Original Article

Treatment outcomes of various force applications in growing patients with skeletal Class III malocclusion: *A comparative lateral cephalometric study*

Li-In Lim[a]; Jin-Young Choi[b]; Hyo-Won Ahn[c]; Seong-Hun Kim[d]; Kyu-Rhim Chung[e]; Gerald Nelson[e]

ABSTRACT

Objectives: To evaluate skeletal, dentoalveolar, and soft tissue changes between intraoral light force application and extraoral heavy force application in growing patients with skeletal Class III malocclusion.

Materials and Methods: A retrospective study was conducted with pretreatment and posttreatment lateral cephalometric data from 50 subjects with skeletal Class III malocclusion. In the first group (15 boys, 10 girls; 8.67 ± 2.13 years old), each subject wore a biocreative horseshoe appliance (CHS) with two Class III elastics that exerted a force of 200 g. In the second group (13 boys, 12 girls; 8.96 ± 1.82 years old), each subject wore a Petit-type facemask and a lingual arch with hooks fixed to the maxillary arch with a total force of 700 g. Both groups of patients were instructed to wear the appliance approximately 14 hours a day, and 22 linear measurements and 8 angular measurements were evaluated. Changes of measurements from each group were compared by paired *t*-tests, considering a 5% significance level.

Results: Forward growth of the maxilla, improvement of the maxilla–mandible relationship, and upper incisor flaring were achieved in both groups without any statistically significant difference between them. Lateral cephalometric analysis also showed that U1 exposure, IMPA (Angle between mandibular plane and mandibular incisor axis), FMIA (Angle between FH plan and mandibular incisor axis), and L1-APog (Angle formed by the intersection of tooth axis of lower incisor and A-Pog line, Distance from lower incisor edge to A-Pog line) showed statistically significant differences. Lower incisors were inclined lingually in the CHS group.

Conclusions: During treatment of skeletal Class III malocclusion, the CHS with light Class III intermaxillary elastics therapy exhibits similar orthopedic changes to the maxillary complex and more dental changes to the lower anterior teeth compared with facemask therapy. (*Angle Orthod.* 2021;91:449–458.)

KEY WORDS: Class III malocclusion; Growing patient; Facemask; Biocreative strategy; Horseshoe appliance; Intermaxillary elastics

INTRODUCTION

Growing patients with Class III malocclusion typically have complex skeletal and dental factors.[1,2] Therefore, the concepts of diagnosis and treatment modalities for these patients are different from those for patients without any skeletal discrepancies. Treatment options are limited when growing patients are diagnosed with a Class III malocclusion compared with patients with normal growth patterns.[3] Functional appliances such as the Frankel III appliance have been chosen for patients with a retruded maxilla,[4] and chin cups have been used for patients with a protruded mandible.[5] Facemasks (FMs), one of the appliances that were first introduced and popularized by Delaire in 1972, were modified by Petit in 1982 and are commonly used for

The first two authors contributed equally to this work.

[a] Resident, Department of Orthodontics, Graduate School, Kyung Hee University, Seoul, Korea.

[b] Clinical Fellow, Department of Orthodontics, Graduate School, Kyung Hee University, Seoul, Korea.

[c] Associate Professor, Department of Orthodontics, Graduate School, Kyung Hee University, Seoul, Korea.

[d] Professor and Head, Department of Orthodontics, Graduate School, Kyung Hee University, Seoul, Korea.

[e] Clinical Adjunct Professor, Department of Orthodontics, Graduate School, Kyung Hee University, Seoul, Korea.

Corresponding author: Seong-Hun Kim, Professor and Head, Department of Orthodontics, Graduate School, Kyung Hee University, #1 Hoegi-dong, Dongdaemun-gu, Seoul 130-701, Republic of Korea
(e-mail: bravortho@khu.ac.kr)

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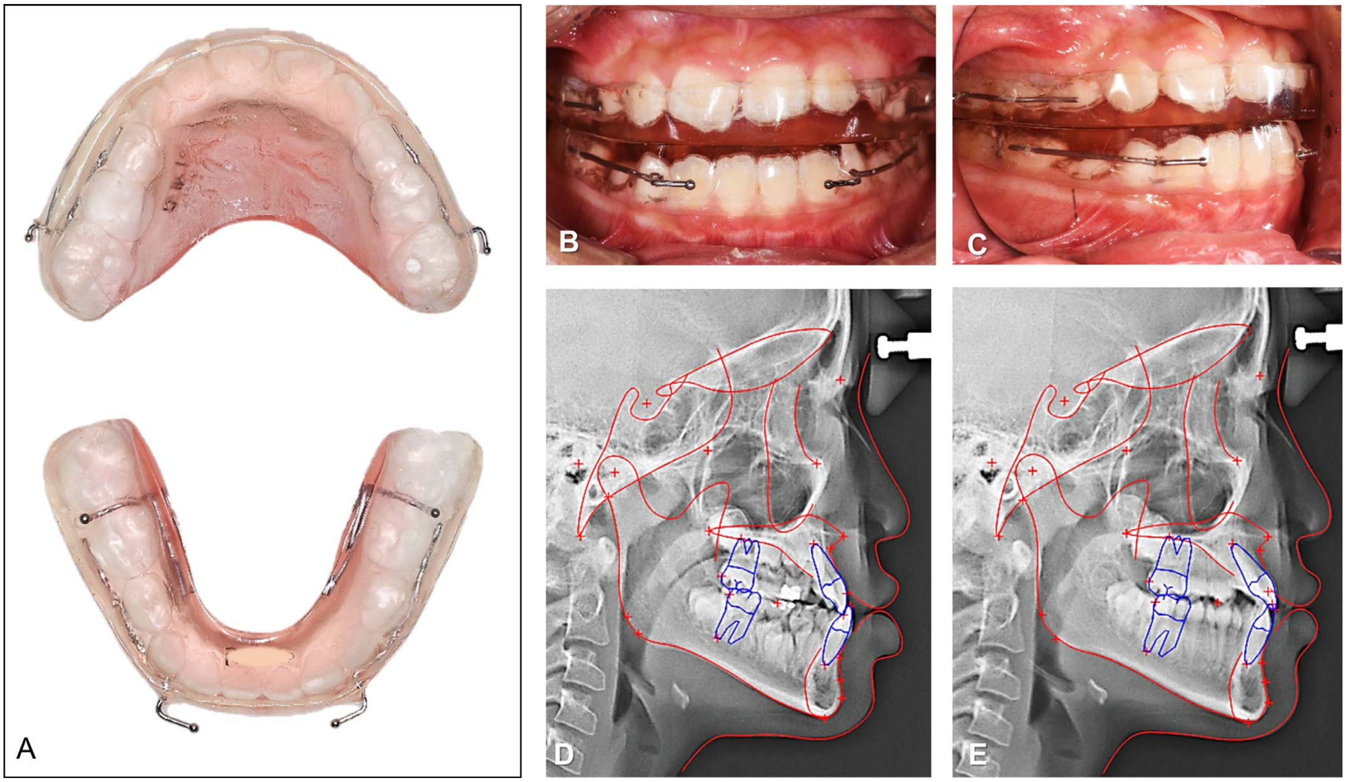


