Original Article

Factors associated with long-term vertical skeletal changes induced by facemask therapy in patients with Class III malocclusion

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ABSTRACT

Objectives: This study investigated the long-term vertical skeletal changes induced by facemask therapy in patients with Class III malocclusion and different vertical skeletal patterns.

Materials and Methods: A total of 54 patients (20 boys and 34 girls; mean age, 7.7 ± 2.0 years) with Class III malocclusion who were successfully treated with facemask therapy were included in this study. Vertical skeletal changes (overbite depth indicator, angle between the Sella-Nasion (SN) plane and Gonion-Gnathion (GoGn) line, angle between the Frankfort horizontal (FH) plane and mandibular plane, gonial angle, and angle between the SN plane and palatal plane) were measured on lateral cephalograms from before treatment (T0) to after facemask therapy (T1) and from T0 to after retention (T2). Multivariate linear regression analysis was used to study the associations of the patients' skeletal patterns with the short-term (T0–T1) and long-term (T0–T2) vertical skeletal changes as a result of facemask therapy.

Results: The mean treatment period of facemask therapy (T0–T1) was 1.4 ± 0.6 years, and the mean retention period (T1–T2) was 6.9 ± 2.6 years. Age at T0 was significantly correlated with vertical skeletal changes from T0 to T1. Differences in the treatment results between sexes were not significant. The angle between point A-point B line and mandibular plane to mandibular plane angle at T0 and the angle between the FH plane and mandibular plane at T0 were significant predictors for short-term and long-term changes. Changes in the Sella-Nasion-point A from T0 to T1 and from T1 to T2 significantly affected vertical changes in the short term and long term, respectively.

Conclusions: Vertical skeletal changes as a result of facemask therapy are significantly associated with severity of the skeletal Class III malocclusion and mandibular plane angulation before treatment and the amount of forward maxillary growth during the treatment and retention periods. (*Angle Orthod.* 2018;88:157–162.)

KEY WORDS: Class III malocclusion; Facemask; Vertical facial pattern; Facial growth

INTRODUCTION

Facemask therapy in patients with Class III malocclusion results in forward maxillary displacement and backward mandibular displacement.[1–4] The rotational changes of the jaws that occur in addition to the translational movements may lead to undesirable effects in patients with excessive vertical facial growth.[5–7] In patients with maxillary retrusion and a low mandibular plane angle, facemask therapy increases the facial height and leads to favorable esthetic results.[8] However, in patients with normal or increased vertical facial dimensions, facemask therapy may increase facial height, which is a concern.

Regarding the effects of facemask therapy in patients with different vertical facial patterns, Yoshida et al.[9] reported a greater forward maxillary displacement and a larger increase in maxillary body length (A–Ptm) in patients with a short face than in those with a long face. In contrast, patients with a steep mandibular plane had unsuccessful results after facemask therapy.[10] Meanwhile, Pavoni et al.[11] reported no significant difference in the skeletal changes induced by facemask therapy among patients with hypodivergent, normal, and hyperdivergent facial patterns.

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Successful facemask therapy requires long-term stability of the treatment results related to normal anteroposterior and vertical relationships of the jaws. However, previous reports have focused on the cephalometric variables that can be used as predictors of favorable outcomes.[12–16] Moreover, these outcomes are mostly based on the short-term effects of sagittal skeletal relationships. Long-term studies on the vertical skeletal changes induced by facemask therapy are scarce.

The purpose of this study was to investigate the long-term vertical skeletal effects of facemask therapy in patients with skeletal Class III malocclusion and different vertical skeletal patterns. The null hypothesis was that there are no differences in vertical skeletal changes among patients with different vertical growth patterns.

MATERIALS AND METHODS

This retrospective study was approved by the institutional review board of Korea University Guro Hospital (Seoul, Republic of Korea; 2006-01-0003), and informed consent was obtained from all patients. Long-term vertical skeletal changes were studied in all growing patients with Class III malocclusion who had undergone facemask therapy at Korea University Guro Hospital between March 1990 and June 2014, provided they met the following inclusion criteria: (1) skeletal Class III malocclusion (A point-Nasion-B point angle of less than 1°, anteroposterior dysplasia indicator of greater than 84°, and incisor overjet of less than 0 mm) with maxillary retrusion; (2) patients in the primary or mixed dentition; (3) those who had their anterior crossbite resolved at the end of facemask therapy; and (4) those who had cephalometric records taken before treatment (T0), at the end of the treatment (T1), and more than 5 years after the end of orthopedic treatment (T2). The exclusion criteria were as follows: (1) maxillary transverse deficiency at the start of treatment, (2) congenital deformities in the craniofacial area, (3) congenitally missing permanent teeth, (4) permanent teeth extracted before or during treatment, and (5) signs or symptoms of temporomandibular joint problems.

