Original Article

Long-term skeletodental changes with early and late treatment using modified C-palatal plates in hyperdivergent Class II adolescents

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ABSTRACT

Objectives: To compare skeletodental changes between early and late treatment groups using modified C-palatal plates (MCPP) and long-term retention outcomes in hyperdivergent Class II adolescents.

Materials and Methods: Seventy-one hyperdivergent Class II patients were divided into four groups according to treatment modality and treatment timing: group 1, early treatment with MCPP (n = 16; 9.9 ± 0.9 years); group 2, late treatment with MCPP (n = 19; 12.3 ± 0.8 years); group 3, early treatment with headgear (HG; n = 18; 9.6 ± 0.8 years); and group 4, late treatment with HG (n = 18; 12.1 ± 1.2 years). Lateral cephalograms were taken and skeletal and dental variables were measured. For statistical analysis, paired *t*-tests, independent *t*-tests, and multiple regression were performed.

Results: The early MCPP group showed a more significant decrease in mandibular plane angle than the late MCPP group did, and vertical control was more efficient in the early group than in the late group. In the MCPP groups, both FMA and SN-GoGn were increased with late treatment but decreased with early treatment, and the difference was statistically significant ($P < .01$). The early-treatment MCPP group had a significant decrease in SN-GoGn of 0.6° compared with an increase of 1.7° in the early treatment HG group ($P < .01$). Posttreatment stability of both the early and late MCPP groups was maintained in long-term retention.

Conclusions: Early MCPP showed more significant vertical control than late MCPP. However, there was no difference in long-term stability between early and late groups. (*Angle Orthod*. 2024;94:303–312.)

KEY WORDS: Class II malocclusion; Hyperdivergent growth; MCPP; Stability; Early treatment

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INTRODUCTION

Functional appliances can be an effective treatment option for Class II growing patients with maxillary excess or mandibular deficiency. Various types of appliances have been used to achieve functional and esthetic treatment goals.[1–3] However, treatment of a hyperdivergent growth pattern is challenging for clinicians because the appliances used cause some deleterious side effects, such as extrusion of molars during treatment, which rotate the mandible clockwise[1,2] and/or increase the lower anterior facial height.[3] Although high-pull headgear has frequently been used, several studies report that it cannot alter the vertical skeletal relationship[4–6] and might induce an unpredictable outcome.[7]

To achieve vertical control without these side effects, intrusion of maxillary molars using temporary skeletal anchorage devices (TSADs) at various installation sites has induced counterclockwise rotation of the mandible of hyperdivergent adult patients.[8–10] Buschang et al.[11] reported that counterclockwise rotation of the mandible was achieved with palatal TSADs in the early permanent dentition. However, this allowed only vertical adjustment of the maxillary teeth, not anteroposterior correction.

Modified C-palatal plates (MCPPs) were introduced by Kook et al.[12] and have been installed in palatal areas as a distalizer for mixed dentition patients (Figure 1). MCPP showed skeletal and dental effects similar to headgear (HG) anteroposteriorly in adolescent Class II patients.[13] Especially, intrusion of maxillary molars and reduction of the mandibular plane angle was reported in treatment with MCPP.[14]

Previous studies[1,15–19] analyzed only the anteroposterior effects of Class II treatment; however, vertical changes were not evaluated. Several reports[5,20–23] targeted growing hyperdivergent Class II patients, but among them, only one study evaluated treatment timing[20] and no studies discussed the optimal treatment timing and effects in hyperdivergent Class II treated with palatal TSADs. Therefore, this study aimed to compare skeletodental changes between early and late treatment groups using MCPP and long-term retention outcomes in hyperdivergent Class II adolescents.

MATERIALS AND METHODS

In this retrospective study, samples consisted of 71 Class II division 1 malocclusion patients with lateral cephalograms; 35 patients were treated with MCPP at the Department of Orthodontics at Seoul St. Mary's Hospital from January 2010 to December 2021, while 36 patients were treated with HG at a private practice. Approval to conduct this study was obtained from the institutional review board of the Catholic University of Korea (KC22RISI0262).

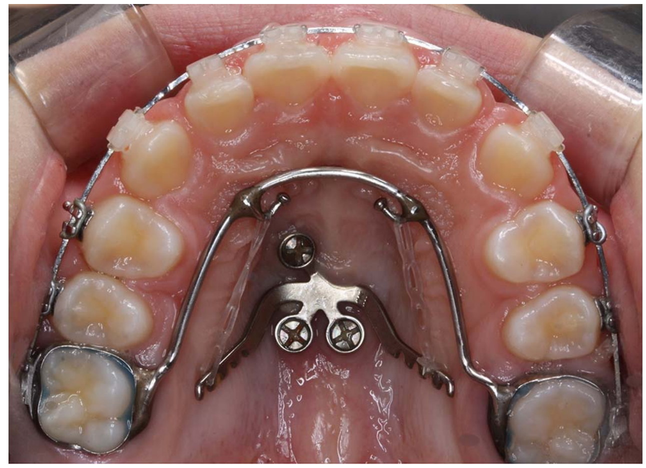


Figure 1. Modified C-palatal plate.

