

Skeletal and dental effects of molar distalization using a modified palatal anchorage plate in adolescents

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ABSTRACT

Objective: To evaluate and compare skeletal effects and the amount of molar distalization in maxilla using modified palatal anchorage plate (MPAP) vs headgear appliances in adolescent patients.

Materials and Methods: Pre- and posttreatment lateral cephalograms of 45 Class II malocclusion patients were analyzed; 24 were treated with MPAP appliances (age, 12.4 years) and 21 with headgear (age, 12.1 years). Fixed orthodontic treatment started with the distalization process in both groups. Thirty-two variables were measured and compared between both groups using multivariate analysis of covariates.

Results: There was no significant main effect of the appliance type on the treatment results ($P = .063$). Also, there was no significant main effect of the appliance type on both pre- and posttreatment comparisons ($P = .0198$ and $.135$, respectively). The MPAP and headgear groups showed significant distalization of maxillary first molars (3.06 ± 0.54 mm and 1.8 ± 0.58 mm, respectively; $P < .001$). Sagittal skeletal maxillomandibular differences were improved after treatment ($P < .001$), with no significant differences between the two groups. No significant difference in treatment duration was found between the groups.

Conclusions: The MPAP showed a significant skeletal effect on the maxilla. Both MPAP and headgear resulted in distalization of maxillary first molars. Therefore, it is recommended that clinicians consider the application of MPAP, especially in noncompliant Class II patients. (*Angle Orthod.* 2015;85:657–664.)

KEY WORDS: Modified palatal anchorage plate; Maxillary molar distalization; Headgear; Skeletal effect

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INTRODUCTION

It is challenging to perform distalization of maxillary molars without tipping and extrusion that could cause relapse. Traditionally, headgear has shown successful results in Class II treatment.^{1,2} While its effect is a combination of distal movement of molars, inhibition of maxillary growth, and rotation of the palate,^{3,4} it is dependent on patient cooperation and may cause psychological distress.^{5,6} Also, it is difficult to achieve bodily tooth movement.

To avoid the negative aspects of headgear, several intraoral appliances such as distal jet, Herbst, and pendulum springs have been developed to distalize molars^{7–9}; however, they have some drawbacks. For

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Figure 1. The MPAP placed on the palate of a patient with late mixed dentition.

instance, the distal jet has been known to lead to mesial rotation of the molars during distalization, and the pendulum appliance has resulted in distal tipping of molars, anchorage loss, and a tendency for reciprocal effects.^{10–12} In general, the side effects of these appliances are anchorage loss at the reactive part causing flaring of the incisors, distal tipping, and rotation of the distalized molars.

To reduce these shortcomings, several studies have considered the application of temporary anchorage devices (TADs).^{13,14} TADs have been applied to the buccal plate of bone to achieve molar distalization.^{15–17} However, the buccal approach poses an increased risk of contact with the roots of adjacent teeth, and the range of action might be limited by the interradi- cular space in adolescents.

Table 1. Demographic Data^a

		MPAP Group (n = 24)	Headgear Group (n = 21)	P Value
Gender	Male	6	11	.073
	Female	18	10	
Severity	1/4 cusp	8	4	.636
	1/2 cusp	6	8	
	3/4 cusp	8	8	
	Full cusp	2	1	
Second molar eruption status	Erupted	16	6	.025
	Coronal	7	13	
	Middle	1	2	
Skeletal age	CVS 1	2	0	.128
	CVS 2	1	5	
	CVS 3	10	7	
	CVS 4	11	8	
	CVS 5	0	1	
	CVS 6	0	1	

^a MPAP indicates modified palatal anchorage plate; Coronal, the crown of the second molar is within the vertical level of the coronal third of the first molar root; Middle, the crown of the second molar is within the vertical level of the middle third of the first molar root. Chi-square test.

