AJO-DO

Short-term cone-beam computed tomography evaluation of maxillary third molar changes after total arch distalization in adolescents

Yoon-Jin Lee,[a] Yoon-Ah Kook,[a] Jae Hyun Park,[b] Justyn Park,[c] Mohamed Bayome,[d] Nikhilesh R. Vaid,[e] and Yoonji Kim[a]

Seoul, Korea, Mesa, Ariz, San Francisco, Calif, Asunción, Paraguay, and Dubai, United Arab Emirates

Introduction: Our objectives were to evaluate changes in the position of maxillary third molars with cone-beam computed tomography images in adolescents after total arch distalization using a modified C-palatal plate (MCPP) and to compare them with the changes in a matched control group. **Methods:** We included 68 maxillary third molars of 40 adolescent patients (mean age, 12.6 years). They were divided into MCPP and control groups. Cone-beam computed tomography images were taken before and after molar distalization (mean duration, 14.4 months) in the MCPP group and also in the control group (mean duration, 12.9 months). The changes in the position, angulation, and rotation of the third molars were assessed, and the volumes of maxillary tuberosity were measured. **Results:** After distalization, the third molars moved backward (1.2 mm) and upward (0.5 mm) in the MCPP group with a significant difference ($P < 0.003$), and they moved downward and forward in the control group. The changes in rotation and angulation were insignificant. The volumes of maxillary tuberosity increased in both groups. **Conclusions:** Maxillary total arch distalization caused unerupted third molars to move backward and upward, with an insignificant difference in the posttreatment volume of maxillary tuberosity. Therefore, it may be possible to perform maxillary total arch distalization in adolescents with unerupted third molars without a germectomy, at least in the short term. (Am J Orthod Dentofacial Orthop 2019;155:191-7)

Distalization of maxillary molars is a viable, nonextraction treatment option for patients with Class II malocclusion.[1-3] Extraoral appliances such as headgear are unesthetic and depend on patient cooperation. Although conventional intraoral appliances such as the pendulum and distal jet address compliance issues, the disadvantages of tooth-anchored appliances include loss of anchorage and distal tipping of the molars.[2,4,5] Bone-anchored pendulum appliances cause less anchorage loss, yet distal tipping of the molars remains unresolved.[3]

The modified C-palatal plate (MCPP) has been introduced as a simple and effective approach to maxillary molar distalization (Fig 1).[6,7] It does not require compliance and is effective in minimizing distal tipping and molar extrusion during distalization without anchorage loss. MCPPs have shown significant amounts of molar distalization in adolescents and adults, and they produce a skeletal effect on the maxilla that is comparable with headgear.[8]

Previous studies have reported the effect of the maxillary second molar eruption stage on distalization treatment. Several studies have suggested that the most effective time for maxillary molar distalization is before the maxillary permanent second molars have erupted,[4,9-11] although other studies have found minimal effects of the maxillary second molar eruption

[a]Department of Orthodontics, Seoul St. Mary's Hospital, Catholic University of Korea, Seoul, Korea.
[b]Postgraduate Orthodontic Program, Arizona School of Dentistry & Oral Health, A. T. Still University, Mesa; Graduate School of Dentistry, Kyung Hee University, Seoul, Korea.
[c]Dental School, University of California, San Francisco.
[d]Department of Postgraduate Studies, Universidad Autonoma del Paraguay, Asunción, Paraguay.
[e]European University College, Dubai, United Arab Emirates.
All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and none were reported.
Partly supported by funds from the Department of Dentistry and Graduate School of Clinical Dental Science, The Catholic University of Korea, Seoul, Korea.
Address correspondence to: Yoonji Kim, Department of Orthodontics, Seoul St. Mary's Hospital, Catholic University of Korea, 222 Banpo-daero, Seocho-Gu, Seoul, 06591 Korea; e-mail, juice@catholic.ac.kr; kyoonji@hotmail.com.
Submitted, January 2018; revised and accepted, April 2018.
0889-5406/$36.00

https://doi.org/10.1016/j.ajodo.2018.04.023

Fig 1. The MCPP placed on the palate of a patient. The most apical hook is engaged. It results in more intrusion and more root movement of the maxillary first molars compared with the other force vectors.[8]