The patients were selected according to the following inclusion criteria: (1) Class II division 1 malocclusion, (2) ANB $>$4 mm, (3) high mandibular plane angle (FMA $>$30° or SN-GoGn $>$37°), (4) mild maxillary crowding ($<$5 mm), (5) nonextraction treatment, and (6) treatment modality of either MCPP or HG. Exclusion criteria were (1) facial deformity or craniofacial syndromes and (2) surgical orthognathic treatment.

The samples were divided into four groups according to treatment modality and timing. To differentiate treatment timing, the cervical vertebral maturation (CVM) method and dentition at pretreatment were used (Table 1).[24,25] There was no significant difference in sex distribution, chronological and skeletal age at pretreatment, or treatment duration between the early treatment MCPP and HG groups or between the late treatment MCPP and HG groups. For evaluation of long-term stability between the early and late treatment MCPP groups, there was no difference in the chronological age at postretention.

All samples in the MCPP and HG groups were treated by a single-phase process. A fixed edgewise appliance was used for the MCPP group, and patients were treated by one operator (Dr. Kook). The MCPP appliance has already been described elsewhere.[26] The MCPPs were installed using three 10-mm-long and 2.0-mm-diameter miniscrews (Jeil Corporation, Seoul, Korea). They were placed in the paramedian area to avoid interference with sutural growth. Distalization was initiated by engaging elastomeric chains, applying approximately 250 g of force per side.

All headgear cases used HG followed by a fixed appliance and were treated by one operator (Dr Park). 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 log card to report when they wore the headgear to motivate better wear. Most of the reports indicated satisfactory compliance.

Table 1. Demographic Data in the Early and Late Treatment Groups[a]

		Early Treatment Group			Late Treatment Group		
		MCPP	HG	*P* Value	MCPP	HG	*P* Value
Patients (n)		16	18		19	18	
Age (y)[b]	Pretreatment (T0)	9.9 ± 0.9	9.6 ± 0.8	.382	12.3 ± 0.8	12.1 ± 1.2	.515
	Posttreatment (T1)	12.8 ± 1.2	12.8 ± 0.9	.858	15.1 ± 1.1	14.6 ± 1.4	.239
	Postretention (T2)[c]	19.3 ± 2.2	N/A	N/A	18.9 ± 1.4	N/A	N/A
Treatment duration(y)[b]	T1-T0	2.9 ± 1.1	3.2 ± 1.0	.386	2.8 ± 0.7	2.4 ± 0.5	.117
Retention period(y)[b,d]	T2-T1	6.3 ± 2.5	N/A	N/A	3.8 ± 1.6	N/A	N/A
Gender[e]	Male	9	10	.968	9	10	.618
	Female	7	8		10	8	
Skeletal age (cervical vertebral maturation) at pretreatment (n)[e]	Stage 1	8	8	.746	0	0	.419
	Stage 2	8	10		0	0	
	Stage 3	0	0		7	9	
	Stage 4	0	0		12	9	
	Stage 5	0	0		0	0	
	Stage 6	0	0		0	0	

[a] HG indicates headgear; MCPP, modified C-palatal plates.
[b] Data were analyzed using an independent *t*-test.
[c] $P = .655$ between the chronological age of the early and late treatment MCPP groups at postretention.
[d] $P = 0.003$ between the retention period of the early treatment and late treatment MCPP groups.
[e] Data were analyzed using a chi-square test.

Eighteen angular, linear, and proportional variables were examined for each patient and are described in Table 2 and Figures 2 and 3. Lateral cephalograms were taken and traced at pretreatment (T0), posttreatment (T1), and postretention (T2) by one investigator (Dr Kim) using V-Ceph software (CyberMed, Seoul, Korea). Ten patients were randomly selected and remeasured after 4 weeks to evaluate measurement reliability. The intraobserver reliability was calculated by the intraclass correlation coefficient, which ranged from 0.965 to 0.982 with a 95% confidence interval. The investigator (Dr Kim) was also blinded to the treatment protocols (MCPP and HG).

Long-term retention data were gathered for the MCPP group. There was an average of 6.3 years of retention in the early treatment group and 3.8 years in the late

