary tuberosity after maxillary distalization. Some studies have evaluated the skeletal effect of molar distalization in adolescents and adults,[20-22] but few studies have evaluated the maxillary molar position after distalization with vs without the second molar eruption.

Kinzinger et al[7] assessed the effectiveness of molar distalization with a modified pendulum appliance relative to the second and third molar eruption stage. However, side effects of the pendulum treatment, such as anchorage loss which resulted in increased overjet and molar tipping by a mean change in angulation of 15.7°.[23] Modified C-palatal plates (MCPPs) used in this study showed greater distalization and intrusion with less distal tipping of the first molar and more extrusion of the incisor than the buccal miniscrews.[4] Unfortunately, until now, there has not been any analysis or long-term evaluation of the maxillary molar distalization related to the second and third molar eruption stage. The null hypothesis in this study was that maxillary molar distalization using MCPPs induces a significant positional change of third molars in a group without the eruption of the second molar, compared with the group with erupted second molar.

Therefore, the purpose of this study was to analyze the treatment effects after molar distalization with and without the second molar eruption and to evaluate the three-dimensional (3D) position of the molars during long-term retention.

MATERIAL AND METHODS

This study was based on Strengthening the Reporting of Observational Studies in Epidemiology reporting guidelines. This sample comprised 74 third molars in 42 patients. Twenty-seven adolescent patients (mean age, 12.6 years) having 48 maxillary third molars underwent bilateral distalization of maxillary molars with MCPPs at the Department of Orthodontics at Seoul St. Mary's Hospital, The Catholic University of Korea from January 2009 to December 2013 and were divided into 2 groups according to the eruption of their second molars; 15 patients with second molar eruption (group 1), 12 patients without second molar eruption (group 2). In group 1, the bracket positioning was possible on second molars that had fully erupted as far as the occlusal plane. In group 2, second molars were not yet erupted under the gingival coverage (Fig 1). In addition, to evaluate the eruption level of the second molar, the perpendicular distance from the occlusal line (the line connected between the mesiobuccal cusp tip and the distobuccal cusp tip of the first molar) to the midpoint of the mesiobuccal and distobuccal cusp tip of the second molar was measured (Table I).

Cone-beam computed tomography (CBCT) images were scanned before and after molar distalization (group 1, 18.1 ± 13.12 months; group 2: 13.1 ± 7.04 months) for pretreatment and posttreatment evaluation. Long-term data (mean, 5.2 years) was derived from CBCT images from January 2017 to May 2019.

Control groups that have not received orthodontic treatment were used to compare skeletal growth during distalization. Control group 1 (age, 12.7 ± 1.1 years) was used as a cross-sectional sample used as a short-term study (12.9 ± 4.04 months) and was applied to compare the MCPPs treatment effect and amount of growth.[19] The control group 2 was used for long-term evaluation (age, 19.3 ± 1.6 years) included 15 dental patients with Class II malocclusion with 26 maxillary third molars who had taken 1 CBCT image for other reasons such as an impacted tooth or pathology (Table I).

Institutional Review Board approval of this study was obtained from the Catholic University of Korea (KC19RESI0172). The sample size necessary for a significance level of $P < 0.05$, a $\beta = 0.2$, and an effect size of 1.5 was determined to be at least 23 third molars (www.clincalc.com). The inclusion criteria for groups 1 and 2 in this retrospective study were as follows: (1) age range from 11 to 14 years, (2) dental Class II molar relationship

Fig 1. Different eruption stages of patients before treatment: **A,** completed eruption of the second molars in group 1; **B,** eruption of the second molars was not completed in group 2.

Table I. Baseline characteristics of subjects in the Group 1, 2 and the control 1, 2 groups

	Group 1		*Group 2*		*Control group 1*		*Control group 2*	
Characteristics	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Patients (n)	15		12		20		15	
Third molars (n)	25		23		35		26	
Age, y	13.2	1.32	12.0	1.24	12.65	1.14	19.4	1.69
Sex (male/female), n	5/10		5/7		12/8		4/11	
Eruption level of second molar, mm*	2.12	0.52	10.35	1.35				

*$P < 0.001$.