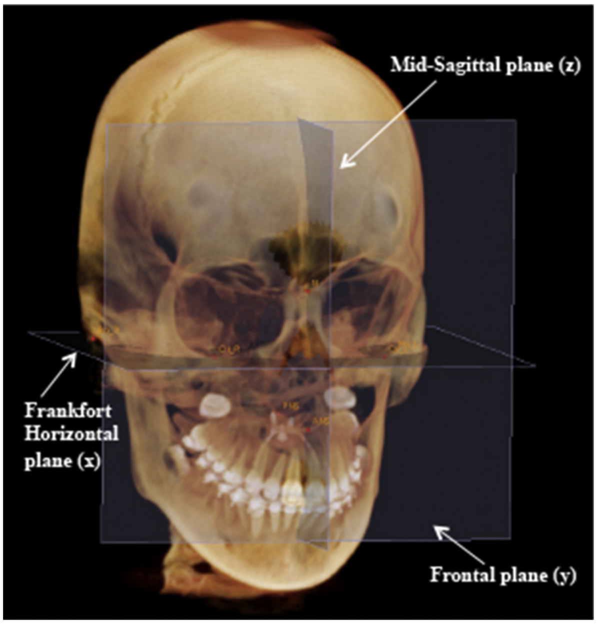

Fig 2. Reorientation of x, y, z reference planes using landmarks: *N*, nasion; *Po*, porion; *Or*, orbitale; *ANS*, anterior nasal spine; *PNS*, posterior nasal spine.

stage on molar distalization.[12,13] This is still a controversy.

Headgears have been shown to produce 2.3 mm of distalization and 4.3° of distal tipping of the first molars.[14] The conventional distal jet produced 2.7 mm of distalization and 5.0° of distal tipping.[4] In comparison, the MCPP has recently shown 2.7 mm of distalization and 2.0° of distal tipping in adults.[6] These results may suggest an effect on third molars, especially when they are unerupted, since the second molar will push back the third molar.

In adults with erupted maxillary third molars, extraction of the third molars is recommended so that the extraction site can make room for distalization and the regional acceleratory phenomenon can help with molar distalization. On the contrary, adolescents usually have unerupted third molars with partially formed roots[15]; the mean age of third molar alveolar emergence is 20 years.[16,17] Kinzinger et al[18] recommended a germectomy of the third molars before distalization using a pendulum appliance in young patients, so that bodily distalization of the molars can be achieved. However, the surgical extraction of unerupted third molars in adolescents might be difficult and traumatic. For this reason, germectomy of maxillary third molars before molar distalization should be carefully considered in young patients. To the best of our knowledge, no study has evaluated the effect of molar distalization on unerupted maxillary third molars in adolescents.

Therefore, the purpose of this study was to evaluate the effect of maxillary molar distalization with MCPPs on unerupted third molars. Changes in the position of the maxillary third molars and the volume of maxillary tuberosity after distalization were measured and compared with those in the control group.

MATERIAL AND METHODS

The study sample included 40 patients who visited the Department of Orthodontics at Seoul St. Mary's Hospital, Catholic University of Korea. Twenty subjects were consecutively treated with maxillary molar distalization using MCPP appliances (MCPP group: mean age, 12.5 years; SD, 1.2 years; 14 girls, 6 boys), and 20 had no treatment in the maxillary arch (control group: mean age, 12.7 years; SD, 1.1 years; 8 girls, 12 boys). The MCPP group included 33 maxillary third molars; 13 patients had both third molars, and 7 patients had 1 third molar. Cone-beam computed tomography (CBCT) images were taken before MCPP placement for a pretreatment evaluation of the anatomy and again after MCPP removal after distalization for the posttreatment evaluation of 3-dimensional (3D) effects (mean duration, 14.4 months).