Table 2. Definitions of the Cephalometric Variables

Relationship	Cephalometric Variable	Definition
Sagittal skeletal relationships	SNA, °	Angle between the anterior cranial base (Sella to Nasion) and the NA (Nasion to point A) line
	SNB, °	Angle between the anterior cranial base (Sella to Nasion) and the NB (Nasion to point B) line
	ANB, °	Angle between NA and NB lines
	PTV-A, mm	Perpendicular distance from point A to the pterygoid perpendicular line to the Frankfort horizontal (FH) plane
	PTV-B, mm	Perpendicular distance from point B to the pterygoid perpendicular line to the Frankfort horizontal (FH) plane
Vertical skeletal relationships	SN-PP, °	Angle between the SN plane and ANS-PNS line
	FMA, °	Angle between the FH plane and Go-Gn line
	SN-GoGn, °	Angle between the SN plane and Go-Gn line
	SN-OP, °	Angle between the SN plane and the occlusal plane
	Facial height ratio (PFH/AFH)	Ratio of posterior facial height (Sella to Gonion) to anterior facial height (Nasion to Menton)
Dental relationships	U1-SN, °	Angle between the maxillary incisor axis line and the SN plane
	IMPA, °	Angle between the mandibular incisor axis line and the mandibular plane
	U6-PP, mm	Distance between the mesiobuccal cusp of the maxillary first molar and the palatal plane
	L6-MP, mm	Distance between the mesiobuccal cusp of the mandibular first molar to the mandibular plane
	PTV-U6, mm	Distance from the mesiobuccal cusp of the maxillary first molar to the pterygoid perpendicular line to the Frankfort horizontal (FH) plane
	MEV-L6, mm	Distance from the mesiobuccal cusp of the mandibular first molar to the menton perpendicular line to the mandibular plane
	OJ, mm	Incisor overjet
	OB, mm	Incisor overbite

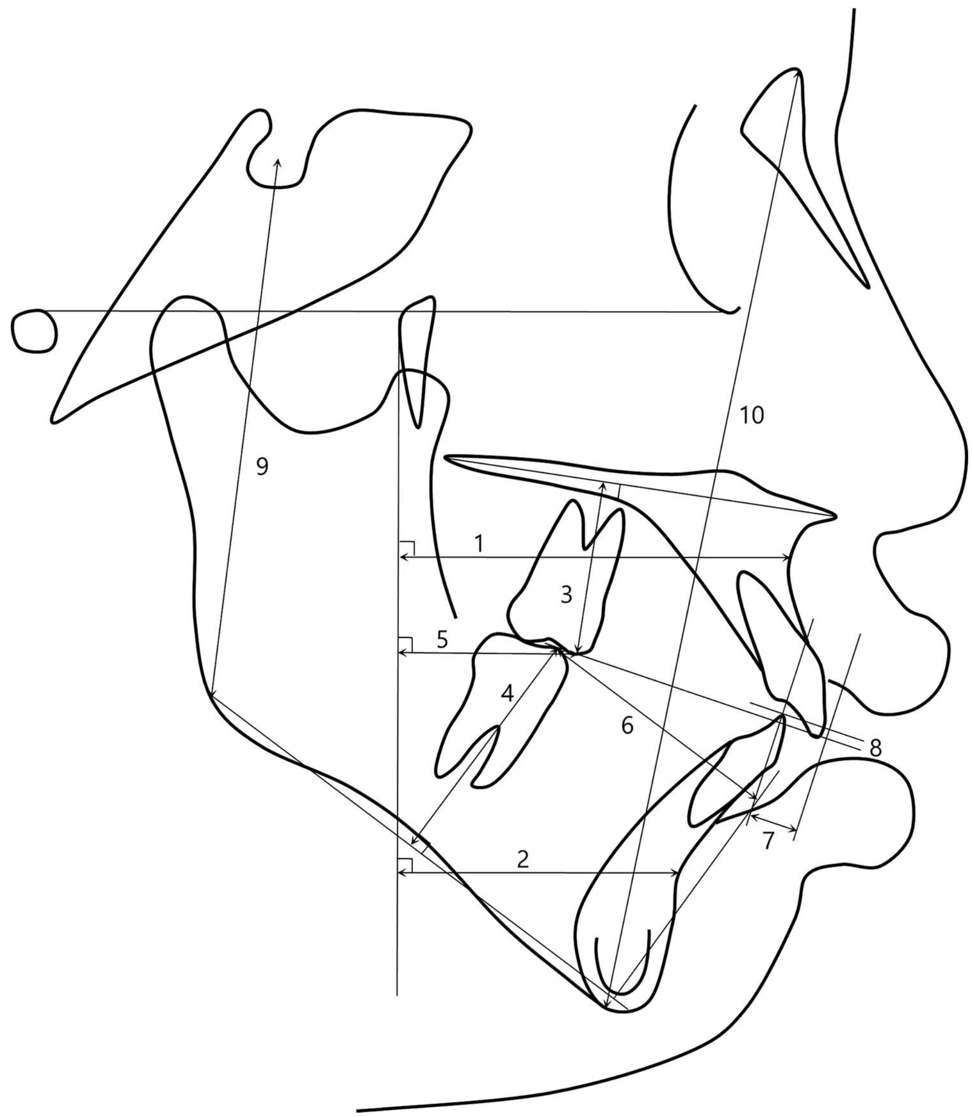


Figure 2. Linear measurements (mm). 1, PTV-A; 2, PTV-B; 3, U6-PP; 4, L6-MP; 5, PTV-U6; 6, MEV-L6; 7, OJ; 8, OB; 9/10, facial height ratio.

treatment group. Five patients in the early MCPP group and three patients in the late MCPP group were excluded from the retention period because their retention data were not available.

The sample size evaluation for this study was based on a previous study in which mandibular plane angles between MCPP and headgear groups were compared.[14] Sufficient statistical power (.8 power, .05 level of significance, and two-sided tests) showed an effect size of 1.22, which required a total sample size of 24 subjects. Given the sample size of this study, there was sufficient power to detect meaningful vertical changes in the mandible.