Fig 2. Modified C-palatal plate placed on the palate of a patient.

more than 1/4 cusp, (3) unilaterally or bilaterally developing maxillary third molars, (4) mild to moderate crowding <5 mm in the maxilla, and (5) high-quality CBCT images. For the long-term evaluation of the maxillary molar position, the control 2 group was selected on the basis of the same criteria as groups 1 and 2. An I-CAT computed tomography scanner (Imaging Science International, Hatfield, Pa) was used for all patients, with 120 kVp, 47.7 mA, a standard voxel size of 0.4 mm, 200 × 400 mm field of view. The MCPP and 3 miniscrews (2.0 mm in diameter, 8 mm in length; Jeil Corporation, Seoul, South Korea) were inserted by the same operator (Y.A.K.) in the paramedian region of the palate (Fig 2). A palatal arch with 2 hooks in the anterior part was placed with the elastomeric chain applying approximately 300 g of force on each side. Class I molar relationship was achieved in all patients with normal overjet and overbite. Hawley retainers in combination with a fixed retainer were used for long-term retention.

For 3D volume rendering, the resulting data were exported in a Digital Imaging and Communications in Medicine multifile format and imported into Invivo software (version 5.3; Anatomage, San Jose, Calif).

One examiner (J.H.P.) did the orientation and took measurements of oriented landmarks (Fig 3, *A*). The repeated measurements done by these observers were used to calculate the intraclass correlation coefficient, which ranged from 0.92 to 0.95 for intraobserver reliability.

Additional landmarks were digitized; the mesiobuccal and distobuccal cusps of the maxillary molars and the palatal root tip of the maxillary molars. For assessment of the linear and angular dimensions, the distance from the mesiobuccal cusp of the maxillary molar to the horizontal, frontal, and sagittal planes was measured. The horizontal plane (x-axis) was set as the plane passing through the right orbitale and porions. The sagittal plane (z-axis) was set perpendicular to the horizontal plane passing through the anterior nasal spine and posterior