Figure 1. Class III CHS. (A) The appliance consisted of acrylic resin plates and hooks for attaching Class III elastics. (B,C) Intraoral photographs of application of the Class III CHS. (D) Pretreatment lateral cephalometric image showing anterior crossbite and Class III occlusion. (E) Posttreatment lateral cephalometric image showing positive anterior overjet and Class I occlusion.

the correction of Class III malocclusion in growing patients.[6] Conditions contributing to the development of a Class III malocclusion, such as a retruded maxilla, protruded mandible, and reduced lower facial height, can be improved by use of the FM, a bonded maxillary splint, and heavy force elastics. McNamara suggested that FMs could be applied to most Class III cases in growing patients.[7] A systematic review by Woon and Thiruvenkatachari suggested FMs for most patients with Class III malocclusion in the early mixed dentition or late deciduous dentition, with dramatic effects produced in short periods.[5]

Schwarz and Gratzinger introduced the intraoral removable horseshoe appliance.[8] It had upper and lower acrylic resin plates in the shape of a horseshoe that covered the entire dentition. Intermaxillary elastics are recommended to use for orthopedic treatment. The horseshoe appliance was modified by Chung et al. and named the biocreative horseshoe appliance (CHS; Figure 1).[9] The appliances were classified into a Class I horseshoe appliance as a space regainer, a Class II horseshoe appliance, a Class III horseshoe appliance, a horseshoe expander, and a splint-oriented horseshoe appliance.[9] For the growing patient with Class III malocclusion, the Class III horseshoe appliance can be used. It consists of acrylic resin plates and light Class III elastics that are attached at the hooks on the appliances.[10] This appliance is useful especially in the primary and mixed dentition, even with unerupted permanent teeth that prevent the use of a fully bonded appliance because it connects all the dentition regardless of the presence of spaces. The retention of the horseshoe appliance is achieved by the undercuts of the teeth and the elasticity of the acrylic resin.

There have been various studies on the treatment effects for CHS only or CHS and a FM combination approach.[9–13] However, there have been no comparative studies of the FM vs the horseshoe appliance with Class III elastics. Therefore, the aim of this retrospective lateral cephalometric study was to compare the effects of treatment with the CHS therapy and light Class III intermaxillary elastics with that of FM therapy in growing patients with Class III malocclusion.

MATERIALS AND METHODS

The sample for this retrospective study consisted of 100 lateral cephalograms of 50 growing Asian patients with skeletal Class III malocclusions treated using a CHS or FM confirmed by G*Power analysis (a power of 80% to detect significant differences with an 0.8 effect size and a value of 0.05). The inclusion criteria were