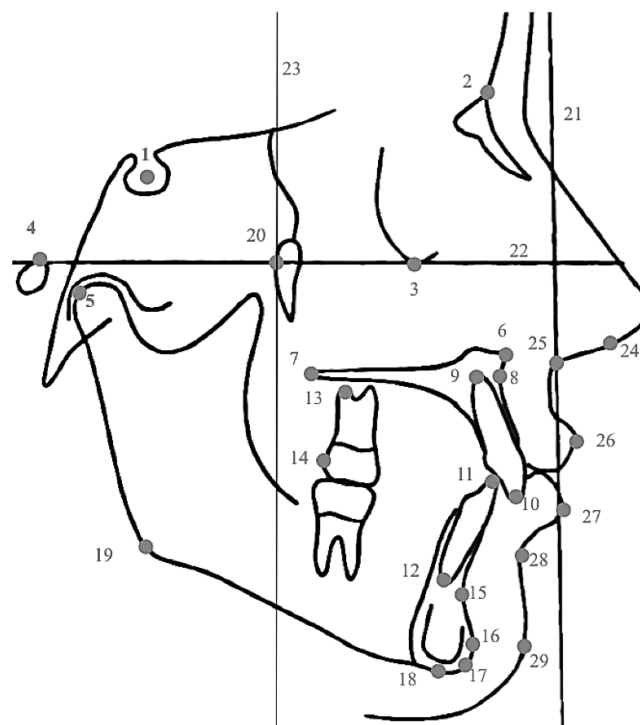


Figure 2. Landmarks and reference lines: 1, sella; 2, nasion; 3, orbitale; 4, porion; 5, condylion; 6, anterior nasal spine (ANS); 7, posterior nasal spine (PNS); 8, a point; 9, maxillary central incisor root apex; 10, maxillary central incisor incisal edge; 11, mandibular central incisor incisal edge; 12, mandibular central incisor root apex; 13, maxillary first molar root apex; 14, maxillary first molar crown; 15, B point; 16, pogonion; 17, gnathion; 18, menton; 19, gonion; 20, pterygoid point; 21, true vertical line; 22, Frankfort horizontal plane; 23, vertical reference line; 24, columella; 25, subnasale; 26, upper lip; 27, lower lip; 28, soft tissue B point; 29, soft tissue pogonion.

Triaca et al.¹⁸ have introduced the palate for skeletal anchorage. The placement of TADs in the palate eliminates the need for reimplanting mini-screws as in the buccal approach. Therefore, palatal bone thickness and density as well as palatal soft tissue thickness have recently been evaluated in adolescents.^{19–21}

Currently, the modified palatal anchorage plate (MPAP) offers a simple and effective nonextraction approach for distalization of the maxillary dentition in adults.²² However, the effect of palatal plates on the growth of the maxilla has not been evaluated. Moreover, no comparison has been made of the treatment effects with MPAP appliances vs headgear.

Therefore, the purpose of this study was to evaluate the amount of molar distalization and skeletal effects in maxilla resulting from molar distalization using MPAPs and to compare these effects with those of headgear appliances in adolescent patients.

MATERIALS AND METHODS

The sample of this retrospective study consisted of lateral cephalograms of 45 Class II division 1