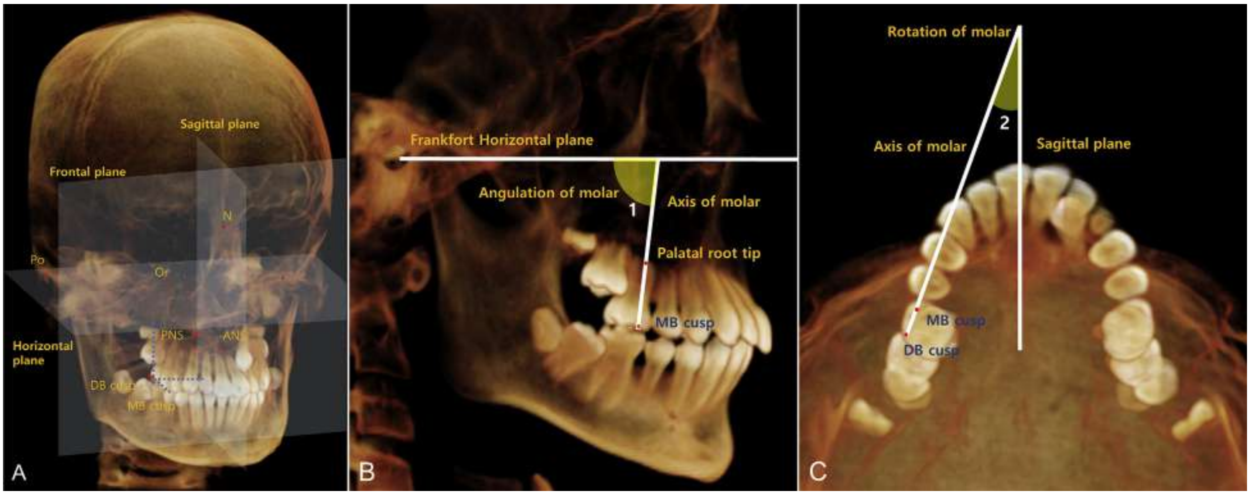

Fig 3. A, Landmarks. *N*, Nasion; *Po*, porion; *Or*, orbitale; *ANS*, anterior nasal spine; *PNS*, posterior nasal spine; *MB cusp*, mesiobuccal cusp of the first molar; *DB cusp*, the distobuccal cusp of the first molar; *horizontal plane (x-axis)*, plane connecting the orbitale and porions; *sagittal plane (z-axis)*, a plane perpendicular to both x-axes passing through ANS and PNS; *frontal plane (y-axis)*, a plane perpendicular to the x-axis and z-axis passing through the nasion. Position of the maxillary first, second, and third molars. *1, 6 sagittal positions*, distance from the mesiobuccal cusp of the maxillary molar to the horizontal plane; *2, 6 vertical positions,* distance from the mesiobuccal cusp of the maxillary molar to the frontal plane; *3, 6 horizontal positions*, distance from the mesiobuccal cusp of the maxillary molar to the sagittal plane. **B** and **C**, Reference lines for measurement of the angulation and rotation of the maxillary first, second, and third molars. *1*, Angulation of the molar (the angle between the FH line projected on the sagittal plane and the long axis of the molar); *2*, rotation of the molar (the angle between the sagittal plane projected on the horizontal plane and the crown axis of the molar).

nasal spine. The frontal plane (y-axis) was set perpendicular to the x-axis and z-axis, passing through nasion. The changes in sagittal, vertical, and transverse positions were analyzed (Fig 3, *B*).

The angles between the Frankfort horizontal line projected on the sagittal plane and the long axis of the first and second molars, defined as the line from mesiobuccal cusp to the tip of the palatal root, were measured. The angulation change of the first and second molars was analyzed (Fig 3, *B* and *C*).

The angles were measured between the sagittal plane projected on the horizontal plane and the crown axis of the molars, which is defined as a line tangent to the mesiobuccal and distobuccal cusps. The mean change in rotation of the maxillary molars was analyzed (Fig 3, *C*).

Statistical analysis

SPSS software (version 16.0; SPSS, Chicago, Ill) was used for the statistical analysis. All data were confirmed to be normally distributed using the Shapiro-Wilk test. The Wilcoxon rank-sum test was performed when the data did not follow a normal distribution. Independent and paired *t* tests were used to compare variables of the 2 groups and the control group for analysis of changes between pretreatment, posttreatment, and long-term effects. Age and gender were used as covariates. Differences with probabilities of less than 5% ($P < 0.05$) were considered statistically significant. The Kruskal-Wallis and Mann-Whitney tests were used to evaluate the difference in skeletal variables before and after the treatment of group 1, group 2, and control group 1.

RESULTS

Group 1, group 2, and control group 1 showed skeletal Class II malocclusion in the predistalization stage. Group 2 had a larger ANB than control group 1. In addition, group 1 had a smaller SNB than control group 1. Group 2 had a smaller mandibular plane angle than group 1. After distalization, groups 1 and 2 showed a decreased ANB compared with control group 1 (Table II).

Distalization of the maxillary molars was achieved with MCPPs within an average of 15.8 months (18.1 months in group 1 and 13.1 months in group 2, respectively). Table I demonstrates the distribution of subjects.