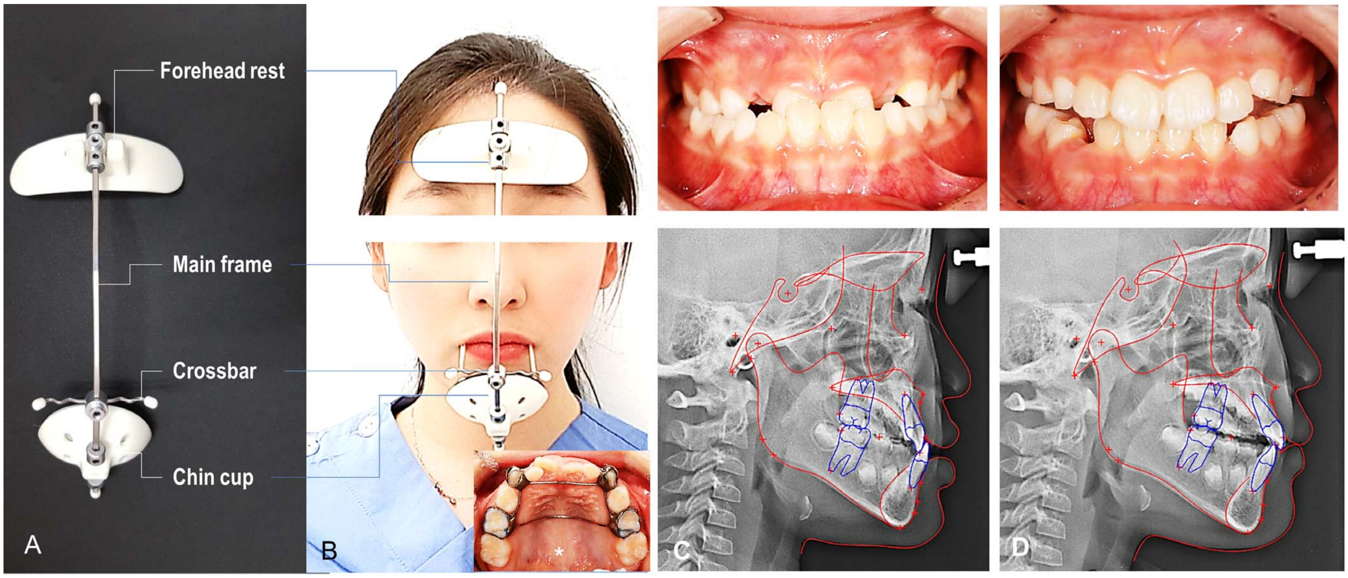


Figure 2. Petit-type FM. (A) Composition of FM (forehead rest, main frame, cross bar, chin cup). (B) Facial photo of application of the FM with an intraoral banded-type fixed labio-lingual appliance (*). (C) Pretreatment intraoral photo and lateral cephalometric image showing anterior cross bite. (D) Intraoral photo and lateral cephalometric image after the achievement of positive anterior overjet.

skeletal Class III growing patients with anterior crossbite and Class III molar relationship, patients with erupted first molars and upper central incisors, and patients with pretreatment and posttreatment cephalometric X-rays. The exclusion criteria were transverse maxillary expansion cases attributed to a transverse discrepancy between the maxilla and mandible and cases in which treatment was combined with other appliances, such as a fixed appliance. A total of 50 patients were selected for this comparative study. Of the patients, 25 (15 boys and 10 girls; 8.67 ± 2.13 years old) were treated with the CHS, and the other 25 patients (13 boys and 12 girls; 8.96 ± 1.82 years old) were treated with a FM. Two clinicians treated these patients (CHS by Dr Kim and FM by Dr Ahn) in the Department of Orthodontics, Kyung Hee University Dental Hospital. This study was approved by the institutional review board of Kyung Hee University Dental Hospital (KH-DT19020).

Subjects in the Class III CHS group (Figure 1) were instructed to wear the appliances for more than 14 hours a day. The Class III elastic force was 100 g per side. The fit of the appliances was checked every 4 weeks, and if the fit was poor, it was adjusted by relining the inner surface of the appliance to improve retention (Forestacryl, Forestadent Co., Pforzheim, Germany). Patients were informed to wear the appliances until the anterior crossbite was corrected and Class I occlusion was achieved.

Subjects in the FM group (Figure 2) were instructed to wear the Petit-type FM for more than 14 hours a day with a band-type fixed labio-lingual appliance (Figure 2). About 350 g per side of extraoral force was applied.[14] The patients visited the clinic every 4 weeks, and the occlusal changes and the state of the appliances were checked. Patients in this group were also treated until a Class I occlusion was achieved. The overall treatment periods were 9.84 ± 4.76 months for the CHS group and 8.76 ± 3.86 months for the FM group.

For all subjects, pretreatment (T1) and posttreatment (T2) lateral cephalometric X-rays were taken (CX-100, Asahi Roentgen Co., Kyoto, Japan). Cephalometric images were digitized and traced with the V-ceph program, version 8.0 (Osstem Implant Co., Seoul, Korea) by one researcher (Dr Lim). A total of 22 angular measurements and 8 linear measurements were evaluated in both T1 and T2 lateral cephalometric images for every patient. The definitions of the 30 measurements are shown in Table 1 and Figure 3. These data were confirmed by repeating the same data collection process 2 weeks later. To verify the reliability of the measurements, an intraclass correlation coefficient (ICC) was calculated. The measured cephalometric data were reliable as the ICC derived was greater than 0.95 at a 95% confidence interval.

Statistical Analysis

The Shapiro-Wilk test was conducted to confirm the normality in both groups. The data of each group at T1 were compared with each other, and the amounts of change from T1 to T2 for each measurement in each group were compared by independent *t*-tests. The statistical analysis was carried out with SPSS Statistics

Table 1. Description of the Cephalometric Measurements[a]

Measurements	Description
Skeletal divergency	
SUM (°)	Saddle angle (①) + Articulare angle (②) + Gonial angle (③)
PFH/AFH	Distance between Ar and Go (④) / distance between ANS and Me (⑤)
LFH/AFH	Distance between ANS and Me (⑤) / distance between Na and Me (⑥)
PP-FH (°)	Palatal plane angle, angle between FH plane (⑦) and palatal plane (⑧)
OP-FH (°)	Occlusal plane angle, angle between FH plane (⑦) and occlusal plane (⑨)
MP-FH (°)	Mandibular plane angle, angle between FH plane(⑦) and Me-Go line (⑩)
Facial axis (°)	Angle between FH plane (⑦) and S-Gn line (⑪)
ODI (°)	A-B to Mn plane (⑫) ± FH to palatal plane
Skeletal maxilla	
SNA (°) ⑬	Angle between S-N line and N-point A line
NA-FH (°) ⑭	Angle between FH plane and N-point A line
Nper-A (mm) ⑮	Distance between point A and perpendicular line from N to FH
Convexity (°) ⑯	Angle between point A and N-Pog line
Skeletal mandible	
SNB (°) ⑰	Angle between S-N line and N-point B line
NB-FH (°) ⑱	Angle between FH plane and N-point B line
Nper-Pog (mm) ⑲	Distance between Pog and perpendicular line from N to FH
Facial plane angle (°) ⑳	Angle between FH plane and N-Pog line
Skeletal Mx-Mn relation	
ANB (°) ㉑	Angle between N-point A line and N-point B line
Wits ㉒	Wits appraisal (Ao to Bo)
APDI (°)	Facial plane (㉓) to FH plane ± facial plane to AB ± FH plane to palatal plane
Dental	
Interincisal angle (°) ㉔	Angle formed by intersection of tooth of upper incisor and lower incisor
U1-FH (°) ㉕	Angle formed by the intersection of tooth axis of upper incisor and FH plane
U1 exposure (mm) ㉖	Distance from upper lip to maxillary incisor tip
IMPA (°) ㉗	Angle between mandibular plane and mandibular incisor axis
FMIA (°) ㉘	Angle between FH plan and mandibular incisor axis
L1-APog (°) ㉙	Angle formed by the intersection of tooth axis of lower incisor and A-Pog line
L1-APog (mm) ㉚	Distance from lower incisor edge to A-Pog line
U6 PTV (mm) ㉛	Distance between pterygoid vertical to the distal of upper molar
Soft tissue	
Nasolabial angle (°) ㉜	Angle formed by intersection of Cm-Sn line and Sn-Ls
E-line LL (mm) ㉝	Distance from point LL to E-line
Z angle (°) ㉞	Angle between FH plane and profile line (line formed by touching chin and most procumbent lips)