The control group included 35 maxillary third molars; 15 patients had both maxillary third molars, and 5 patients had unilateral maxillary third molars. Two CBCT images (medium field of view) were taken (mean duration, 12.9 months) for other reasons such as an impacted tooth or pathology. Approval was obtained from the institutional review board of the Catholic University of Korea (KC11RASI0790), and informed consent was provided according to the Declaration of Helsinki. The sample size calculation showed that at least 23 third molars

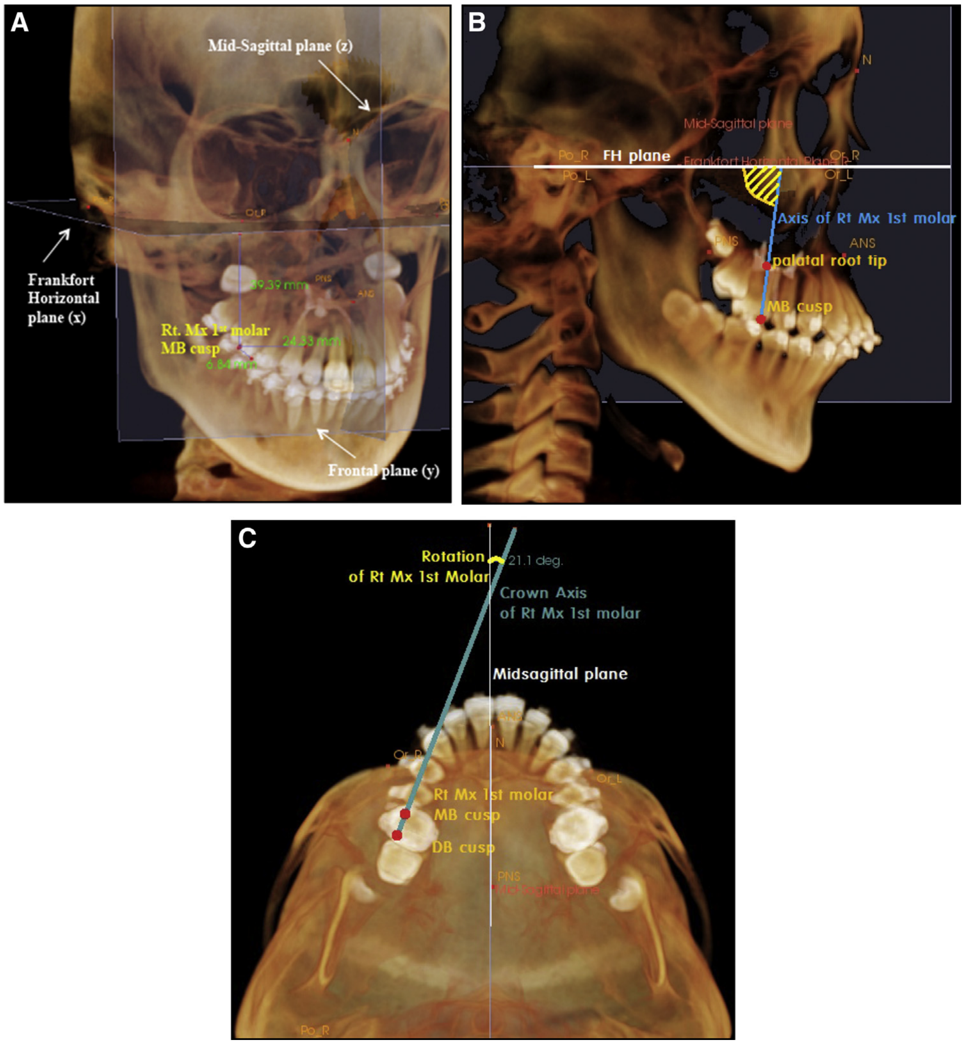

Fig 3. A, Position of the maxillary right first molar: the distance from the mesiobuccal cusp to the horizontal (*x*), frontal (*y*), and sagittal (*z*) planes. *Rt*, Right; *Mx*, maxillary; *MB*, mesiobuccal. **B,** Angulation of the maxillary first molar: the angle between the long axis of the first molar (mesiobuccal cusp-palatal root tip) and Frankfort horizontal plane projected on the sagittal (*z*) plane. *Rt*, Right; *Mx*, maxillary; *MB*, mesiobuccal. **C,** Rotation of maxillary first molar: the angle between the crown axis of the first molar (mesiobuccal cusp-distobuccal cusp) and sagittal (*z*) plane projected on the horizontal (*x*) plane. *Rt*, Right; *Mx*, maxillary; *MB*, mesiobuccal.