Statistical Analysis

All statistical analyses were performed using SPSS Statistics (version 22, IBM Corp, Armonk, NY, USA), and statistical significance was set at $P < .05$. The age distribution, gender, and skeletal age were compared with the chi-square test. The Kolmogorov-Smirnov test was used to confirm a normal distribution of measurements. When normality was not satisfied, a nonparametric test was performed. An independent *t*-test and Mann-Whitney *U* test were performed to evaluate the differences between the groups. To assess the treatment effects within each group, a paired *t*-test and Wilcoxon signed-rank test were used. Stepwise multiple regression analysis was performed with $P < .05$ variables to adjust for possible confounders. The statistical methods used are specified in each table.

RESULTS

The initial status of the MCPP and HG groups is presented in Table 3. There was no significant difference in skeletal variables except for the facial height ratio in

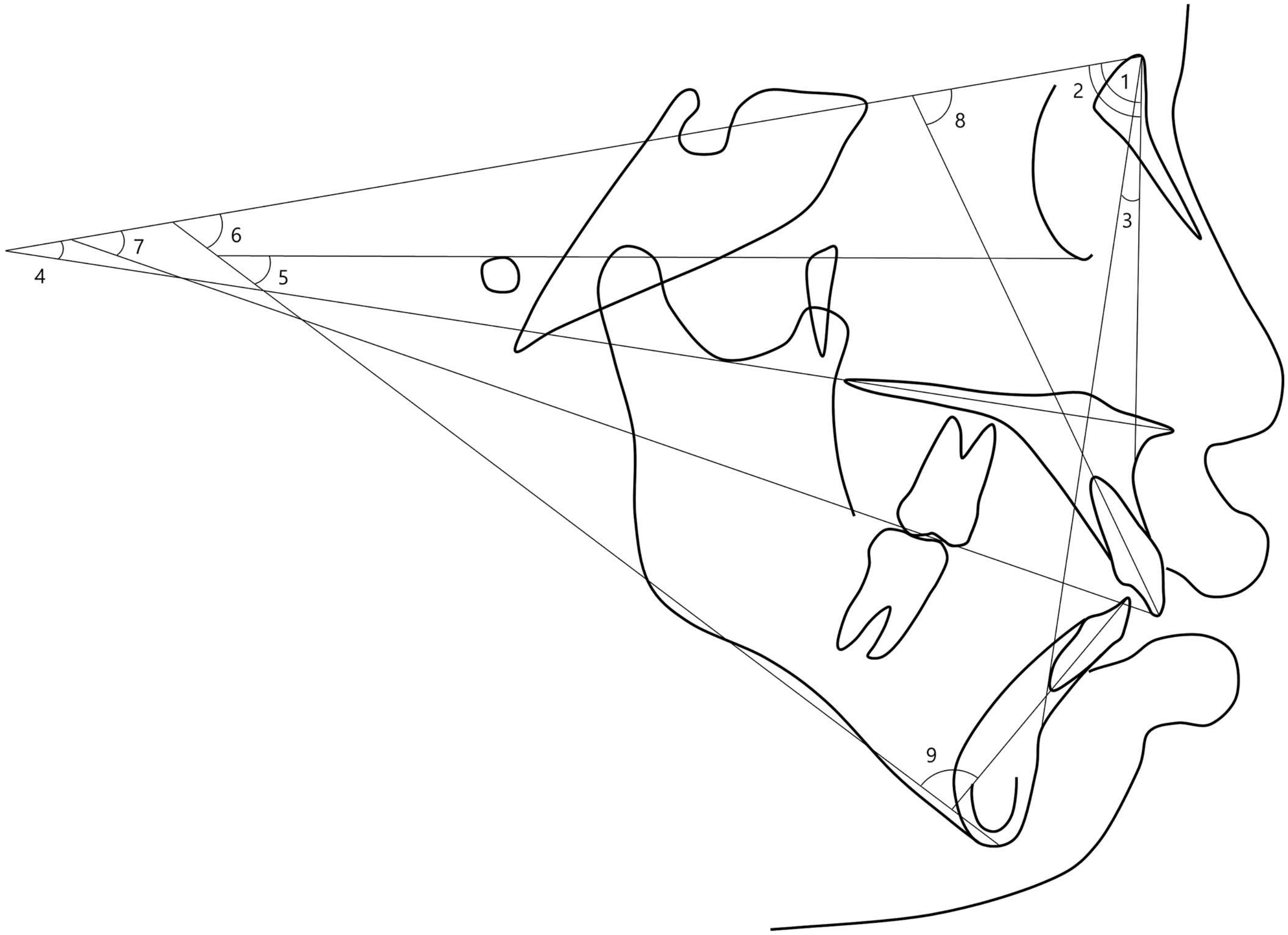


Figure 3. Angular measurements (°). 1, SNA; 2, SNB; 3, ANB; 4, SN-PP; 5, FMA; 6, Sn-GoGn; 7, SN-OP; 8, U1-SN; 9, IMPA

the late treatment group and some differences in some dental variables.