Changes in postdistalization and long-term retention are presented in Table III. In group 1 with the

Table II. Comparison of skeletal variables between predistalization and postdistalization in group 1, group 2, and control group 1

	Predistalization (T1)							*Changes between predistalization and postdistalization (T2 − T1)*						
	Control 1		*Group 1*		*Group 2*			*Control 1*		*Group 1*		*Group 2*		
Characteristics	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	P*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	P*
SNA	82.0	3.5	80.1	2.7	81.1	1.2	0.197	0.28	1.63	−0.18	0.47	0.04	0.39	0.337
SNB	78.0	3.5	75.5	3.1	76.0	1.7	0.062 (b < a)[†]	0.63	1.58	0.52	0.39	1.08	0.75	0.137
ANB	4.0	0.4	4.6	1.3	5.2	1.2	0.032 (c > a)[†]	−0.35	0.22	−0.69	0.50	−1.04	0.60	0.001 (b, c < a)[†]
Facial angle	88.7	3.2	87.3	3.1	88.4	3.1	0.565	0.58	1.43	−1.05	1.47	1.34	2.09	0.001(b < a, c)[†]
Palatal plane angle	−2.8	4.2	−4.2	3.0	−3.1	2.9	0.432	−0.21	1.84	0.23	0.63	−1.62	3.47	0.290
Mandibular plane angle	25.7	4.3	28.1	3.7	23.1	4.3	0.015 (b > c)[†]	0.77	3.29	2.43	2.51	−0.02	3.76	0.074
A point-N perpendicular	2.0	3.3	1.8	3.6	3.3	2.9	0.363	0.37	1.53	−0.44	0.75	0.26	1.27	0.204
B point-N perpendicular	−3.4	5.5	−5.1	5.7	−3.0	4.6	0.779	1.07	2.34	0.35	1.49	2.08	2.22	0.172
Maxillary length	82.6	3.8	83.7	6.0	83.8	3.7	0.760	0.96	3.84	1.56	1.08	0.24	1.56	0.100
Mandibular length	109.6	6.3	109.7	6.1	107.1	5.9	0.636	3.27	6.51	3.06	1.43	3.13	2.27	0.551

T1, pretreatment; *T2*, posttreatment; *SD*, standard deviation; *a*, control group 1 (n = 20); *b*, group 1 (n = 15); *c*, group 2 (n = 12).
*Kruskal-Walis test; [†]Mann-Whitney test.

Table III. Changes in postdistalization and long-term retention of groups 1 and 2

	Postdistalization					*Long-term retention*				
	Group 1		*Group 2*			*Group 1*		*Group 2*		
Variables	*Mean*	*SD*	*Mean*	*SD*	P	*Mean*	*SD*	*Mean*	*SD*	P
Angulation (°)										
6 angulation	−0.94	6.59	−4.36	8.54	0.254	−0.37	9.25	3.54	7.73	0.262
7 angulation	−3.22	8.16	−7.39	10.79	0.247	2.68	9.98	9.76	11.00	0.017*
8 angulation	−8.91	10.18	−3.08	11.88	0.077	3.94	13.53	6.14	11.52	0.571
Rotation (°)										
6 rotation	−0.05	11.65	3.22	11.25	0.304	0.43	10.92	−4.99	10.43	0.070
7 rotation	3.28	10.48	0.08	7.91	0.221	−3.28	11.49	−2.86	7.38	0.602
8 rotation	4.94	9.86	−0.88	8.42	0.035*	0.39	9.82	2.03	10.03	0.592
Position (mm)										
6 sagittal position	4.36	4.26	3.18	3.33	0.284	−2.67	3.04	−3.56	3.92	0.347
6 horizontal position	0.95	2.69	0.36	2.69	0.433	0.62	3.05	1.08	3.51	0.787
6 vertical position	−0.04	2.54	−0.95	2.55	0.361	2.77	2.50	6.41	4.52	0.001*
7 sagittal position	4.26	4.01	2.85	3.03	0.161	−1.87	2.61	−0.97	3.43	0.277
7 horizontal position	1.33	3.57	1.77	3.17	0.645	−0.45	2.93	1.07	3.79	0.102
7 vertical position	1.27	2.65	1.21	3.93	0.761	2.96	2.94	9.79	7.16	<0.001***
8 sagittal position	3.40	4.10	1.55	3.82	0.198	−0.43	4.68	2.39	3.78	0.116
8 horizontal position	0.66	3.67	1.25	5.55	0.530	0.26	3.31	−0.27	5.69	0.706
8 vertical position	1.10	3.21	0.58	2.84	0.924	5.11	5.64	10.86	6.33	0.004*
Width (mm)										
Maxillary intercanine width	0.91	1.42	1.70	5.41	0.942	−0.30	4.13	1.18	3.20	0.251
Maxillary intermolar width	4.36	4.26	3.18	3.33	0.284	−2.67	3.04	−3.56	3.92	0.347