[a] Ar, Intersection of inferior cranial base surface and posterior surface of condyle; Go, Most posterior inferior point on angle of mandible; ANS, Anterior point on maxillary bone; Me, Lowest point on mandibular symphysis; Na, Most anterior point on frontonasal suture; FH, Frankfurt horizontal plane; S, Midpoint of sella turcica; Gn, Point located perpendicular on mandibular symphysis midway between pogonion and menton; Mx, Maxilla; Mn, Mandible; Pog, Most anterior point of mandibular symphysis; S-N, Line from sella to nasion; AB, Line from point A and point B; LL, (Li = Labrale inferior), the muco-cutaneous border of the lower lip; Ls, labrale superius (a point on the muco-cutaneous junction of upper lip and philtrum); Sn, subnasale (a point at which the nasal septum merges with the upper cutaneous lip in the midsagittal plane); Cm, columella (the most anterior point on the columella of the nose); Ao, Projecting point A in a perpendicular line along the functional occlusal plane; Bo, Projecting point B in a perpendicular line along the functional occlusal plane; PTV, Pterygoid vertical (line drawn through PTM and is perpendicular to the FH plane).

25.0 (IBM, Armonk, N.Y.), considering a 5% significance level.

RESULTS

The means and the standard errors of the CHS group and the FM group at T1 are shown in Table 2. All measurements showed no differences between the groups, except Nper-A which was smaller in the CHS group ($P < .05$). Figures 4 and 5 and Table 3 show the changes of each measurement from T1 to T2 in both groups. SNA, NA-FH, Nper-A, Convexity, ANB, Wits, and U1-FH increased after treatment in both groups, and APDI, interincisal angle, L1-APog (distance), and E-line to LL decreased in both groups. FMIA (3.57°, $P < .001$) and U6-PTV (2.28 mm, $P < .001$) showed increases only in the CHS group, and OP-FH (–1.78°, $P < .01$), U1 exposure (–0.83 mm, $P < .05$), IMPA (–3.62°, $P < .001$), and L1-APog angle (–4.21°, $P < .001$) decreased only in the CHS group ($P < .05$). In contrast, Z angle showed a significant change only in the FM group, and it was decreased after treatment (–2.57°, $P < .01$). Changes of each measurement between the groups were also compared. As a result, U1 exposure, IMPA ($P < .01$), FMIA, and L1-APog (both distance and angle) showed statistically significant differences between the CHS group and the FM group ($P < .05$).