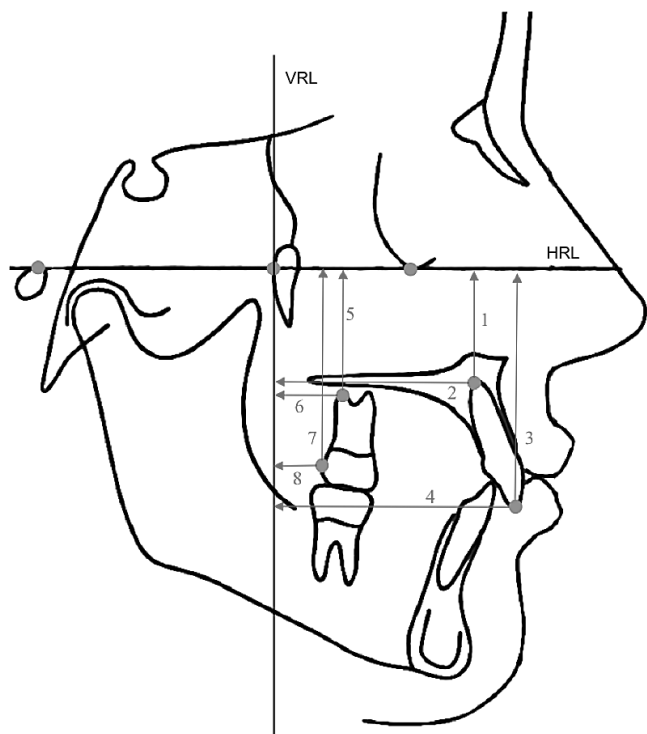


Figure 3. Linear measurements: 1, vertical distance of maxillary central incisor root apex to horizontal reference line (HRL); 2, horizontal distance of maxillary central incisor root apex to vertical reference line (VRL); 3, vertical distance of maxillary central incisor crown to HRL; 4, horizontal distance of maxillary central incisor crown to VRL; 5, vertical distance of maxillary first molar root apex to HRL; 6, horizontal distance of maxillary first molar root apex to VRL; 7, vertical distance of maxillary first molar crown to HRL; 8, horizontal distance of maxillary first molar crown to VRL.

malocclusion patients; 24 were treated with MPAP appliances (age, 12.42 ± 1.69 years; 18 girls) at the Department of Orthodontics, Seoul St. Mary's Hospital, The Catholic University of Korea, and 21 with cervical pull headgear (age, 12.05 ± 1.40 years; 10 girls) at a private practice office. The inclusion criteria were age range from 10 to 16 years, Class II division 1 malocclusion with normal divergent growth pattern, moderate maxillary crowding (<5 mm) and protrusion, nonextraction treatment, molar distalization via either MPAPs or headgear exclusively, and absence of craniofacial syndromes. Approval to conduct this study was granted by the Institutional Review Board (KC11RASI0790).

The MPAP appliance has been described previously.^{23,24} The MPAPs were installed by a single operator using three 8-mm-length and 2.0-mm-diameter mini-screws (Jeil Corporation, Seoul, Korea) in the paramedian area to avoid interference with the growth of the suture. A palatal bar with two hooks extending along the gingival margins of the teeth was bonded to the maxillary first molars. Distalization was initiated by

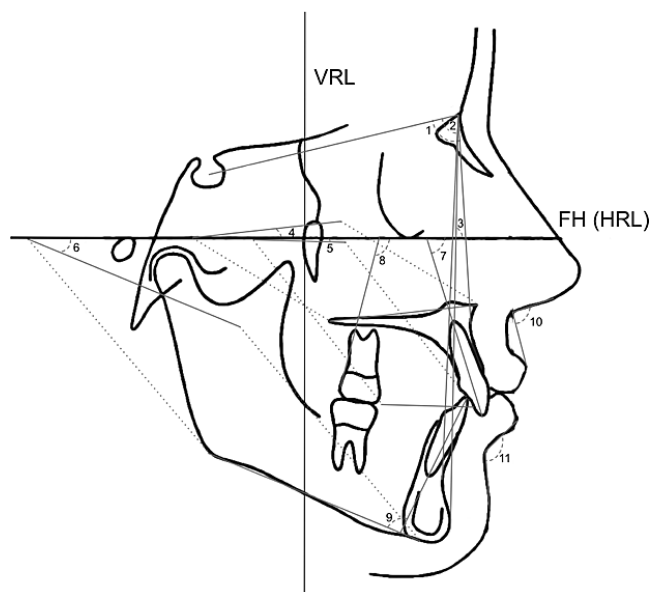


Figure 4. Angular measurements: 1, SNA; 2, SNB; 3, facial angle (FH/N-Pg); 4, palatal plane angle (FH/ANS-PNS); 5, occlusal plane angle (FH/OP); 6, mandibular plane angle (FH/Go-Me); 7, maxillary central incisor inclination; 8, maxillary first molar inclination; 9, incisor mandibular plane angle (IMPA); 10, nasolabial angle; 11, mentolabial fold angle.

engaging elastics or NiTi closed-coil springs between the MPAP arm notches and the hooks on the palatal bar, applying approximately 300 g of force per side (Figure 1).