6, first molar; *7*, second molar; *8*, third molar; ***angulation***, the angle between the FH line projected on the sagittal plane and the long axis of the molar; ***rotation***, the angle between the sagittal plane projected on the horizontal plane and the crown axis of the molar; ***sagittal position***, distance from the mesiobuccal cusp of the maxillary molar to the horizontal plane; ***vertical position***, distance from the mesiobuccal cusp of the maxillary molar to the frontal plane; ***horizontal position***, distance from the mesiobuccal cusp of the maxillary molar to the sagittal plane; ***maxillary intercanine width***, distance between mesiobuccal cusps of the maxillary canines; ***maxillary intermolar width***, distance between mesiobuccal cusps of the maxillary first molars.
*$P < 0.05$; ***$P < 0.0001$.

second molar eruption, the third molars showed distal tipping of 8.9° (95% confidence interval [CI], 7.7°-10.2°) and backward movement of 3.4 mm (95% CI, 2.6-4.2 mm) with less tipping movement of the first (0.9°; 95% CI, −0.1° to 1.9°) and second molars (3.2°; 95% CI, 2.1°-4.3°). However, in group 2 without the second molar eruption, the tipping tendency of the first (4.4°; 95% CI 3.2°-5.6°) and second molars (7.4°; 95%

Table IV. Comparison of the measurements among long-term retention of group 1, group 2, and the control group 2

	Group 1		*Group 2*			*Group 2*		
Variables	*Mean*	*SD*	*Mean*	*SD*	P	*Mean*	*SD*	P
Angulation (°)								
6 angulation	88.76	1.44	82.63	8.31	0.002*	86.39	3.01	0.015*
7 angulation	86.81	2.52	80.1	7.96	<0.001***	83.46	4.63	0.008*
8 angulation	79.26	11.01	73.16	9.64	0.017*	73.94	9.58	0.030*
Rotation (°)								
6 rotation	10.5	3.45	13.33	10.13	0.520	9.42	4.47	0.327
7 rotation	8.39	3.45	9.38	8.23	0.729	6.46	3.22	0.041*
8 rotation	28.62	11.70	19.21	8.57	0.002*	19.07	9.42	0.005*
Position (mm)								
6 sagittal position	23.87	3.60	28.21	4.15	<0.001	26.05	3.44	0.030*
6 horizontal position	28.95	2.08	28.81	2.80	0.823	29.04	2.87	0.895
6 vertical position	49.95	3.77	47.78	2.95	0.017*	49.65	4.05	0.777
7 sagittal position	33.88	3.69	38.61	4.21	<0.001	35.97	3.52	0.040*
7 horizontal position	31.43	2.11	30.33	2.87	0.035*	31.84	3.04	0.570
7 vertical position	45.99	3.56	44.90	3.22	0.220	46.43	4.13	0.670
8 sagittal position	38.87	4.97	42.05	5.70	0.067	41.70	2.65	0.059
8 horizontal position	31.45	4.43	29.13	3.58	0.047*	30.64	2.28	0.603
8 vertical position	35.99	3.71	33.66	5.56	0.024*	35.08	6.41	0.575
Width (mm)								
Maxillary intercanine width	36.14	2.79	36.6	2.10	0.521	37.99	2.05	0.067
Maxillary intermolar width	58.1	3.66	57.76	3.70	0.803	58.14	5.14	0.980