Table 4 demonstrates that the early MCPP group showed a more significant decrease in the mandibular plane angle than the late MCPP group. The late treatment group showed an increase in FMA of 1.3° and SN-GoGn of 1.3° ($P < .01$) from T0 to T1, but the early treatment group had a decrease in FMA of 1.3°. The difference was statistically significant ($P < .01$). Late treatment decreased SNB by 0.7° compared with early treatment ($P < .05$).

There was a greater decrease in SN-GoGn of 0.6° in the early treatment MCPP group than the increase of 1.7° in the early treatment HG group ($P < .01$). The occlusal plane increased by 2.7° in the early treatment MCPP group but decreased by 1.4° in the early treatment HG group ($P < .01$). There was no difference in ANB between the early and late MCPP groups, but in the HG group, it was significantly reduced in the early treatment group ($P < .05$).

The posttreatment stability of both the early and late-treatment MCPP groups was maintained in the long-term retention (Table 5). The early MCPP group showed significantly greater maxillary and mandibular molar eruption than the late MCPP group did (3.1 mm vs 0.6 mm in U6-PP, $P < .001$, and 2.0 mm vs -0.5 mm in L6-MP, $P < .01$). The early MCPP group exhibited an increase in the facial height ratio of 1.7% (PFH/AFH, $P < .05$), while the late MCPP group showed an increase in U1-SN of 2.7° ($P < .05$) and IMPA of 3.5° ($P < .01$), respectively. There were no significant intergroup differences.

As shown in Table 6, the CVM stage at pretreatment, Δ SNB, and Δ U1-SN significantly affected Δ SN-GoGn. In addition, Δ PTV-B and Δ U1-SN had a significant effect on Δ FMA.

DISCUSSION

For some time now, TSADs have been applied on the buccal and palatal sides to achieve absolute anchorage. The palatal area is safe for installation in adolescents in the mixed dentition because there is no risk of root damage.[12,27]

Table 3. Comparison of Pretreatment Variables Between MCPP and HG Groups in Early and Late Treatment[a]

	Early Treatment			Late Treatment		
Variable	MCPP Mean ± SD	HG Mean ± SD	*P* Value	MCPP Mean ± SD	HG Mean ± SD	*P* Value
SNA, °	81.70 ± 3.44	82.06 ± 3.01	.747	81.11 ± 3.56	81.85 ± 3.01	.497
SNB, °	75.98 ± 3.26	75.60 ± 4.17	.825†	75.48 ± 3.52	76.23 ± 2.27	.451
ANB, °	5.71 ± 1.37	6.07 ± 1.74	.441	5.63 ± 1.06	5.63 ± 1.65	.997
PTV-A, mm	43.16 ± 4.11	42.48 ± 4.12	.313†	44.74 ± 2.24	42.91 ± 3.34	.061
PTV-B, mm	34.31 ± 5.53	32.14 ± 4.80	.230	35.56 ± 3.24	33.39 ± 4.87	.118
FMA, °	33.61 ± 4.32	32.59 ± 3.56	.456	32.01 ± 2.97	31.47 ± 3.44	.608
SN-GoGn, °	39.22 ± 4.91	39.85 ± 4.48	.443†	39.86 ± 3.63	39.92 ± 3.05	.940†
SN-PP, °	7.87 ± 2.96	8.75 ± 2.81	.379	9.44 ± 2.61	9.35 ± 2.16	.915
SN-OP, °	20.69 ± 4.94	20.90 ± 3.44	.889	23.18 ± 4.40	19.60 ± 3.72	.011*
PFH/AFH, %	59.34 ± 3.39	61.28 ± 4.14	.147	60.75 ± 3.55	62.83 ± 2.51	.048*
U1-SN, °	108.23 ± 7.78	107.45 ± 8.33	.780	104.33 ± 9.86	108.20 ± 5.88	.156
IMPA, °	94.24 ± 5.87	88.63 ± 4.33	.003**	92.01 ± 6.15	93.63 ± 4.54	.371
U6-PP, mm	19.26 ± 1.35	18.51 ± 4.63	.239	21.09 ± 1.83	20.64 ± 2.11	.493
L6-MP, mm	27.96 ± 1.88	27.53 ± 4.54	.543	29.29 ± 1.90	28.75 ± 2.63	.479
PTV-U6, mm	16.57 ± 4.11	13.94 ± 3.61	.055	17.61 ± 2.53	15.73 ± 4.36	.123
MEV-L6, mm	29.21 ± 2.67	27.31 ± 2.29	.033*	29.46 ± 3.00	26.79 ± 2.85	.009*
OJ, mm	5.05 ± 2.30	6.62 ± 2.45	.117†	4.98 ± 1.45	5.51 ± 1.55	.289
OB, mm	2.74 ± 1.81	4.98 ± 1.83	.001**	3.94 ± 2.04	3.66 ± 1.92	.668

[a] Data were analyzed using an independent *t*-test except for variables with the †Mann-Whitney U test, which did not satisfy normality. HG indicates headgear; MCPP, modified C-palatal plates; SD, standard deviation.

* $P < .05$; ** $P < .01$.