were required in each group to identify an effect size of 1.5 units, with an alpha of 0.05 and beta of 0.2 (www.clincalc.com). The inclusion criteria of the MCPP and control groups were (1) age from 11 to 14 years, (2) unerupted unilateral or bilateral maxillary third molars, (3) dental Class II relationship more than a quarter cusp, (4) mild to moderate maxillary crowding up to 5 mm, and (5) CBCT images of good quality. One operator (Y.A.K.) inserted the MCPPs with 3 miniscrews (diameter, 2.0 mm; length, 8 mm; Jeil, Seoul, Korea) in the paramedian area of the palate (Fig 1).[7] A palatal bar with 2 hooks was banded on the maxillary first molars. Elastics were connected from the MCPPs to the hooks of the palatal bar to apply approximately 300 g of force per side. The mean distalization period was 14.4 months. CBCT images were taken with an iCAT scanner (Imaging Sciences International, Hatfield, Pa), with a 200 × 400-mm field of view, 120 kV(p), and 47.7 mA, resulting in a voxel size of 0.4 mm.

The CBCT data were exported in DICOM multifile format and imported into Invivo software (version 5.3; Anatomage, San Jose, Calif) for 3D volume rendering.

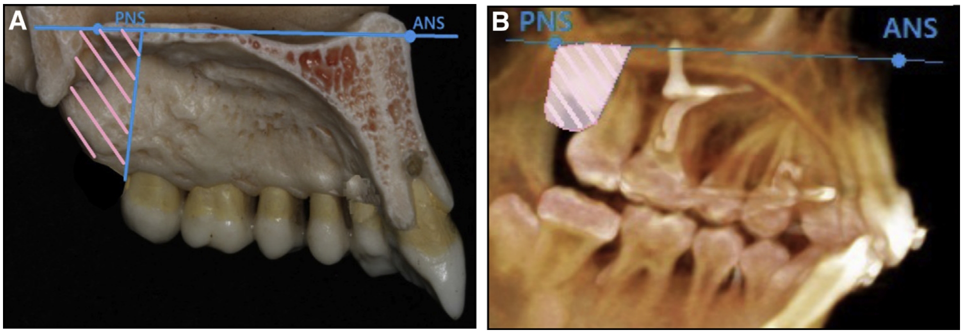

Fig 4. Volume of the maxillary tuberosity in the CBCT image: **A,** volume under the palatal plane (ANS-PNS) and posterior to the maxillary second molar; **B,** maxillary tuberosity in the CBCT image.

Table I. Baseline characteristics of subjects in the MCPP and control groups

	MCPP (n = 20)		*Control (n = 20)*	
	Mean	*SD*	*Mean*	*SD*
Patients (n)	20		20	
Third molar (n)	33		35	
Age (y)	12.4	1.27	12.65	1.14
Sex				
Male	6		12	
Female	14		8	
Treatment duration (mo)	14.4	6.35	12.9	4.04

Table II. Pretreatment evaluation of parameters

	MCPP		*Control*		
	Mean	*SD*	*Mean*	*SD*	P *value*
Volume (mm^3)	419.64	340.50	406.51	427.22	0.897
Angulation (°)					
6 axis with FH	94.80	5.95	99.11	6.36	0.004*
7 axis with FH	88.22	11.12	90.44	6.69	0.564
8 axis with FH	140.97	16.11	140.03	14.60	0.669
Rotation (°)					
6 Cr with midsag	11.26	6.71	11.42	7.44	0.524
7 Cr with midsag	5.53	3.62	6.74	6.14	0.102
8 Cr with midsag	15.15	11.88	13.19	9.07	0.873
Position (mm)					
6 MBcusp to midsag	26.30	2.54	26.66	2.24	0.878
6 MBcusp to horz	43.65	2.36	44.00	3.91	0.921
6 MBcusp to front	28.00	4.96	27.23	3.70	0.379
7 MBcusp to midsag	29.06	2.39	29.83	2.56	0.473
7 MBcusp to horz	37.16	4.92	38.90	4.58	0.178
7 MBcusp to front	36.60	4.55	36.11	3.71	0.497
8 MBcusp to midsag	28.59	2.53	29.36	2.62	0.591
8 MBcusp to horz	24.73	3.84	25.46	4.06	0.380
8 MBcusp to front	39.85	3.34	40.80	3.86	0.557

6, First molar; *7,* second molar; *8,* third molar; *Cr,* crown; *FH,* Frankfort horizontal plane; *MBcusp,* mesiobuccal cusp; *midsag,* midsagittal plane; *horz,* horizontal plane; *front,* frontal plane.
**P* <0.05.