6, first molar; *7*, second molar; *8*, third molar; ***angulation***, the angle between the FH line projected on the sagittal plane and the long axis of the molar; ***rotation***, the angle between the sagittal plane projected on the horizontal plane and the crown axis of the molar; ***sagittal position***, distance from the mesiobuccal cusp of the maxillary molar to the horizontal plane; ***vertical position***, distance from the mesiobuccal cusp of the maxillary molar to the frontal plane; ***horizontal position***, distance from the mesiobuccal cusp of the maxillary molar to the sagittal plane; ***maxillary intercanine width***, distance between mesiobuccal cusps of the maxillary canines; ***maxillary intermolar width***, distance between mesiobuccal cusps of the maxillary first molars.
$^{*}P < 0.05$; $^{***}P < 0.0001$.

CI, 6.0°-8.7°) was greater, whereas changes in the third molar positions were insignificant.

In a long-term evaluation, molar angulation showed a distal tipping tendency in both groups compared with the control group. However, the eruption status of the second and third molars was not significantly different between group 1 to group 2 and control group 2, except for the vertical position of the third molar in group 1 ($P < 0.05$). Table III shows the long-term changes in MCPP-treated patients, and Table IV demonstrates the long-term difference between groups 1 and 2 compared with the control group 2.

DISCUSSION

After maxillary arch distalization, the second molar eruption and the location of the third molar buds in adolescents are of concern to clinicians. Insufficient space after the maxillary molar distalization might lengthen treatment duration because of the delayed eruption of the molars.[16,24]

However, no study has used CBCT to evaluate the positional changes of molars after maxillary distalization with developing second and third molars. Therefore, our study analyzed the treatment effect and maxillary molar position after distalization with and without the second molar eruption. The eruption level of the second molar to analyze the vertical position of the second molar was evaluated between groups 1 and 2. It was 8 mm longer in group 1 than in group 2 ($P < 0.001$).

In group 2, for those who had no second molar eruption, the positional change of the third molars was insignificant, but treatment time was shorter. In the long-term, the full eruption of the second molars and favorable position of the third molars were found after distalization. Therefore, the null hypothesis was rejected.

In our study, group 1 showed less distal tipping movement of the first and second molars by 0.9° and 3.2°, respectively, compared with respective values of 4.4° and 7.4° in group 2. This finding was in agreement with Kinzinger et al,7 who reported less distal tipping of the first and second molars in a group with second molar eruption (0.9° and 4.1° to the palatal plane, respectively) than in the group without second molar eruption (5.8° and 7.9°, respectively). We believe there was less tipping