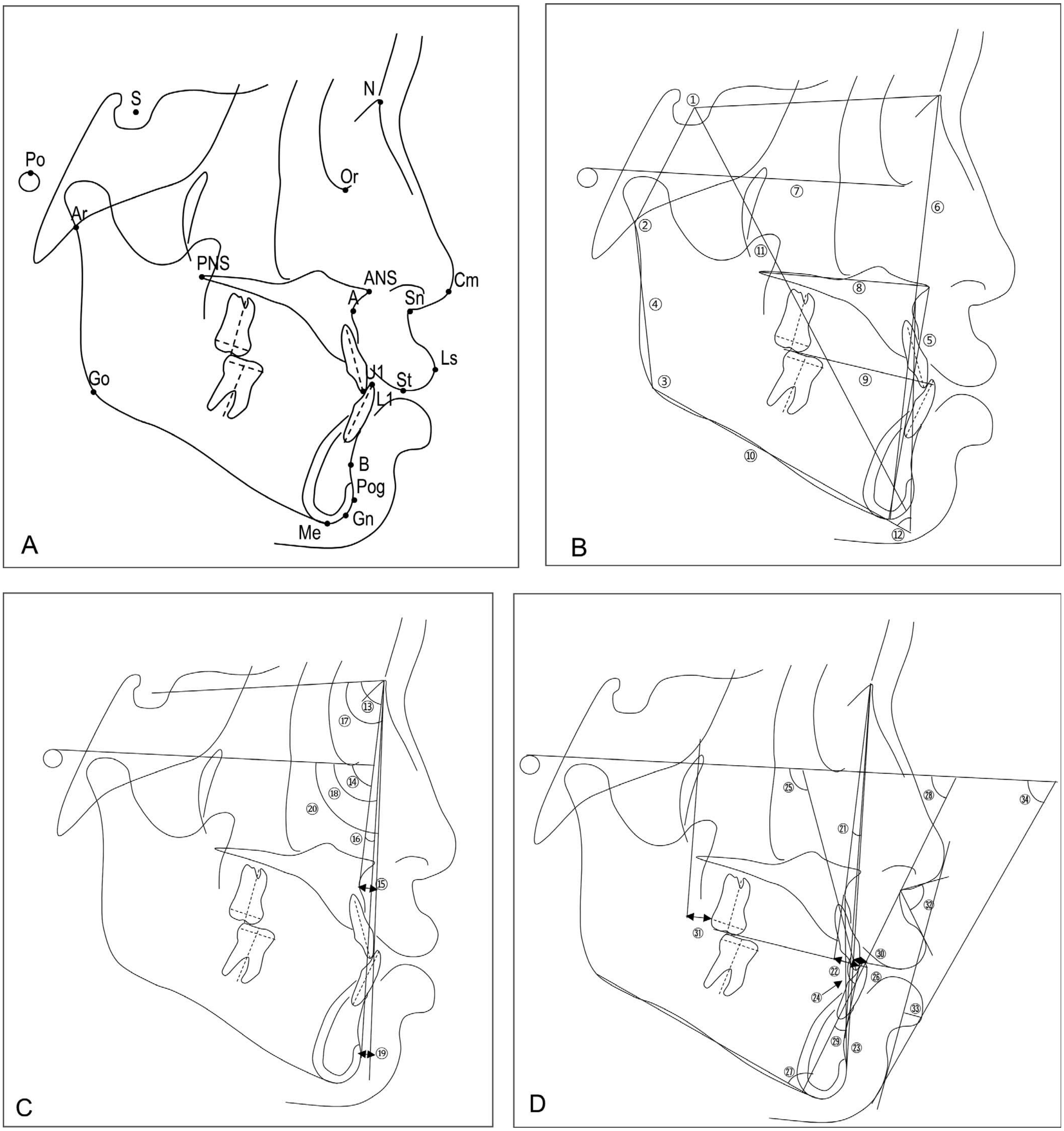


Figure 3. Lateral cephalometric measurements: (A) landmarks of cephalometric image used in this study, (B) skeletal linear measurements, (C) skeletal angular measurements, (D) dental and soft tissue measurements.

DISCUSSION

A meta-analysis of the effectiveness of FM therapy in patients with skeletal Class III malocclusion by Kim et al.[14] showed the anterior and inferior movements of the maxilla, slight superior movement of the anterior teeth, slight inferior movement of the posterior teeth, and clockwise rotation of the mandible, resulting in improvement of the anteroposterior relationship between the maxilla and mandible. It was also suggested that the lower facial height increased and the overjet of the anterior teeth was improved.[14] This was similar to the results of the current study. The maxilla was protruded significantly, and the occlusal plane tended

Table 2. Pretreatment Mean Values and Statistical Differences Between the CHS and FM Groups[a]

	CHS		FM		Comparison
Measurements	Mean	SE	Mean	SE	*P* Value
Skeletal divergency					
SUM (°)	394.55	1.09	396.45	1.05	.216
PFH/AFH	64.56	0.98	62.56	0.90	.140
LFH/AFH	54.48	0.47	54.88	0.45	.539
PP-FH (°)	2.14	0.60	1.36	1.05	.520
OP-FH (°)	14.23	0.82	14.27	0.79	.969
MP-FH (°)	28.53	1.11	28.84	0.85	.826
Facial axis (°)	85.17	0.70	86.95	0.92	.131
ODI (°)	67.17	1.09	64.85	1.46	.208
Skeletal maxilla					
SNA (°)	80.31	0.78	80.66	0.78	.755
NA-FH (°)	86.31	0.75	88.26	0.67	.058
Nper-A (mm)	−3.39	0.67	−1.55	0.59	.045*
Convexity (°)	0.79	1.03	2.20	0.98	.329
Skeletal mandible					
SNB (°)	80.37	0.72	80.37	0.72	.995
NB-FH (°)	86.36	0.66	87.97	0.58	.073
Nper-Pog (mm)	−6.97	1.17	−4.48	0.94	.103
Facial plane angle (°)	85.95	0.67	87.22	0.58	.162
Skeletal Mx-Mn relation					
ANB (°)	−0.05	0.41	0.29	0.43	.568
Wits	−9.06	0.51	−9.70	0.52	.378
APDI (°)	88.58	0.93	89.03	1.30	.779
Dental					
Interincisal angle (°)	134.97	2.01	132.87	2.14	.477
U1-FH (°)	106.60	1.67	110.34	1.66	.118
U1 exposure (mm)	1.71	0.31	1.67	0.41	.935
IMPA (°)	89.90	1.30	87.95	1.09	.257
FMIA (°)	61.57	1.27	63.22	1.18	.349
L1 APog (°)	23.94	1.00	22.85	1.02	.445
L1 APog (mm)	4.51	0.28	4.09	0.33	.342
U6 PTV (mm)	4.99	0.68	7.43	1.02	.052
Soft tissue					
Nasolabial angle (°)	98.46	3.60	99.91	2.25	.735
E-line LL (mm)	2.80	0.36	2.71	0.37	.868
Z angle (°)	75.64	1.18	76.73	0.96	.479

[a] An independent *t*-test was performed for the intergroup comparison with the control group. SE indicates standard error of the mean.

* $P < .05$.