All headgear cases (cervical pull) were treated by one operator. The outer bows of the headgear were adjusted upward to pass close to the center of resistance of the maxillary first molars. Each patient was given a wearing-time recording card for motivation, and most of the patients reported satisfactory records.

Table 1 shows the demographic data of the two groups including the severity of Class II molar relationship (very mild, 1/4 cusp; mild, 1/2 cusp; moderate, 3/4 cusp; and severe, full cusp), the eruption status of the maxillary second molar, and the skeletal age according to the method of Baccetti et al.²⁵

Cephalometric Measurements

The pre- (T1) and posttreatment (T2) lateral cephalograms were digitized using V-Ceph 5.5 (Cybermed, Seoul, South Korea). The horizontal reference line was the FH plane, and the vertical reference line was a perpendicular line passing through the pterygoid. Thirty-two linear and angular measurements were made by one examiner (Figures 2–4). Differences between T1 and T2 were calculated.

Table 2. Comparison Between Cephalometric Variables of MPAP and Headgear Groups at Pretreatment^a

Variable	MPAP Group		Headgear Group		95% CI		P Value
	Mean	SE	Mean	SE	Lower Bound	Upper Bound	
Skeletal							
SNA, °	82.13	0.65	82.21	0.69	−2.06	1.89	.933
SNB, °	76.45	0.72	76.92	0.78	−2.68	1.74	.669
ANB, °	5.68	0.31	5.29	0.33	−0.55	1.32	.405
Wits, mm	1.38	0.65	1.84	0.70	−2.45	1.53	.646
Havold, mm	23.85	0.97	21.49	1.04	−0.59	5.32	.114
Facial angle, °	87.30	0.70	86.69	0.76	−1.55	2.76	.572
Palatal plane angle, °	−2.34	0.68	−0.31	0.73	−4.11	0.05	.055
Mandibular plane angle, °	27.46	0.94	26.27	1.01	−1.68	4.06	.408
A-point to N perpendicular, mm	2.66	0.87	1.64	0.93	−1.64	3.67	.444
A-point to TVL, mm	11.88	0.41	12.31	0.44	−1.67	0.81	.487
B-point to TVL, mm	20.24	0.69	20.81	0.74	−2.67	1.52	.584
Maxillary length, mm	86.18	1.29	90.35	1.38	−8.10	−0.24	.038
Mandibular length, mm	110.03	1.63	111.84	1.76	−6.81	3.19	.469
Dental							
First molar crown−VRL, mm	13.99	0.64	17.03	0.68	−4.98	−1.09	.003
First molar root−VRL, mm	19.29	0.57	22.62	0.61	−5.07	−1.58	<.001
First molar cusp−FH, mm	43.12	0.86	43.89	0.93	−3.41	1.87	.559
First molar root−FH, mm	30.73	0.74	30.86	0.80	−2.40	2.14	.91
First molar−FH angle, °	113.45	1.11	112.99	1.19	−2.94	3.85	.787
Central incisor crown−VRL, mm	55.06	1.14	57.42	1.22	−5.84	1.12	.178
Central incisor root−VRL, mm	45.62	0.76	48.33	0.82	−5.04	−0.38	.024
Central incisor crown−FH, mm	54.73	1.01	55.76	1.08	−4.11	2.04	.499
Central incisor root−FH, mm	37.03	0.82	38.43	0.88	−3.89	1.10	.264
Central incisor−FH angle, °	61.84	1.58	62.44	1.69	−5.43	4.22	.802
Occlusal plane angle, °	11.46	1.02	11.06	1.09	−2.70	3.50	.796
IMPA, °	95.32	1.45	95.01	1.55	−4.11	4.74	.886
Overjet, mm	5.03	0.33	5.80	0.35	−1.77	0.24	.132
Overbite, mm	3.75	0.22	4.07	0.24	−0.99	0.36	.358
Soft tissue							
Nasolabial angle, °	93.17	1.90	95.45	2.04	−8.08	3.51	.43
Mentolabial fold, °	132.03	2.16	130.17	2.32	−4.74	8.46	.572
Upper lip to TVL, mm	5.74	0.50	4.90	0.53	−0.67	2.36	.265
Lower lip to TVL, mm	3.14	0.46	2.69	0.50	−0.96	1.87	.519
Soft tissue pgonion to TVL, mm	5.01	0.74	5.88	0.80	−3.14	1.41	.448

^a MANCOVA, adjusted means according to second molar eruption status. MPAP indicates modified palatal anchorage plate; TVL, true vertical line; VRL, vertical reference line; CI, confidence interval for difference. Significance level: $P < .016$ according to Bonferroni correction.