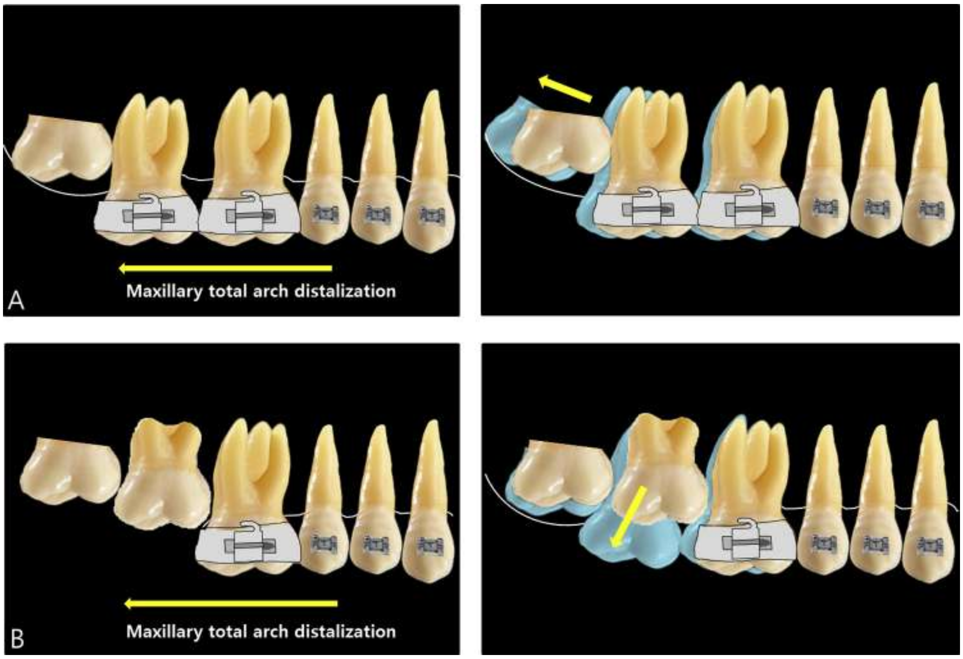

Fig 4. Schematic drawing of long-term evaluation after distalization with and without second molar eruption: **A,** less tipping movement of the first and second molars with a distal tipping movement of the third molars in group 1; **B,** distal tipping movement of first and second molars with the insignificant positional change of the third molars in group 2.

movement in our study because temporary anchorage devices were used, and a bracket or tube was placed on the second molars.

Regarding the positional changes of the third molars after distalization, group 1 showed greater distal tipping movement than group 2 (8.9° vs 3.0°). Although both groups showed similar Nolla stage 3-7 of the third molars, of which the crown or one-third of the root was completed, the smaller change in the position of the third molars in group 2 might have been because of a difference in the vertical positions of the first, second and third molars, which allowed 3D space for molar movement, inducing less of a backward pushing effect (Fig 4).[25]

To reduce pronounced tipping of the second molars, a germectomy of the third molars is recommended because they can function as a fulcrum during molar distalization.[7] However, their study included evaluation immediately after treatment with a small sample size of germectomy group and used 2-dimensional method, which has several disadvantages, including confounded images. In our study, CBCT images were analyzed to make a 3D determination of the positioning of the first, second, and third molars.[26,27]

The presence of a third molar showed no significant effect on molar distalization, which harmonizes with findings in another study.[10] Furthermore, Lee et al[19] reported that maxillary molars could be distalized in adolescents who retained their third molars. These findings may indicate that a germectomy may not be necessary before distalization in adolescents with partially formed third molars.[28-30]

In the long-term, there was an insignificant difference in the eruption status of the second and third molars between group 1, group 2, and control group 2, except for the vertical position of the third molar in group 1 (Fig 5). This means the second molars were able to fully erupt, and there was a developmental movement of the third molars after molar distalization regardless of whether there was second molar eruption or not as maxillary third molars consequentially develop downwards, backward, and often outwards.[31] Although results of other studies have consistently suggested the extraction of the third molars for molar distalization to produce a regional acceleratory phenomenon, this long-term evaluation supported the fact that distalization of molars is possible without extraction of developing third molars in adolescents, even before the eruption of the second molars.[32]

In our study, groups 1 and 2 before treatment showed similar skeletal Class II patterns compared to the control group 1. In addition, the amount of skeletal growth during distalization in groups 1 and 2 showed