Since hyperdivergent patients often have vertical growth patterns and inadequate muscular function that results in lip incompetence or mouth breathing, early intervention to minimize vertical and muscular problems is important.[20,28] TSADs are used to induce restriction of maxillary dentoalveolar growth and rotate the mandible counterclockwise in Class II hyperdivergent patients. In addition, Kook et al.[12] reported treatment of Class II malocclusion with late mixed dentition using MCPP. This study aimed to compare the treatment effects and stability of early and late MCPP in hyperdivergent Class II patients.

In the current study, the late-treatment MCPP group significantly increased in both FMA and SN-GoGn, but the early treatment group decreased in these measures. The mandible moved significantly to the posterior in the late treatment group but not the early treatment group. These results were similar to those of Hart et al.,[29] who reported that more favorable mandibular autorotation in adolescents than adults resulted in much more prominent anteroposterior Class II correction.

Compared with the changes in the vertical position of the maxillary first molars in the HG group, the early and late MCPP groups showed extrusion of 0.8 mm and intrusion of 0.4 mm, respectively, after a treatment duration with an average of 2.9 years, but there was no significant intergroup difference of molar position. In addition, in untreated growing patients, Zhang et al.[30] reported that the eruption of maxillary first molars was 1.7 mm and 1.8 mm at 10.5 to 12.5 years and 12.5 to 14.5 years of age, respectively. Buschang et al.[31] showed that the maxillary molars erupted 1.2 mm yearly. Therefore, considering this annual eruption amount of the first molars, treatment with MCPP appears to be effective in vertical control of the maxillary first molars eruption.

With regard to the vertical change of the mandibular first molars, Buschang et al.[31] reported the mandibular molars erupted 0.9 mm per year during the growth and development period. On the other hand, some studies reported the mandibular molars supraerupted when maxillary molars were intruded or held vertically in place.[32,33] In agreement with these studies, there was significantly more compensatory extrusion in the mandibular first molars in the MCPP groups in this study. Rice et al.[34] intruded the mandibular molars using maxillary molar intrusion. The mandibular molar of their treated group erupted by only 0.7 mm, while the untreated control group erupted by 2.9 mm. Buschang et al.[11] demonstrated that 2.1° of chin projection was attained through vertical control of both maxillary and mandibular molars using TSADs in growing hyperdivergent patients. However, in the current study, no additional skeletal anchorage was used to prevent extrusion of the mandibular molars because efficient use of interdental screws in the mixed dentition during eruption of mandibular premolars and second molars seems to be limited.

The results showed that early treatment with MCPP induced a significant decrease in FMA and SN-GoGn compared with their increase in late treatment ($P < .01$),

Table 4. Comparison of Treatment Effects (T1–T0) Between the MCPP and HG Groups in Early and Late Treatment[a]

Variable	Group	Early Treatment (T1–T0) Mean ± SD	Late Treatment (T1–T0) Mean ± SD	*P* Value
SNA,°	MCPP	−0.14 ± 1.38	−0.85 ± 1.22**	.117
	HG	−1.42 ± 1.53**	−1.51 ± 0.95***	.833
	P value	.015*	.074	
SNB, °	MCPP	0.47 ± 1.97	−0.69 ± 1.28*	.044*
	HG	1.01 ± 2.25	0.11 ± 1.27	.406†
	P value	.472	.068	
ANB, °	MCPP	−0.61 ± 1.31	−0.16 ± 0.94	.241
	HG	−2.43 ± 1.08***	−1.62 ± 0.76***	.014*
	P value	.001***	.000***	
PTV-A, mm	MCPP	2.35 ± 2.09***	−0.02 ± 1.59	.001**
	HG	0.15 ± 2.76	−0.55 ± 1.35	.126†
	P value	.014*	.282	
PTV-B, mm	MCPP	2.92 ± 2.88**	−0.67 ± 2.10	.000***
	HG	2.29 ± 4.33*	0.72 ± 2.35	.293†
	P value	.624	.066†	
FMA, °	MCPP	−1.30 ± 2.38*	1.31 ± 2.16*	.002**
	HG	−0.27 ± 2.24	0.50 ± 1.92	.279
	P value	.202	.075†	
SN-GoGn, °	MCPP	−0.59 ± 1.93	1.28 ± 1.63**	.004**
	HG	1.65 ± 2.55*	1.50 ± 1.72**	.839
	P value	.007**	.692	
SN-PP, °	MCPP	0.15 ± 1.37	0.43 ± 1.10	.510
	HG	1.17 ± 2.64	0.69 ± 1.83	.526
	P value	.164	.610	
SN-OP, °	MCPP	2.73 ± 3.72*	2.85 ± 4.03**	.927
	HG	−1.43 ± 3.47	2.43 ± 4.78*	.009**
	P value	.002**	.772	
PFH/AFH, %	MCPP	2.13 ± 3.20*	0.48 ± 2.04	.074
	HG	1.68 ± 2.57*	1.01 ± 1.60*	.606†
	P value	.653	.389	
U1-SN, °	MCPP	−5.79 ± 11.58	−9.97 ± 8.22***	.222
	HG	−1.65 ± 9.50	−3.86 ± 8.06	.458
	P value	.261	.029*	
IMPA, °	MCPP	−0.65 ± 5.15	−2.06 ± 4.98	.415
	HG	4.28 ± 5.55**	1.72 ± 6.52	.214
	P value	.012*	.054	
U6-PP, mm	MCPP	0.80 ± 1.93	−0.40 ± 1.95	.078
	HG	3.90 ± 2.06***	2.68 ± 0.93***	.028*
	P value	.000***	.000†***	
L6-MP, mm	MCPP	3.39 ± 1.68***	3.15 ± 1.77***	.685
	HG	1.66 ± 1.84**	1.51 ± 1.31***	.781
	P value	.008**	.003**	
PTV-U6, mm	MCPP	0.43 ± 3.61	−2.01 ± 2.49**	.025*
	HG	1.88 ± 3.77	−0.67 ± 2.75	.027*
	P value	.261	.129	
MEV-L6, mm	MCPP	0.21 ± 1.41	0.53 ± 1.55	.535
	HG	0.91 ± 2.22	0.88 ± 2.20	.976
	P value	.291	.571	
OJ, mm	MCPP	−1.86 ± 2.20**	−2.20 ± 1.49***	.584
	HG	−4.60 ± 2.42***	−3.47 ± 1.64***	.111
	P value	.002**	.019*	
OB, mm	MCPP	0.50 ± 1.67	−0.83 ± 1.89	.036*
	HG	−3.29 ± 1.69***	−1.96 ± 1.70***	.024*
	P value	.000***	.064	