Ten randomly selected cases from each group were redigitized and analyzed 2 weeks later by the same examiner. Intraexaminer reliability was evaluated by intraclass correlation coefficient and was $>.9$.

Statistical Analysis

Statistical evaluation was performed using SPSS 16.0 (SPSS Inc, Chicago, Ill). Paired t -test was used to evaluate the skeletal, dental, and soft tissue changes from T1 to T2 within each group. A multivariate analysis of covariates (MANCOVA) was performed to evaluate the differences pre- and posttreatment and the treatment effects between the groups. An independent-sample t -test showed no significant difference in age ($P = .433$), and a chi-square test showed no significant differences in frequency distribution of gender ($P = .073$), severity ($P = .636$), or skeletal

age ($P = .128$) between the groups. However, a significant difference was found in the second molar eruption status ($P = .025$; Table 1). Therefore, this variable was used as a covariate in the MANCOVA. Statistical significance was set at .05, and by applying Bonferroni correction, it became .0016.

RESULTS

There was no significant main effect of the type of the appliance on the comparison of pre- and post-treatment variables ($P = .198$ and .135, respectively; Tables 2 and 3). Also, there was no significant effect of the second molar eruption status on both comparisons ($P = .384$ and .532, respectively). Similarly, there was no significant main effect of the type of the appliance or second molar eruption status on the treatment effects ($P = .063$ and .396, respectively; Table 4).

Table 3. Comparison Between Cephalometric Variables of MPAP and Headgear Groups at Posttreatment^a

Variable	MPAP Group		Headgear Group		95% CI		P Value
	Mean	SE	Mean	SE	Lower Bound	Upper Bound	
Skeletal							
SNA, °	80.2	0.8	80.3	0.9	−2.62	2.38	.924
SNB, °	76.0	0.8	77.3	0.9	−3.87	1.31	.323
ANB, °	4.2	0.3	3.0	0.3	0.36	1.97	.006
Wits, mm	−1.1	0.5	−1.0	0.6	−1.71	1.54	.914
Havold, mm	25.8	1.0	26.3	1.0	−3.47	2.45	.729
Facial angle, °	86.3	0.6	87.2	0.7	−2.78	0.97	.336
Palatal plane angle, °	−1.8	0.7	0.5	0.8	−4.62	−0.11	.04
Mandibular plane angle, °	28.7	1.0	27.0	1.1	−1.35	4.65	.274
A-point to N perpendicular, mm	−0.3	0.8	−1.0	0.9	−1.92	3.26	.604
A-point to TVL, mm	14.8	0.4	15.2	0.5	−1.69	0.92	.556
B-point to TVL, mm	22.5	0.7	21.1	0.8	−0.88	3.68	.223
Maxillary length, mm	88.1	1.3	91.0	1.4	−6.87	1.00	.139
Mandibular length, mm	113.8	1.8	117.3	1.9	−8.99	2.10	.216
Dental							
First molar crown−VRL, mm	10.9	0.8	15.2	0.8	−6.67	−1.94	.001
First molar root−VRL, mm	16.2	0.7	21.1	0.7	−7.08	−2.82	<.001
First molar cusp−FH, mm	44.8	1.0	46.8	1.0	−4.93	0.98	.185
First molar root−FH, mm	31.8	0.9	33.4	0.9	−4.26	1.04	.227
First molar−FH angle, °	111.9	1.2	113.8	1.2	−5.44	1.64	.286
Central incisor crown−VRL, mm	51.7	1.0	55.7	1.0	−6.90	−1.01	.01
Central incisor root−VRL, mm	44.5	0.9	46.7	1.0	−4.98	0.71	.137
Central incisor crown−FH, mm	57.9	1.0	58.2	1.1	−3.48	2.80	.828
Central incisor root−FH, mm	38.4	0.9	41.0	0.9	−5.24	0.04	.054
Central incisor−FH angle, °	69.5	1.2	62.4	1.3	3.35	10.84	<.001
Occlusal plane angle, °	13.6	0.9	11.3	1.0	−0.42	5.04	.095
IMPA, °	94.5	1.3	98.7	1.4	−8.20	−0.16	.042
Overjet, mm	2.9	0.1	2.7	0.1	−0.08	0.31	.237
Overbite, mm	2.6	0.1	2.4	0.1	−0.09	0.54	.156
Soft tissue							
Nasolabial angle, °	95.8	2.0	95.3	2.1	−5.48	6.62	.851
Mentolabial fold, °	131.4	2.6	130.5	2.8	−7.12	8.96	.818
Upper lip to TVL, mm	4.5	0.5	3.9	0.5	−0.86	1.96	.435
Lower lip to TVL, mm	2.5	0.4	3.1	0.4	−1.86	0.65	.335
Soft tissue pogonion to TVL, mm	5.5	0.5	4.6	0.5	−0.62	2.42	.239