Reorientation of the head position of each scan was performed as follows. The horizontal plane (x) was defined as the plane passing through the right orbitale and the right and left porions, and the sagittal plane (z) was defined by the plane perpendicular to the horizontal plane passing through anterior nasal spine and posterior nasal spine. The frontal plane (y) was defined as the perpendicular plane to x and z through nasion (Fig 2). All orientations and measurements were made by 1 examiner (Y.J.L.). Blinding was done for both the assessor and the biostatistician.

Six landmarks were digitized for reorientation: nasion, orbitale, bilateral porions, anterior nasal spine, and posterior nasal spine (Fig 2). Eight landmarks were digitized on each side of the dentition: the mesiobuccal and distobuccal cusps of the maxillary first, second, and third molars, and the palatal root tip of the maxillary first and second molars (Fig 3).

The software calculated the linear and angular dimensions between certain landmarks as follows.

The distances from the mesiobuccal cusps of the maxillary first, second, and third molars to the horizontal (x), frontal (y), and sagittal (z) planes were measured. The changes in vertical, transverse, and sagittal positions were calculated using the distance differences before and after distalization (Fig 3, *A*).

The angles between the long axes of the first and second molars (mesiobuccal cusp-palatal root tip) and the Frankfort horizontal line projected on the sagittal (z) plane were measured. The changes in mean tipping angles of the maxillary first and second molars before and after distalization were calculated (Fig 3, *B*).

The angles between the crown axes of the first, second, and third molars (mesiobuccal cusp-distobuccal cusp) and sagittal (z) plane projected on the horizontal (x) plane were measured. The changes in mean angles and mean rotations of the maxillary first, second, and

Table III. Treatment effects of the MCPP group compared with observed changes in the control group (similar time interval)

	MCPP		Control		
	Mean	*SD*	*Mean*	*SD*	P *value*
Volume (mm^3)	93.97	262.93	301.40	219.20	0.001†
Angulation (°)					
6 axis with FH	0.93	8.26	0.68	4.17	0.944
7 axis with FH	−1.28	11.98	0.51	6.43	0.380
8 axis with FH	−9.21	18.09	−1.11	17.62	0.078
Rotation (°)					
6 Cr with midsag	−0.42	7.88	−0.22	5.55	0.402
7 Cr with midsag	−0.40	4.08	−0.09	5.56	0.691
8 Cr with midsag	0.88	12.94	2.01	12.00	0.806
Position (mm)					
6 MBcusp to midsag	0.07	1.94	−0.03	2.02	0.886
6 MBcusp to horz	−0.35	2.13	1.84	2.21	<0.001‡
6 MBcusp to front	1.65	3.74	−0.88	2.31	<0.001‡
7 MBcusp to midsag	0.02	2.12	0.19	2.06	0.808
7 MBcusp to horz	0.60	2.62	3.14	2.92	0.001†
7 MBcusp to front	2.62	3.69	−0.67	2.36	<0.001‡
8 MBcusp to midsag	0.42	2.36	0.23	2.16	0.761
8 MBcusp to horz	−0.47	2.46	2.79	2.34	<0.001‡
8 MBcusp to front	1.21	3.45	−0.14	2.26	0.010*

6, First molar; *7*, second molar; *8*, third molar; *Cr*, crown; *FH*, Frankfort horizontal plane; *MBcusp*, mesiobuccal cusp; *midsag*, midsagittal plane; *horz*, horizontal plane; *front*, frontal plane.
*P <0.05; †P <0.001; ‡P <0.0001.

third molars before and after distalization were calculated (Fig 3, *C*).

The bone volume of the maxillary tuberosity was measured with the Invivo software. The volume of bone, under the palatal plane (ANS-PNS) and posterior to maxillary second molar, was measured (Fig 4).

Ten randomly selected subjects were reprocessed 4 weeks later to evaluate intraoperator reliability. The intraclass correlation coefficient showed that the measurements were reliable (>0.9).

To eliminate interexaminer reliability, a trained orthodontist (Y.J.L.) measured all subjects. Intraexaminer reliability scores confirmed the reliability of the CBCT measurements.