A total of 54 patients (20 boys and 34 girls; mean age 7.7 ± 2.0 years) met the inclusion criteria. A Delaire-type facemask was applied to the removable intraoral appliance made of acrylic resin, and the patients were instructed to use heavy elastics to exert an orthopedic force ranging from 400 g to 500 g per side. Rapid maxillary expansion was not performed because the patients who were included had no maxillary transverse deficiencies. The orthopedic force was applied in a downward and forward direction at an inclination of 30° from the occlusal plane to ensure that the force vector would pass through the maxillary center of resistance. The patients were instructed to wear the facemask for at least 14 hours per day. Treatment was continued until a positive overjet of at least 4 mm was achieved. After facemask therapy, fixed appliances were used to attain functional occlusion. At the end of treatment, a circumferential removable retainer or a Class III activator was used as a retainer, and the patients were followed up once a year.

Cephalometric analysis was performed on lateral cephalograms acquired at T0, T1, and T2 by one investigator (H-JP). Differences in the cephalometric variables were calculated from T0 to T1 (treatment effects) and from T0 to T2 (long-term effects). For intraexaminer reliability analysis, the lateral cephalograms of all patients were reanalyzed by the same researcher 3 weeks later. The intraclass correlation coefficient was 0.93.

Statistical Analysis

The normality of all cephalometric variables used for multivariate tests was confirmed using the Shapiro-Wilk test. After deriving descriptive statistics, multivariate linear regression analysis was used to study the associations between patients' skeletal patterns and the short-term (T0–T1) and long-term (T0–T2) vertical skeletal changes related to facemask therapy. The outcome variables that were investigated were as follows: short-term changes from T0 to T1 in overbite depth indicator (ODI; ΔODI_T0–T1), angle between the Sella-Nasion (SN) plane and Gonion-Gnathion (GoGn) line (SN-GoGn; ΔSN-GoGn_T0–T1), angle between the Frankfort horizontal (FH) plane and mandibular plane (FMA; ΔFMA_T0–T1), gonial angle (Δgonial angle_T0–T1), and angle between the SN plane and palatal plane (SN-PP; ΔSN-PP_T0–T1); and long-term changes from T0 to T2 in ODI (ΔODI_T0–T2), SN-GoGn (ΔSN-GoGn_T0–T2), FMA (ΔFMA_T0–T2), gonial angle (Δgonial angle_T0-T2), and the SN-PP (ΔSN-PP_T0–T2). Lateral cephalometric variables that were significant, representing the patients' skeletal patterns, were considered as predictor variables. As age, sex, treatment/retention period, and other cephalometric variables may influence the results and act as confounders, their significance was also tested for inclusion in the analysis. The statistical analyses were performed using IBM SPSS Statistics for Windows (version 20.0; IBM Corp., Armonk, N.Y.). Statistical significance was set at $P < .05$.

RESULTS

The mean age of the patients was 7.7 ± 2.0 years at T0, 9.0 ± 2.0 years at T1, and 16.0 ± 2.4 years at T2

Table 1. Mean Ages of the Patients in and Durations of Each Period and Results of the Mean Comparison Tests[a]

Time	Total, n = 54 Mean ± SD	Boys, n = 20 Mean ± SD	Girls, n = 34 Mean ± SD	P[b]
Before treatment (T0)	7.7 ± 2.0	8.4 ± 2.1	7.2 ± 1.8	.039
End of treatment period (T1)	9.0 ± 2.0	9.7 ± 2.1	8.6 ± 1.9	.079
End of retention period (T2)	16.0 ± 2.4	16.1 ± 1.2	15.8 ± 2.9	.128
Treatment period (T0–T1)	1.4 ± 0.6	1.3 ± 0.6	1.4 ± 0.6	.993
Retention period (T1–T2)	6.9 ± 2.6	6.4 ± 2.0	7.2 ± 2.8	.519
Overall period (T0–T2)	8.3 ± 2.4	7.8 ± 2.1	8.6 ± 2.6	.479

[a] All values are given in years. SD indicates standard deviation.
[b] Statistical significance for the difference between boys and girls tested using Mann-Whitney *U*-test.

(Table 1). Boys were older than the girls at the start of treatment (boys, 8.4 ± 2.1 years; girls, 7.2 ± 1.8 years; $P = .039$). The mean treatment period of facemask therapy (T0–T1) was 1.4 ± 0.6 years and the mean retention period (T1–T2) was 6.9 ± 2.6 years (Table 1).