^a MANCOVA, adjusted means according to second molar eruption status. MPAP indicates modified palatal anchorage plate; TVL, true vertical line; VRL, vertical reference line; CI, confidence interval for difference. Significance level: $P < .016$ according to Bonferroni correction.

Several skeletal variables showed significant changes between pre- and posttreatment values within each group. ANB decreased $1.53^\circ \pm 0.24^\circ$ in the MPAP group and $2.30^\circ \pm 0.26^\circ$ in the headgear group. The Wits also decreased 2.44 ± 0.50 mm and 2.81 ± 0.54 mm, respectively ($P < .001$; Table 4). Nonetheless, there was no significant difference between the groups regarding all of the skeletal variables based on univariate analysis (Table 4).

Sagittally, the amounts of distal movement of the maxillary first molar crown were 3.06 ± 0.54 mm in the MPAP group and 1.8 ± 0.58 mm in the headgear group. Meanwhile, the first molar root was distalized 3.11 ± 0.48 mm and 1.49 ± 0.51 mm, respectively. Vertically, the MPAP group showed slight extrusion of the maxillary first molar (-1.66 ± 0.55 mm), while the headgear group demonstrated significant extrusion ($-2.87 \pm$

0.59 mm; $P < .001$). In addition, both groups showed no significant distal tipping of the maxillary first molar ($P = .502$ and $.993$, respectively). However, univariate analysis showed no significant difference between the groups regarding dental variables (Table 4).

For the central incisor, the MPAP group showed significant retraction, extrusion, and lingual inclination ($P < .001$), while the headgear group showed significant extrusion ($P < .001$). Nevertheless, univariate analysis showed no significant difference between the groups regarding these variables (Table 4).

Regarding soft tissue, in the MPAP group, the upper lip was significantly retracted (1.25 ± 0.33 mm; $P < .001$), and the nasolabial angle was increased $-2.67^\circ \pm 1.81^\circ$, although not significantly. Likewise, in the headgear group, the change was not significant (0.96 ± 0.35 mm and $0.18^\circ \pm 1.95^\circ$, respectively). Soft