Statistical analysis

Statistical evaluations were performed with software (version 16.0; SPSS, Chicago, Ill). The Shapiro-Wilk test was used to confirm the normal distribution of the measurements. A paired *t* test was used to evaluate the changes between CBCT images in each group. A multivariate analysis of covariatestest was performed to evaluate the pretreatment and posttreatment differences and the treatment effects between the groups. Age and sex were the covariates. Statistical significance was set at 0.05, and the Bonferroni correction was applied.

Table IV. Posttreatment parameters of the MCPP group compared with those of the control group

	MCPP		Control		
	Mean	*SD*	*Mean*	*SD*	P *value*
Volume (mm^3)	513.61	329.81	707.91	538.81	0.090
Angulation (°)					
6 axis with FH	95.73	9.33	99.80	5.50	0.016*
7 axis with FH	86.94	17.08	90.95	5.83	0.283
8 axis with FH	131.77	22.48	138.92	12.51	0.164
Rotation (°)					
6 Cr with midsag	10.84	6.63	11.20	7.44	0.901
7 Cr with midsag	5.13	2.94	6.65	4.59	0.114
8 Cr with midsag	16.03	11.54	15.20	12.53	0.905
Position (mm)					
6 MBcusp to midsag	26.37	2.14	26.64	1.79	0.969
6 MBcusp to horz	43.30	2.84	45.85	3.31	0.007*
6 MBcusp to front	29.65	5.35	26.34	3.58	<0.001‡
7 MBcusp to midsag	29.08	2.25	30.03	2.26	0.303
7 MBcusp to horz	37.77	5.56	42.04	3.43	0.001†
7 MBcusp to front	39.23	4.84	35.44	3.34	<0.001‡
8 MBcusp to midsag	29.01	2.38	29.59	2.45	0.780
8 MBcusp to horz	24.26	4.50	28.25	3.40	<0.001‡
8 MBcusp to front	41.05	4.44	40.65	3.54	0.159

6, First molar; *7*, second molar; *8*, third molar; *Cr*, crown; *FH*, Frankfort horizontal plane; *MBcusp*, mesiobuccal cusp; *midsag*, midsagittal plane; *horz*, horizontal plane; *front*, frontal plane.
*P <0.05; †P <0.001; ‡P <0.0001.

RESULTS

Table I shows the distributions of subjects in the MCPP and control groups. There were no significant differences in ages and times between the groups. Table II demonstrates that the pretreatment variables were also insignificantly different between the 2 groups (P <0.003).

Table III describes the comparison of treatment effects in the MCPP group with those of the control at a similar time interval. The positions of the maxillary first, second, and third molars had significant differences (P <0.001). Although the maxillary first, second, and third molars moved downward and forward during the eruption process in the control group, the molars moved backward and upward in the MCPP group. The first and third molars moved 0.35 and 0.47 mm upward, respectively, in the MCPP group; the first, second, and third molar moved 1.8, 3.1, and 2.8 mm downward, respectively, in the control group. The first, second, and third molars moved 1.7, 2.6, and 1.2 mm backward, respectively, in the MCPP group, and they moved 0.9, 0.7, and 0.1 mm forward in the control group. Although the volume of maxillary tuberosity increased in both groups, the

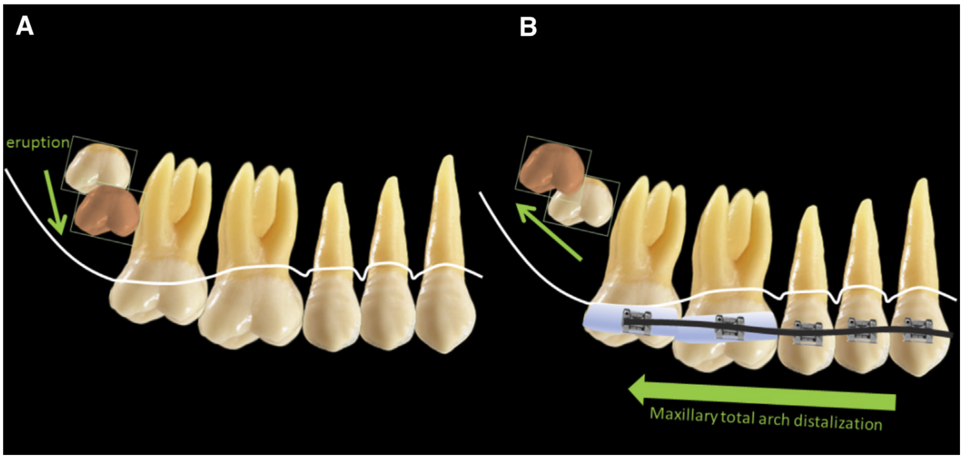

Fig 5. Differences in third molar positions in the control and MCPP groups: **A,** the control group had a downward and forward pattern of movement; **B,** the MCPP group had a backward and upward pattern of movement.