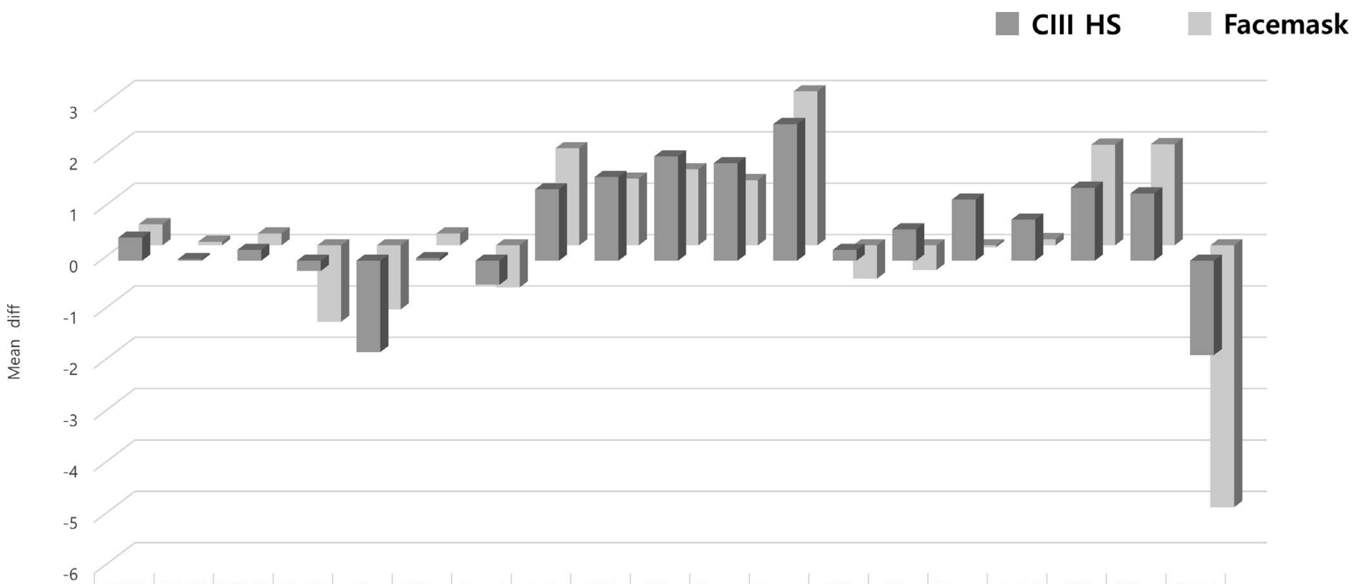
to rotate counterclockwise while the mandible rotated clockwise. Although the changes were not statistically significant, they contributed to the improvement of the anteroposterior skeletal discrepancy.

Compared with studies on the effect of FMs, studies evaluating the Class III horseshoe appliances are insufficient. A few studies were conducted,[10–13] but the sample sizes were small or the criteria for selecting subjects were not standardized in terms of age, sex, skeletal discrepancy, and treatment periods. Regardless of the limitations of the previous studies, they showed that the maxilla was protruded from use of the Class III horseshoe appliance. Marked labial inclination of the upper incisors and lingual inclination of the mandibular incisors and mesial movement of the upper molars contributed to counterclockwise rotation of the occlusal plane. However, there were no rotations of the maxilla and the mandible themselves. These results were similar with those of the current study. There was another study that compared the effect of the Class III horseshoe appliance to the effect of combining the Class III horseshoe appliance with the FM.[11] Unlike those who used only the Class III horseshoe appliance, patients who used FMs with the Class III horseshoe appliances showed clockwise rotation of the mandible. This study did not compare the pure differences between the FM appliance and the horseshoe appliance. The current study is the first comparative study between FMs and Class III horseshoe appliances.

The main differences between the two groups were the dental changes observed. The lower incisors showed a remarkable lingual inclination after treatment in the CHS group, likely because of the force of the intermaxillary Class III elastics. Tiny gaps between the tooth surface and the inside of the horseshoe appliance and the counterclockwise rotation of the occlusal plane might have been the reason lingual inclination of the lower incisors occurred in the CHS group. This feature can be an advantage for young patients without dental compensations or with functional shifts of the mandible attributed to occlusal interferences. The occlusal plane change was greater in the CHS group even though it was not statistically significant, perhaps because of the different line of force (Figure 6). Because the center of resistance of the maxillofacial complex is located near the apex of the maxillary second premolars and first molars[15] and the elastics were applied on the crowns of teeth, a counterclockwise moment was generated, unlike the FM, which clinicians can adjust.[16] The line of action of intermaxillary elastics in the CHS group can be adjusted, but only to a minor extent because of the limited retention of the CHS appliance during wear.

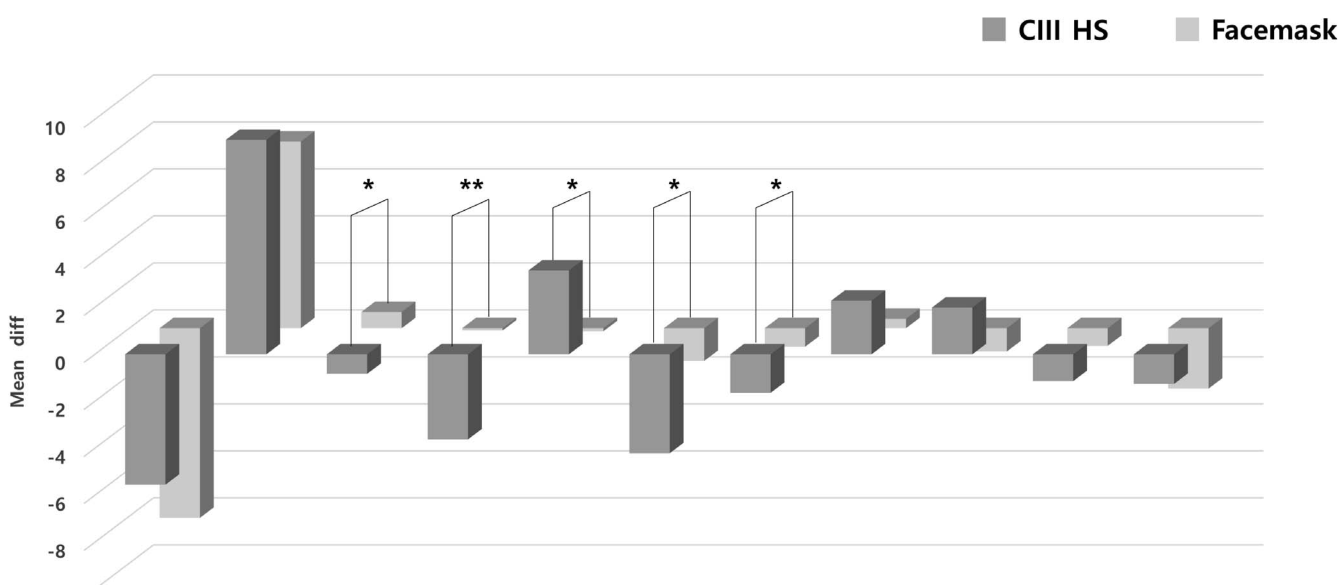
There were no large differences in the skeletal changes between the two groups, but the maxilla was advanced more in the CHS group, whereas the mandible was slightly retruded in the FM group. This was an unexpected result because lighter forces were applied in the CHS group than in the FM group (100 g per side in the CHS group and 350 g per side in the FM group).[11] Generally, it is known that heavy forces are needed for an orthopedic effect because of sutural resistance and distribution in the maxillofacial complex.[17] However, in this study, the same orthopedic results were achieved with much lighter forces.