[a] Intergroup differences were analyzed using an independent *t*-test, except for variables with the † Mann-Whitney *U* test, which did not satisfy normality. Intragroup differences were analyzed using paired *t*-tests, except for variables with the Wilcoxon signed-rank test, which did not satisfy normality. Pretreatment, T0; posttreatment, T1. HG indicates headgear; MCPP, modified C-palatal plates; SD, standard deviation.

* $P < .05$; ** $P < .01$; *** $P < .001$.

Table 5. Comparison of Changes During Retention (T2–T1) Between Early and Late MCPP Treatment Groups[a]

Variable	Early Treatment (n = 11) Mean ± SD	P Value	Late Treatment (n = 16) Mean ± SD	P Value	P Value
SNA, °	0.09 ± 1.33	.828	0.21 ± 0.59	.186	.759
SNB, °	0.22 ± 1.74	.686	0.20 ± 0.96	.414	.973
ANB, °	−0.13 ± 1.65	.799	0.002 ± 0.67	.991	.368†
PTV-A, mm	0.95 ± 1.68	.091	−0.07 ± 1.51	.865	.115
PTV-B, mm	0.86 ± 3.12	.381	0.24 ± 1.85	.617	.518
FMA, °	−0.52 ± 3.01	.582	−0.29 ± 1.54	.796‡	.212†
SN-GoGn, °	0.19 ± 2.21	.776	−0.07 ± 1.62	.872	.726
SN-PP, °	−0.09 ± 1.84	.884	0.31 ± 0.74	.331‡	.610†
SN-OP, °	−1.30 ± 4.17	.324	−0.68 ± 2.12	.221	.652
PFH/AFH, %	1.67 ± 1.86	.013*	0.53 ± 1.21	.103	.061
U1-SN, °	−0.84 ± 10.06	.594‡	2.67 ± 4.00	.018*	.942†
IMPA, °	1.85 ± 5.78	.312	3.45 ± 4.14	.005*	.410
U6-PP, mm	3.07 ± 1.46	.000***	0.58 ± 0.91	.022*	.000***
L6-MP, mm	1.97 ± 1.76	.004**	−0.47 ± 1.60	.263	.001**
PTV-U6, mm	1.55 ± 3.37	.159	0.28 ± 1.62	.495	.268
MEV-L6, mm	0.11 ± 1.78	.838	−0.41 ± 2.02	.430	.496
OJ, mm	−0.24 ± 1.38	.568	0.20 ± 0.64	.230	.294†
OB, mm	−0.64 ± 1.07	.077	−0.26 ± 1.10	.366	.383

[a] Only for patients with retention data. Five patients in the early MCPP group and three patients in the late MCPP group were dropped in the retention period. Intergroup differences were analyzed using an independent *t*-test and the †Mann-Whitney *U*-test on variables that did not satisfy normality. Intragroup differences were analyzed using paired *t*-tests except for variables with the ‡Wilcoxon signed-rank test, which did not satisfy normality. Pretreatment, T0; posttreatment, T1; postretention, T2. HG indicates headgear; MCPP, modified C-palatal plates; SD, standard deviation.

* $P < .05$; ** $P < .01$; *** $P < .001$.

respectively. However, there were differences between the magnitude of changes in FMA and SN-GoGn from T0 to T1, which were 0.71° in early treatment and 0.03° in late treatment. Huh et al.[35] reported that the angle between the SN and FH planes fluctuated by about 0.5° according to age and gender. Therefore, differences between the amount of change of FMA and SN-GoGn after treatment in this study might be influenced by differences in age and gender.