amount of increase was significantly greater in the control group. The posttreatment comparison of the volume of maxillary tuberosity showed no difference ($P = 0.09$).

Table IV shows the posttreatment parameters of the MCPP group compared with those of the control group. The sagittal positions of the first and second molars, and the vertical positions of the second and third molars were significantly different. The angulation and rotation of the molars showed no differences. The volume of maxillary tuberosity also showed no significant difference between the groups.

DISCUSSION

Increased application of molar distalization for Class II treatment has caused interest in position changes of the second and third molars, especially in adolescents. Therefore, in this study, we focused on the maxillary third molar positions after maxillary molar distalization.

In this study, the MCPP group showed 1.7 mm of distalization of the maxillary first molars. This amount of distalization was smaller than in previous studies.[6,7] However, compared with the control group, which showed a 0.9-mm mesial drift of the first molars, the actual amount of distalization could be larger. The amount of distalization was comparable with another study that used MCPPs in adults.[7]

Kinzinger et al[18] assessed the effects on the third molars after maxillary molar distalization with a modified pendulum. The third molar tooth bud acted as a fulcrum so that tipping of the second molar was pronounced: 7.9° to the palatal plane during 2.6 mm of distalization. Kang et al[19] also evaluated this effect using a 3D finite element analysis. The presence or absence of a third molar follicle had no significant effect on first molar movement. However, in our study, the maxillary molars were distalized without distal tipping or rotation with a third molar follicle with 1.3° of distal tipping of the angulation and 0.4° of distal rotation during 2.6 mm of distalization.

The maxillary third molars erupt downward, backward, and often outward.[20] Control group patients showed 0.1 mm of forward and 2.3 mm of downward movement. In the MCPP group, the third molars moved 1.2 mm backward and 0.5 mm upward. However, in the MCPP group, the maxillary third molars moved in a direction opposite to that of the control group (Fig 5).

On comparing the 2 groups, we found that the volume increased by 94.0 mm^3 in the MCPP group and 301.4 mm^3 in the control group. Authors of a previous study evaluated the maxillary tuberosity bone dimensions after distalization with MCPPs in adults and found that the total retromolar bone length—the distance between the curvature of the maxillary tuberosity and cementoenamel junction of the second molars projected on the midsagittal plane—showed a significant increase of 0.57 mm during treatment.[21] Our study also demonstrated increases of maxillary tuberosity in both groups. Although the mean change in the volume was significantly greater in the control group compared with the MCPP group, the posttreatment comparison showed no difference ($P = 0.09$), possibly due to large individual variability.

Because our subjects were adolescents, a matched control group was necessary to evaluate the effects of maxillary distalization on the unerupted third molars in stages 3 to 7 of Nolla.[22] Another limitation of our study was the sex distributions in the groups. Since this was a sample of growing patients, sex can be a confounding factor.

CBCT images provide more accurate location and morphology of impacted teeth. Also, 3D volume analysis can be performed with high precision.[23] Because our study focused on unerupted maxillary third molars, CBCT images were necessary to accurately locate landmarks on third molars in the bone. The position, angulation, and rotation of maxillary molars from 3D perspectives were observed. Also, the volume of maxillary tuberosity was evaluated with CBCT images.

Our findings could be helpful in understanding maxillary molar distalization before third molar eruption. In the MCPP group, molar distalization was successful without a germectomy, and the third molars moved backward and upward. So, in adolescent patients with unerupted third molars that need distalization, clinicians can distalize the molars without removal of the developing third molars at this stage. Assessment of the third molar positions after distalization over a long term will be needed in a future study.

CONCLUSIONS

This study was retrospective; in its confines, we made the following observations.