The cephalometric analyses of the patients at T0, T1, and T2 and the amount of changes in each period are shown in Table 2. The Sella-Nasion-point A (SNA) increased after facemask therapy and continued to increase throughout retention. The Sella-Nasion-point B decreased immediately after treatment, but it returned to the baseline values during retention. Therefore, the Class III skeletal relationship was resolved mainly by anterior repositioning of the maxilla. The mandibular plane represented by SN-GoGn and FMA showed a significant increase from T0 to T1, but decreased to lower than the T0 values at T2. The gonial angle was unchanged from T0 to T1 but decreased at T2. The palatal plane increased from T0 to T1, but it returned to the baseline value at T2. A significant increase of ODI was observed from T0 to T1, and no significant change was observed during retention. The anterior facial height showed maintenance from T0 to T1, and a slight increase from T1 to T2, but the changes in each period showed large standard deviations, and they were not statistically significant. The posterior facial height also showed no significant changes from T0 to T1, but a significant increase was observed during retention ($P = .039$).

The multivariate linear regression analysis revealed that that the following variables had significant correlations with the outcome variables representing the short-term vertical skeletal changes induced by facemask therapy from T0 to T1: age at T0 ($P = .012$), AB to MP at T0 ($P = .001$), FMA at T0 ($P = .007$), and change in SNA from T0 to T1 ($P = .001$). For outcome variables representing the long-term vertical changes from T0 to T2, AB to MP at T0 ($P = .038$), FMA at T0 ($P = .007$), and change in SNA from T1 to T2 ($P = .022$) were significant as predictor variables (Table 3). The influence of sex, treatment, retention, and overall duration on the outcome variables did not show statistical significance; thus, they were excluded from the final regression models.

Table 2. Cephalometric Analyses of the Patients at T0, T1, and T2[a]

Cephalometric Variable	T0	T1	T2	T0–T1	P[b]	T1–T2	P[b]	T0–T2	P[b]
SNA	78.6 ± 2.8	80.3 ± 2.8	81.0 ± 3.0	1.7 ± 1.4	<.001	0.7 ± 1.5	.001	2.4 ± 1.7	<.001
SNB	79.2 ± 2.3	77.9 ± 2.4	80.0 ± 2.7	−1.3 ± 1.4	<.002	2.1 ± 1.9	<.001	0.8 ± 2.1	.006
ANB	−0.6 ± 2.0	2.4 ± 2.1	1.0 ± 1.9	3.0 ± 1.4	<.003	−1.4 ± 1.6	<.001	1.6 ± 1.7	<.001
APDI	89.0 ± 4.4	82.0 ± 4.2	86.9 ± 4.6	−7.0 ± 3.2	<.004	4.9 ± 4.1	<.001	−2.1 ± 4.2	.001
ODI	62.0 ± 5.4	65.2 ± 5.6	64.9 ± 6.9	3.2 ± 3.8	<.005	−0.3 ± 4.3	.581	2.9 ± 5.1	<.001
SN-GoGn	37.6 ± 4.1	39.1 ± 4.2	36.4 ± 5.3	1.5 ± 1.4	<.006	−2.7 ± 2.9	<.001	−1.3 ± 3.0	.003
FMA	29.0 ± 3.9	30.2 ± 4.0	27.5 ± 5.0	1.2 ± 1.9	<.007	−2.7 ± 3.2	<.001	−1.5 ± 3.3	.002
Gonial angle	126.4 ± 4.9	126.0 ± 5.0	122.2 ± 6.1	−0.4 ± 2.3	.228	−3.8 ± 4.1	<.001	−4.2 ± 4.7	<.001
AB-MP	62.0 ± 4.0	66.5 ± 4.2	65.3 ± 5.5	4.5 ± 2.7	<.001	−1.3 ± 3.5	.010	3.3 ± 4.2	<.001
SN-PP angle	−8.6 ± 3.1	−7.6 ± 3.0	−8.5 ± 3.6	1.0 ± 1.6	<.001	−0.9 ± 2.1	.002	0.1 ± 2.3	.635
AFH	127.5 ± 21.0	127.2 ± 18.5	130.4 ± 16.7	−0.3 ± 23.1	.916	3.3 ± 25.6	.353	2.9 ± 25.8	.409
PFH	79.6 ± 13.4	78.6 ± 13.3	84.5 ± 12.3	−1.1 ± 14.5	.592	5.9 ± 16.7	.012	4.9 ± 16.9	.039