Regarding long-term retention in the MCPP groups, the mandibular plane angle was decreased or maintained in the early and late MCPP groups, with an average age of 19.3 and 18.9 years, respectively. In addition, Rice et al.[34] stated that the vertical control outcome using molar intrusion was maintained well at an average retention time of 3.6 years. Buschang et al.[31] reported that the mandibular plane angle was decreased by 0.3° to 0.4° per year. Therefore, the current study showed that the posttreatment results of both early and late treatment MCPP groups remained stable despite residual growth during long-term retention (Figure 4).

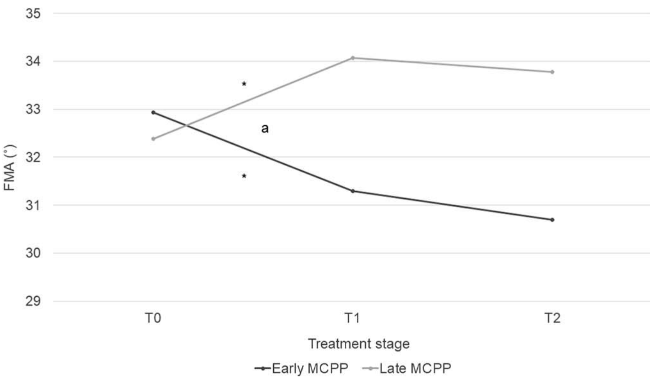
Stepwise multiple regression was performed to evaluate factors affecting changes in the mandibular plane angle during treatment. The CVM stage at pretreatment influenced the SN-GoGn change. As each

Table 6. Factors Affecting the Vertical Change After MCPP[a]

	Δ SN-GoGn					
	B	Beta	*t*	*P* Value	R^2	*F*
(Constant)	−1.491		−2.512	.017	.541 (adjusted $R^2 = 0.498$)	12.567*** (0.000)
CVM stage at pretreatment	0.517	.315	2.547	.016*		
Δ SNB	−0.520	−.448	−3.598	.001**		
Δ U1-SN	−0.061	−.308	−2.508	.017*		
	Δ FMA					
(Constant)	−0.309		−0.673	.506	.383 (adjusted $R^2 = 0.346$)	10.246*** (0.000)
Δ PTV-B	−0.374	−.441	−3.218	.003**		
Δ U1-SN	−0.103	−.399	−2.906	.006**		

[a] Stepwise multiple regression analysis was performed. Δ indicates a difference in variable values, which is posttreatment minus pretreatment. CVM indicates cervical vertebral maturation; MCPP, modified C-palatal plate.

* $P < .05$; ** $P < .01$; *** $P < .001$.



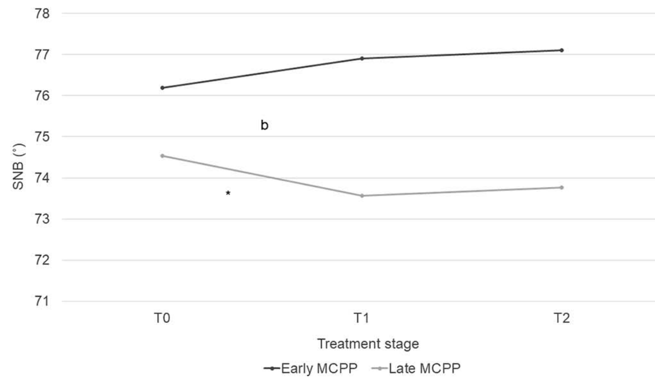


Figure 4. Schematic drawing of FMA (A) and SNB (B) changes from T0 to T2 in each early and late MCPP group. *Significance level indicates $P < .05$ within each group; a, $P < .01$ between groups from T0 to T1; b, $P < .05$ between groups from T0 to T1; T0, pretreatment; T1, post-treatment; T2, postretention. MCPP, modified C-palatal plate.

CVM stage increased by 1, SN-GoGn increased by 0.5° during treatment. Considering that the difference in CVM stages between early and late treatment was 1 to 3, it could be expected that SN-GoGn might increase by 0.5°–1.6° in the late treatment groups.

Even though this study evaluated treatment outcomes of patients treated at different skeletal ages based on CVM stages, it did not consider how gender might affect factors such as the amount and pattern of growth in the four groups. Further study might be necessary to determine what effect gender has on the outcome. Also, considering the small sample size and no control group during retention, larger samples and long-term studies with untreated, growing groups are advisable.

Clinically, early MCPP treatment showed a more significant vertical control effect than late MCPP treatment did. However, there was no difference on the skeletal effect between the early and late treatment groups during long-term follow-up after MCPP treatment. Therefore, this study suggests that treatment using palatal TSADs with appropriate timing might be an option available to achieve vertical control in hyperdivergent Class II growing patients.

CONCLUSIONS

- The early MCPP group showed a more significant decrease in the mandibular plane angle than the late MCPP group did, and the control of vertical growth was more efficient in the early group.
- The early MCPP group had a greater vertical control effect than the early HG treatment group did.
- The posttreatment stability of both early and late-treatment MCPP groups was maintained during long-term retention.

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