1. Maxillary distalization caused the unerupted third molars to move backward and upward in the MCPP group, whereas in the control group, they moved downward and forward.
2. Although the amount of increase in the volume of maxillary tuberosity after distalization was smaller in the MCPP group than in the control group, there were no significant differences between the groups.

The results of this study suggest that distalization in adolescents with unerupted third molars may be done.

REFERENCES

1. Nanda RS, Dandajena CT, Nanda R. Nonextraction Class II correction. In: Nanda R, editor. Esthetics and biomechanics in orthodontics. 2nd ed. St Louis: Elsevier Health Sciences; 2015. p. 206.
2. Bolla E, Muratore F, Carano A, Bowman SJ. Evaluation of maxillary molar distalization with the distal jet: a comparison with other contemporary methods. Angle Orthod 2002;72:481-94.
3. Kircelli BH, Pektaş ZÖ, Kircelli C. Maxillary molar distalization with a bone-anchored pendulum appliance. Angle Orthod 2006;76:650-9.
4. Bussick TJ, Mcnamara JA. Dentoalveolar and skeletal changes associated with the pendulum. Am J Orthod Dentofacial Orthop 2000;117:333-43.
5. Antonarakis GS, Kiliaridis S. Maxillary molar distalization with noncompliance intramaxillary appliances in class II malocclusion: a systematic review. Angle Orthod 2008;78:1133-40.
6. 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.
7. Park CO, Sa'aed NL, Bayome M, Park JH, Kook YA, Park YS, et al. Comparison of treatment effects between the modified C-palatal plate and cervical pull headgear for total arch distalization in adults. Korean J Orthod 2017;47:375-83.
8. Sa'aed NL, Park CO, Bayome M, Park JH, Kim YJ, Kook YA. Skeletal and dental effects of molar distalization using a modified palatal anchorage plate in adolescents. Angle Orthod 2015;85:657-64.
9. Karlsson I, Bondemark L. Intraoral maxillary molar distalization: movement before and after eruption of second molars. Angle Orthod 2006;76:923-9.
10. Gianelly AA. Distal movement of the maxillary molars. Am J Orthod Dentofacial Orthop 1998;114:66-72.
11. Shpack N, Brosh T, Mazor Y, Shapinko Y, Davidovitch M, Sarig R, et al. Long- and short-term effects of headgear traction with and without the maxillary second molars. Am J Orthod Dentofacial Orthop 2014;146:467-76.
12. Flores-Mir C, McGrath L, Heo G, Major PW. Efficiency of molar distalization associated with second and third molar eruption stage a systematic review. Angle Orthod 2013;83:735-42.
13. Nienkemper M, Wilmes B, Pauls A, Yamaguchi S, Ludwig B, Drescher D. Treatment efficiency of mini-implant-borne distalization depending on age and second-molar eruption. J Orofac Orthop 2014;75:118-32.
14. Taner TU, Yukay F, Pehlivanoglu M, Çakirer B. A comparative analysis of maxillary tooth movement produced by cervical headgear and pend-x appliance. Angle Orthod 2003;73:686-91.
15. Liversidge HM. Timing of human mandibular third molar formation. Ann Hum Biol 2008;35:294-321.
16. Schmeling A, Olze A, Pynn BR, Kraul V, Schutz R, Heineke A, et al. Dental age estimation based on third molar eruption in First Nations people of Canada. J Forensic Odontostomatol 2010;28:32-8.
17. Shaweesh AI. Timing of clinical eruption of third molars in a Jordanian population. Arch Oral Biol 2016;72:157-63.
18. Kinzinger GS, 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.
19. 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.
20. Bennett JC, McLaughlin RP. Orthodontic management of the dentition with the preadjusted appliance. 1st ed. Oxford, United Kingdom: ISIS Medical Media; 1997.
21. Park T, Sameshima GT. Three dimensional analysis of maxillary retromolar alveolar bone before and after en-masse distalization [thesis]. Los Angeles: University of Southern California; 2016.
22. Nolla CM. The Development of the Permanent Teeth. J Dent Child 1952;4:254-66.
23. Liu Y, Olszewski R, Alexandroni ES, Enciso R, Xu T, Mah JK. The validity of in vivo tooth volume determinations from cone-beam computed tomography. Angle Orthod 2010;80:160-6.