Table 4. Comparison of Treatment Effects Between MPAP and Headgear Groups^a

Variable	MPAP Group (T1–T2)			Headgear Group (T1–T2)			95% CI		<i>P</i> Value ^c
	Mean	SE	<i>P</i> Value ^b	Mean	SE	<i>P</i> Value ^b	Lower Bound	Upper Bound	
Skeletal									
SNA, °	1.96	0.47	<0.001	1.92	0.51	0.001	−1.41	1.48	.961
SNB, °	0.43	0.45	0.251	−0.38	0.49	0.355	−0.57	2.19	.242
ANB, °	1.53	0.24	<0.001	2.30	0.26	<0.001	−1.51	−0.05	.038
Wits, mm	2.44	0.50	<0.001	2.81	0.54	<0.001	−1.90	1.16	.629
Havold, mm	−1.90	0.58	0.001	−4.78	0.63	<0.001	1.09	4.66	.002
Facial angle, °	0.99	0.43	0.003	−0.52	0.46	0.242	0.21	2.82	.024
Palatal plane angle, °	−0.49	0.38	0.177	−0.82	0.40	0.055	−0.82	1.48	.563
Mandibular plane angle, °	−1.24	0.48	0.011	−0.78	0.51	0.132	−1.92	1.00	.53
A-point to N perpendicular, mm	2.95	0.61	<0.001	2.60	0.66	0.003	−1.53	2.22	.71
A-point to TVL, mm	−2.90	0.37	<0.001	−2.85	0.40	<0.001	−1.18	1.08	.934
B-point to TVL, mm	−2.26	0.56	<0.001	−0.29	0.60	0.478	−3.68	−0.26	.025
Maxillary length, mm	−1.90	0.60	0.015	−0.66	0.64	0.128	−3.07	0.59	.18
Mandibular length, mm	−3.81	0.69	<0.001	−5.44	0.75	<0.001	−0.48	3.76	.127
Dental									
First molar crown–VRL, mm	3.06	0.54	<0.001	1.79	0.58	0.009	−0.40	2.93	.132
First molar root–VRL, mm	3.11	0.48	<0.001	1.49	0.51	0.002	0.17	3.08	.03
First molar cusp–FH, mm	−1.66	0.55	0.017	−2.87	0.59	<0.001	−0.48	2.89	.157
First molar root–FH, mm	−1.10	0.53	0.15	−2.58	0.57	<0.001	−0.13	3.10	.071
First molar–FH angle, °	1.53	0.98	0.502	−0.82	1.05	0.993	−0.64	5.35	.12
Central incisor crown–VRL, mm	3.32	0.79	<0.001	1.72	0.85	0.038	−0.82	4.00	.189
Central incisor root–VRL, mm	1.10	0.53	0.02	1.67	0.57	0.016	−2.21	1.05	.478
Central incisor crown–FH, mm	−3.17	0.52	<0.001	−2.48	0.55	<0.001	−2.28	0.88	.378
Central incisor root–FH, mm	−1.36	0.52	0.042	−2.56	0.56	<0.001	−0.38	2.78	.133
Central incisor–FH angle, °	−7.66	1.80	<0.001	0.03	1.93	0.967	−13.19	−2.19	.007
Occlusal plane angle, °	−2.15	0.82	0.013	−0.24	0.88	0.75	−4.40	0.59	.13
IMPA, °	0.83	1.65	0.652	−3.66	1.77	0.055	−0.53	9.53	.078
Overjet, mm	2.18	0.32	<0.001	3.06	0.34	<0.001	−1.86	0.09	.074
Overbite, mm	1.14	0.19	<0.001	1.68	0.21	<0.001	−1.13	0.06	.076
Soft tissue									
Nasolabial angle, °	−2.67	1.81	0.03	0.18	1.95	0.765	−8.39	2.69	.305
Mentolabial fold, °	0.60	2.22	0.696	−0.34	2.39	0.84	−5.86	7.73	.782
Upper lip to TVL, mm	1.25	0.33	<0.001	0.96	0.35	0.02	−0.70	1.29	.554
Lower lip to TVL, mm	0.65	0.46	0.139	−0.41	0.50	0.49	−0.36	2.48	.138
Soft tissue pogonion to TVL, mm	−0.53	0.66	0.238	1.24	0.71	0.193	−3.79	0.27	.087

^a MPAP indicates modified palatal anchorage plate; TVL, true vertical line; VRL, vertical reference line; CI, confidence interval for difference. Significance level: *P* < .016 according to Bonferroni correction.

^b Paired *t*-test.

^c MANCOVA, adjusted means according to second molar eruption status.

tissue variables demonstrated no significant difference between the groups (Table 4). Treatment duration showed no significant difference between the MPAP (28.0 ± 8.2 months) and headgear groups (28.9 ± 10.5 months).

The survival rate of the miniscrews was 97.2%, with just three cases showing signs of soft tissue inflammation around the MPAP.