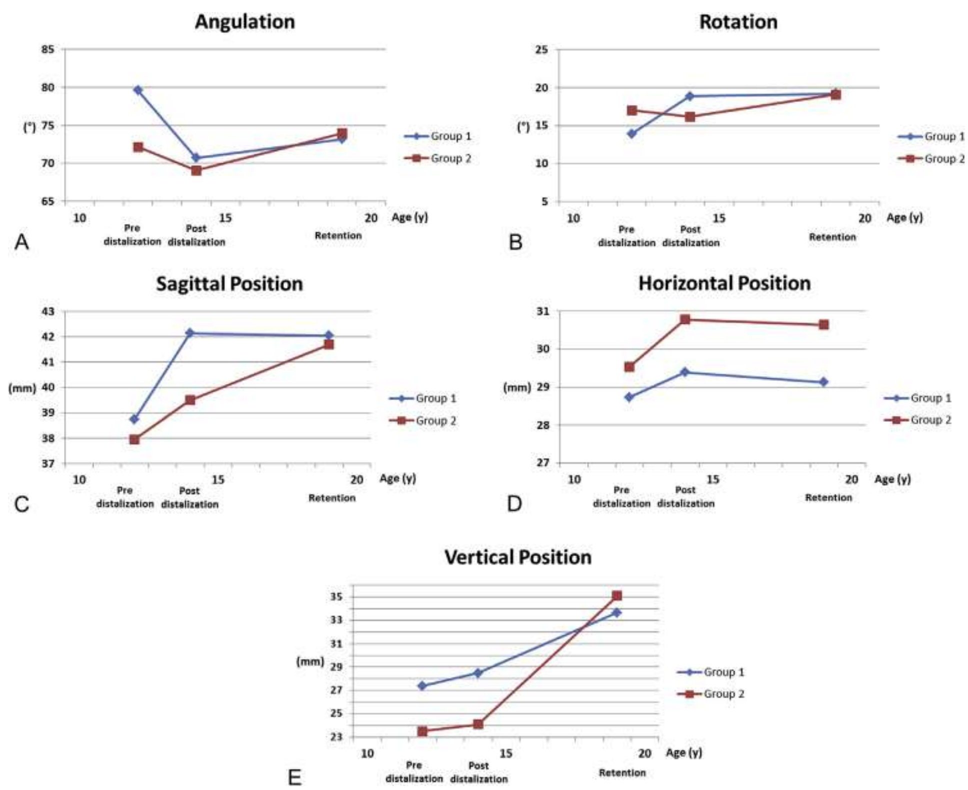

Fig 5. Line graphs of the positional changes of the maxillary third molars at predistalization, postdistalization, and retention between group 1 with the eruption of the second molars and group 2 without the eruption of the second molars: **A,** angulation; **B,** rotation; **C,** sagittal position, **D,** horizontal position; **E,** vertical position.

improvement of sagittal growth compared with control group 1 (Table II). Consistent with this result, Sa'aed et al[20] demonstrated a MCPP showed a significant skeletal effect on the maxilla in adolescents.

A limitation of this study was the small sample size, especially considering gender distribution. Moreover, this study used a matched control group with CBCT images taken for reasons other than the study, such as an impacted tooth or pathology because the longitudinal sample was limited because of ethical issues. Further studies need to focus on second and third molar changes after mandibular molar distalization combined with maxillary molar distalization. In this study, the eruption status of the second molar was used as a variable in a binary fashion with and without an eruption of the second molar. Therefore, a future study may be beneficial to evaluate the association between long-term retention changes and the level of vertical eruptive position of the second molars as a continuous variable.

CONCLUSIONS

We analyzed the treatment effects after molar distalization with and without the second molar eruption (groups 1 and 2), evaluated the 3D position of the molars during long-term retention, and found the following:

1. There was less tipping movement of the first and second molars and distal tipping movement of the third molars in group 1. Treatment time was shorter for group 2 and the positional change of the third molars was insignificant.
2. In the long-term, group 2 showed full eruption of the second molars after distalization and both groups showed a favorable position of the third molars.

These findings would suggest that clinicians do not need to extract developing third molars before distalization in adolescents.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Jou Hee Park: Conceptualization, Methodology, Software. **Yoonji Kim:** Writing – review & editing. **Jae Hyun Park:** Visualization, Investigation. **Nam-Ki Lee:** Supervision. **Seong-Hun Kim:** Software, Validation. **Yoon-Ah Kook:** Data curation, Writing – original draft.

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