[a] SNA indicates Sella-Nasion-point A (or angle between the SN plane and N-A line); SNB, Sella-Nasion-point B (or angle between the SN plane and N-B line); ANB, A point-Nasion-B point (or angle between the N-A line and N-B line); APDI, anteroposterior dysplasia indicator; ODI, overbite depth indicator; SN-GoGn, angle between the SN plane and Go-Gn line; FMA, angle between the FH plane and mandibular plane; gonial angle, Ar-Go-Gn (or angle between the Ar-Go line and Go-Gn line); AB-MP (AB to mandibular plane angle), angle between the A-B line and mandibular plane; SN-PP, angle between the SN plane and palatal plane; AFH, Nasion-Menton; PFH, Sella-Gonion.
[b] Statistical significance for the difference between the two time points tested using a paired *t*-test.

Table 3. Multivariate Linear Regression Analyses for Changes in (Δ) ODI, SN-GoGn, FMA, Gonial Angle, and SN-PP From T0 to T1 and From T0 to T2[a]

Predictor Variable	Wilks' Lambda	F	*P*
ΔT0–T1			
Intercept	0.544	7.6	.000
Age_T0	0.731	3.3	.012
AB-MP_T0	0.650	4.8	.001
FMA_T0	0.707	3.7	.007
SNA_T0–1	0.634	5.2	.001
ΔT0–T2			
Intercept	0.718	3.5	.009
Age_T0	0.814	2.1	.089
AB-MP_T0	0.776	2.6	.038
FMA_T0	0.776	2.6	.038
SNA_T1–2	0.753	3.0	.022

[a] Design = intercept + Age_T0 + AB-MP_T0 + FMA_T0 + SNA_T0–1 for ΔT0–T1, and design = intercept + Age_T0 + AB-MP_T0 + FMA_T0 + SNA_T1–2 for ΔT0–T2. F indicates F statistic; AB-MP (AB to mandibular plane angle), angle between the A-B line and mandibular plane; FMA, angle between the FH plane and mandibular plane; SNA, Sella-Nasion-point A (or angle between the SN plane and N-A line).

To determine how AB-MP and FMA at T0, and changes in SNA from T0 to T1 and T1 to T2 affected the short-term and long-term vertical skeletal changes, the estimated regression coefficients were derived (Table 4). Greater AB-MP at T0 was significantly associated with a decrease in ODI changes from T0 to T1 ($P < .001$) and from T0 to T2 ($P = .013$), as well as FMA changes from T0 to T2 ($P = .028$). Patients with greater FMA at T0 showed a significant decrease of ODI changes from T0 to T1 ($P = .001$) and from T0 to T2 ($P = .002$), and a decrease in FMA changes from T0 to T1 ($P = .029$).

DISCUSSION

As changes in vertical facial dimensions have a significant impact on the facial profile, the vertical skeletal changes induced by facemask therapy should be carefully considered because they may produce undesirable results in patients with long faces. It was hypothesized that rotational changes of the jaws induced by facemask therapy would have a significant effect in growing patients. The aim was to investigate whether and how the long-term effects of facemask therapy differed according to the patients' skeletal pattern by assessing the skeletal changes in patients with Class III malocclusion and various skeletal patterns.

The skeletal changes in patients were investigated using a multivariate analysis. As the cephalometric variables of interest (ODI, SN-GoGn, FMA, gonial

Table 4. Estimated Regression Coefficients of the Regression Models for the Changes (Δ) From T0 to T1 and From T0 to T2[a]