Instead of a FM, bone anchored maxillary protraction (BAMP) was introduced as an alternative.[18,19] Miniplates were placed on the left and right infrazygomatic crests and between the lower left and right lateral incisors and canines. Then, Class III elastics were applied with an initial force of 150 g on each side and



	SUM (°)	PFH/AFH	LFH/AFH	PP-FH (°)	OP-FH (°)	MP-FH (°)	Facial Axis (°)	ODI (°)	SNA (°)	NA-FH (°)	Nper-A (mm)	Convexity (°)	SNB (°)	NB-FH (°)	Nper-Pog (mm)	Facial plane angle (°)	ANB (°)	Wits	APDI (°)
CIII HS	0.45	0.03	0.21	-0.2	-1.78	0.05	-0.47	1.39	1.63	2.03	1.9	2.66	0.21	0.61	1.19	0.8	1.42	1.31	-1.84
FM	0.41	0.07	0.23	-1.49	-1.25	0.23	-0.82	1.89	1.3	1.48	1.27	3	-0.65	-0.48	-0.04	0.12	1.96	1.97	-5.1

Figure 4. Comparison of skeletal treatment changes between the CHS and FM groups. There is no statistically significant difference in the measurements.



	Inter incisal angle (°)	U1-FH (°)	U1 exposure (mm)	IMPA (°)	FMIA (°)	L1 APog (°)	L1 APog (mm)	U6 PTV (mm)	Nasolabial angle (°)	E-line LL (mm)	Z Angle (°)
CIII HS	-5.55	9.13	-0.83	-3.62	3.57	-4.21	-1.64	2.28	1.99	-1.14	-1.26
FM	-8.07	7.94	0.69	-0.1	-0.13	-1.39	-0.79	0.4	-0.99	-0.75	-2.57

Figure 5. Comparison of dentoalvoelar and soft tissue treatment changes between the CHS and FM groups. U1 exposure, IMPA, FMIA, and L1-APog (both distance and angle) showed statistically significant differences.

Table 3. Comparison of Treatment Changes Between the CHS and FM Groups[a]

Measurements	CHS Difference	CHS SE	FM Difference	FM SE	Comparison *P* Value
Skeletal divergency					
SUM (°)	0.45	0.63	0.41	0.38	.960
PFH/AFH	0.03	0.51	0.07	0.29	.946
LFH/AFH	0.21	0.41	0.23	0.31	.965
PP-FH (°)	–0.20	0.38	–1.49	1.12	.279
OP-FH (°)	–1.78**	0.52	–1.25	0.75	.562
MP-FH (°)	0.05	0.58	0.23	0.43	.803
Facial axis (°)	–0.47	0.41	–0.82	0.99	.749
ODI (°)	1.39	0.79	1.89	1.10	.714
Skeletal maxilla					
SNA (°)	1.63**	0.45	1.30***	0.29	.549
NA-FH (°)	2.03***	0.41	1.48**	0.40	.347
Nper-A (mm)	1.90***	0.36	1.27**	0.37	.223
Convexity (°)	2.66**	0.76	3.00***	0.57	.723
Skeletal mandible					
SNB (°)	0.21	0.43	–0.65	0.35	.128
NB-FH (°)	0.61	0.46	–0.48	0.38	.076
Nper-Pog (mm)	1.19	0.77	–0.04	0.66	.230
Facial plane angle (°)	0.80	0.46	0.12	0.39	.263
Skeletal Mx-Mn relation					
ANB (°)	1.42***	0.35	1.96***	0.30	.247
Wits	1.31**	0.46	1.97**	0.69	.427
APDI (°)	–1.84*	0.87	–5.10**	1.39	.052
Dental					
Interincisal angle (°)	–5.55***	1.38	–8.07**	2.30	.353
U1-FH (°)	9.13***	1.35	7.94***	1.97	.621
U1 exposure (mm)	–0.83*	0.36	0.69	0.45	.011*
IMPA (°)	–3.62***	0.85	–0.10	0.98	.009**
FMIA (°)	3.57***	0.84	–0.13	1.19	.014*
L1 APog (°)	–4.21***	0.89	–1.39	1.04	.045*
L1 APog (mm)	–1.64***	0.26	–0.79**	0.25	.023*
U6 PTV (mm)	2.28***	0.47	0.40	1.25	.164
Soft tissue					
Nasolabial angle (°)	1.99	3.25	–0.99	1.92	.434
E-line LL (mm)	–1.14**	0.30	–0.75**	0.31	.366
Z angle (°)	–1.26	0.80	–2.57**	0.77	.248

[a] An independent *t*-test was performed for the intergroup comparison with the control group. SE indicates standard error of the mean.
* $P < .05$; ** $P < .01$; *** $P < .001$.

increased to 200 g and 250 g successively. There were several reports of orthopedic changes in the maxilla with minimal rotation of the maxilla and the mandible.[18,20] Although the anchorage is different than BAMP, the effect of the Class III horseshoe appliance with light force can be comparable and explained with this evidence. The similar orthopedic changes between the CHS and the FM groups might have been attributed to different compliance using the appliances.