DISCUSSION

Distalization of the maxillary molars is often performed to gain space or to correct Class II dental relationships using TADs. MPAPs have been developed to offer a simple and effective nonextraction approach for distalization.^{23,24}

Noncompliance appliances for molar distalization produced about 71% molar distalization and 29% reciprocal anchorage loss.⁷ However, TAD-anchored molar distalizing appliances showed 3.3–6.4 mm of distalization of the maxillary first molars without flaring of anterior teeth.²⁶ Sar et al.²⁷ demonstrated 2.81 mm of first molar distalization using skeletal anchorage. In agreement, the amount of distalization of the MPAP group in our study was 3.1 mm, with 3.3 mm of incisor retraction.

In addition to the retraction of anteriors in the MPAP group, there was extrusion and lingual inclination, while the headgear group showed only significant extrusion. This might be due to differences between the two treatment strategies. In the MPAP group, the

upper lip was more protruded and the nasolabial angle was smaller than that of the headgear group, although this was not statistically significant. Moreover, both groups showed >5-mm overjet. In the MPAP group, the overjet was corrected through retracting and retroclining the upper incisors. On the other hand, the upper lip position was slightly better in the headgear group, which might have been due to a subjective difference in facial profile preference between the two different clinicians. Therefore, the correction of the overjet was accomplished by proclination of the mandibular incisors while maintaining the maxillary incisors in their sagittal position.

Yu et al.²⁸ concluded that MPAP showed bodily molar movement without incisor flaring, while buccally placed mini-implants demonstrated distal tipping and extrusion of molars and flaring and intrusion of incisors. Our study showed 3.06 mm of distalization of the first molars for the MPAP group with 1.5° distal tipping. This bodily movement might have been because of the special design of the MPAP appliance (Figure 1). In the headgear group, the distal movement was 1.8 mm and the tipping was 0.82° mesially. Previous studies showed 6.4 and 3.9 mm of first molar distalization using TAD-anchored appliances, with distal tipping of 10.9° and 8.8°, respectively.^{13,14} Meanwhile, Burhan²⁹ showed 5.5 mm of molar distalization, 4.9° of distal tipping, and 2.7 mm loss of anchorage with a Frog appliance; however, when combined with headgear, the values were 5.9 mm, 1.25°, and 0.9 mm, respectively, which increased bodily distalization with less anchorage loss.

The MPAP and headgear groups produced similar skeletal effects such as a reduction of ANB and Wits appraisal. In agreement, Kirjavainen et al.³⁰ reported similar results of decreased ANB by 1.3°, using the cervical headgear.

Vertically, the MPAP group showed slight extrusion of maxillary first molars, while the headgear group demonstrated significant extrusion. This might be because the cervical headgear has limited control over the downward growth of the maxilla. Meanwhile, the MPAPs usually result in intrusion of molars.^{22,28} However, in this study, the intrusion was masked by the downward growth of the maxilla, resulting in extrusion, yet less than in the headgear group.

The effect that the eruption status of second molars has on distalization is still controversial. Several authors have reported minimal or no significant effect on the first molar movement,^{11,31–33} while others have demonstrated that the second molar eruption status might negatively affect first molar movement.^{34–36} Moreover, distal tipping of first molars was less in patients with erupted second molars.³⁷ In addition, the first molar movement rate was almost two times

greater before the eruption of second molars.³⁴ In our study, the second molar eruption had no significant main effect on the comparisons between the groups; however, its effect on molar distalization was not evaluated. A previous study showed that the tooth bud might act as a fulcrum, resulting in an increased degree of tipping of the molars.³⁷

This study compared fixed and removable appliances to show that MPAP could be considered for treatment of Class II patients. Therefore, it is recommended that clinicians consider the application of MPAP especially in noncompliant Class II patients.

CONCLUSIONS

- The modified palatal anchorage plate showed significant skeletal changes on the maxilla. However, this was not significantly different from the headgear group.
- Both MPAP and headgear resulted in significant distalization of maxillary first molars with no significant difference between them. In addition, both groups showed minimal distal tipping.

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