Although statistically significant, the effects on the maxilla were small. Measured at A-point to N-perp, the maxilla advanced 1.9 mm in the CHS group and 1.27 mm in the FM group. This might have been affected by relatively short overall treatment periods in this study compared with previous studies (9.84 ± 4.76 months for the CHS group and 8.76 ± 3.86 months for the FM group).[5] The CHS and FM treatments were finished when the anterior crossbite was corrected and Class I occlusion was achieved. Subsequently, patients were instructed to wear a removable tongue elevator and bio-exercise to improve lip and tongue muscle activity.[20]

In both groups of the current study, the growing mandible did not show a significant forward displacement. Untreated Class III subjects showed 2.2 mm of anterior displacement of the chin in 1.2 years according to previous studies.[21,22] In the CHS group, the mandibular plane was stable after treatment, and there is another factor to explain this. De Clerck et al.[21] suggested that the glenoid fossa at the anterior eminence was remodeled and the bone at the posterior wall was resorbed by BAMP.[20] These glenoid fossa changes were induced by light forces. It may be suggested that the subjects in the CHS group experienced this process, preventing protrusion of the mandible. Appliances with light forces should be used

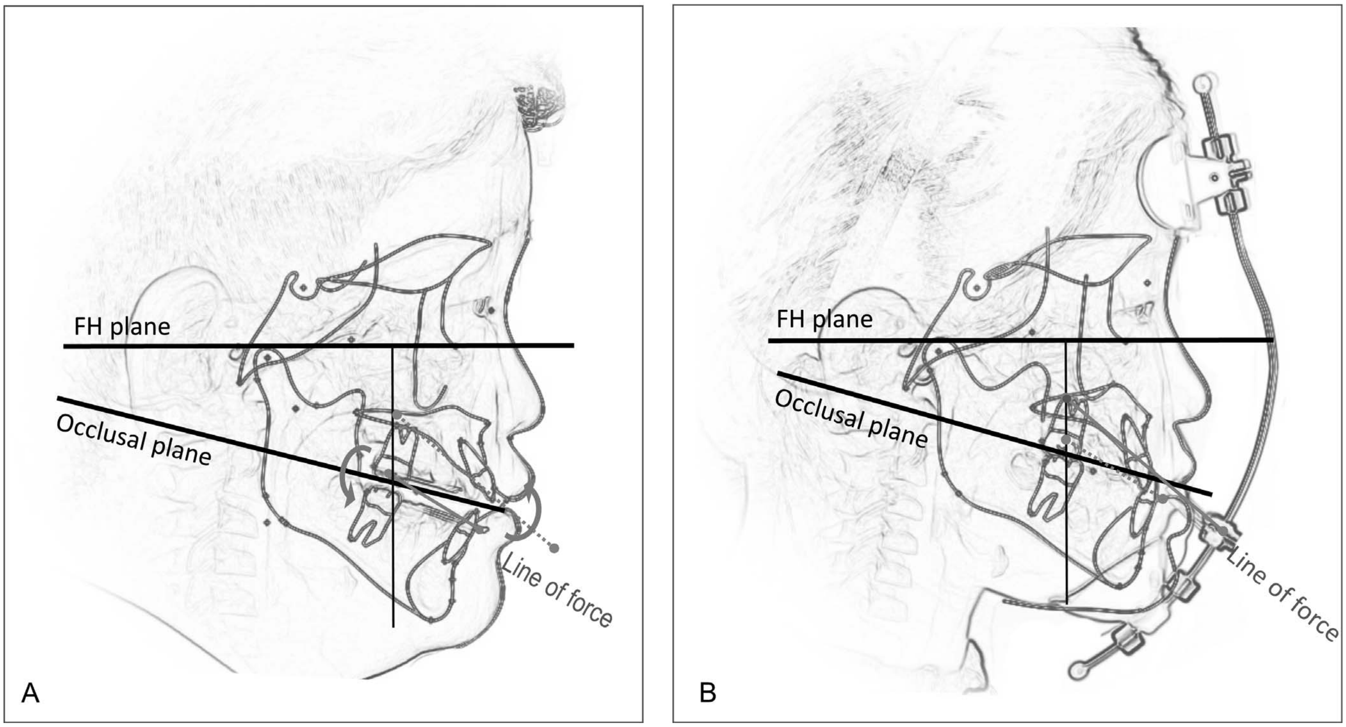


Figure 6. The effect of the appliances on the change of occlusal plane angulation. (A) Line of force from Class III horseshoe appliance that passes beneath the center of resistance of the maxilla resulting in counterclockwise rotation of the occlusal plane. (B) Line of force from the FM that can be adjusted to pass through the center of resistance of the maxilla.

when patients have a high risk of temporomandibular disorders or when relapse of the Class III relationship is expected.

Which appliance is a better choice for each patient depends on two factors. One is the sociopsychological influence because an extraoral appliance may be offensive to a patient's family. The second is the impact of dental compensation; if the lower incisors are tipped lingually pretreatment, a CHS may not be the best choice. FM therapy with a palatal miniscrew for anchorage may promote more maxillary forward growth than FM therapy alone.[23] However, skeletal anchorage-assisted FM therapy may not be recommended for patients in primary and early mixed dentitions.

Skeletal and dental changes were compared between two groups of young patients with similar skeletal characteristics in this study. Further studies about the effects of the appliances in various patient groups, effects related to temporomandibular disorders, changes in pharyngeal airway dimensions, and long-term stability are needed to understand more about the differences between the FM and Class III horseshoe appliances.[24]

CONCLUSIONS

- In the treatment of skeletal Class III malocclusion for growing patients, both appliances were effective in achieving dental and skeletal changes. Sagittally, forward growth of the maxilla, improvement of the relationship between the maxilla and mandible, and upper incisor flaring were similar in both groups.
- The dental contribution to Class III treatment seemed to be greater in the CHS group, especially in the lower anteriors.
- Although the force levels in the CHS group were less than one-third the level of the FM group, maxillary orthopedic changes were induced.
- The factors for choosing the best appliance are patient acceptance and the relative risk of dental compensations.

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