T0-T1				T0-T2			
Outcome Variable	Predictor Variable	B	*P*	Outcome Variable	Predictor Variable	B	*P*
ΔODI_T0–1	Intercept	52.93	<.001	ΔODI_T0–2	Intercept	55.41	.001
	age_T0	−0.75	.006		age_T0	−0.53	.149
	AB-MP_T0	−0.50	<.001		AB-MP_T0	−0.50	.013
	FMA_T0	−0.45	.001		FMA_T0	−0.61	.002
	ΔSNA_T0–1	0.09	.781		ΔSNA_T1–2	0.17	.718
ΔSN-GoGn_T0–1	Intercept	9.17	.054	ΔSN-GoGn_T0–2	Intercept	8.86	.353
	age_T0	−0.19	.079		age_T0	−0.04	.846
	AB-MP_T0	−0.07	.217		AB-MP_T0	−0.14	.231
	FMA_T0	−0.05	.333		FMA_T0	−0.03	.802
	ΔSNA_T0–1	−0.35	.011		ΔSNA_T1–2	−0.84	.003
ΔFMA_T0–1	Intercept	15.70	.019	ΔFMA_T0–2	Intercept	22.58	.032
	age_T0	−0.20	.170		age_T0	−0.33	.148
	AB-MP_T0	−0.12	.107		AB-MP_T0	−0.28	.028
	FMA_T0	−0.17	.029		FMA_T0	−0.14	.253
	ΔSNA_T0–1	−0.32	.089		ΔSNA_T1–2	−0.75	.013
ΔGonial angle_T0–1	Intercept	−15.96	.052	ΔGonial angle_T0–2	Intercept	−10.60	.507
	age_T0	0.11	.558		age_T0	0.40	.254
	AB-MP_T0	0.18	.055		AB-MP_T0	0.03	.862
	FMA_T0	0.12	.182		FMA_T0	0.07	.713
	ΔSNA_T0–1	−0.08	.725		ΔSNA_T1–2	−0.95	.039
ΔSN-PP angleT0–1	Intercept	−8.98	.097	ΔSN-PP angleT0–2	Intercept	−3.10	.680
	age_T0	0.11	.386		age_T0	0.08	.625
	AB-MP_T0	0.10	.115		AB-MP_T0	0.02	.869
	FMA_T0	0.08	.184		FMA_T0	0.04	.612
	ΔSNA_T0–1	0.43	.007		ΔSNA_T1–2	0.63	.005

[a] B indicates regression coefficient; ODI, overbite depth indicator; AB-MP (AB to mandibular plane angle), angle between the A-B line and mandibular plane; SN-GoGn, angle between the SN plane and Go-Gn line; FMA, angle between the FH plane and mandibular plane; gonial angle, Ar-Go-Gn (or angle between the Ar-Go line and Go-Gn line); SN-PP, angle between the SN plane and palatal plane; SNA, Sella-Nasion-point A (or angle between the SN plane and N-A line).

angle, and SN-PP) are closely interrelated, their effects on each other were considered when comparing these values. Moreover, the differences in treatment effects can be modified (or confounded) by various factors or covariates; therefore, they were identified and controlled for in the final analytical model. Age, sex, treatment period, and retention period were considered as covariates, but only age at T0 was significant for the short-term changes ($P = .012$; Table 3), and marginally nonsignificant for the long-term changes ($P = .089$; Table 3). Similar to the current results, Kajiyama et al.[6] reported that age was a significant factor influencing the treatment effects of facemask therapy, whereas no sex-related differences were found. According to the regression analysis results, an increase in age was associated with a decrease in ODI changes, that is, an increase in vertical dimension, from T0 to T1, which may be unfavorable in patients with a normal or long face.

Both anteroposterior and vertical skeletal patterns at the start of treatment significantly affected the vertical skeletal changes induced by facemask therapy; the AB-MP at T0 and FMA at T0 were significant covariates in both short-term and long-term vertical skeletal changes. The AB-MP angle represents the severity of the Class III malocclusion incorporating the vertical skeletal pattern (mandibular plane angulation) and the sagittal intermaxillary relationship (point A-point B plane), and it has been used to predict the prognosis of skeletal Class III treatment.[15] A lower AB-MP angle indicates severe mandibular prognathism with high mandibular plane angles, and the treatment is less predictable. Patients with greater AB-MP at the start of treatment were likely to have increased vertical skeletal dimensions (decreased ODI changes) in short-term and long-term changes, indicating that patients with moderate mandibular prognathism and low mandibular plane angles were likely to have vertical growth as a result of treatment. In contrast, patients with high FMA at T0 tended to have a greater amount of counterclockwise rotation of the mandible after facemask therapy. This pattern was consistent for changes in SN-GoGN and FMA in the short term and long term, but statistical significance was only observed in FMA from T0 to T1.

Another strong predictor for mandibular rotation was the change in SNA during treatment and retention. The patients showed forward maxillary growth as a result of facemask therapy, and further growth was observed during retention. The regression coefficients revealed that the amount of forward displacement of A point from T0 to T1 (SNA_T0–T1) and from T1 to T2 (SNA_T1–T2) was significantly proportionate to the amount of counterclockwise rotation of the mandible from T0 to T1 (ΔSN-GoGn_T0-T1) and from T0 to T2 (ΔSN-GoGn_T0-T2), respectively. Previous researchers reported clockwise rotation of the mandible as one of the major effects of facemask therapy and concluded that counterclockwise rotation of the mandible is highly associated with unsatisfactory treatment outcomes.[6,13] However, mandibular counterclockwise rotation observed in the patients in this study was not associated with unfavorable results, as the Class III malocclusion was resolved through forward maxillary growth that occurred during treatment and throughout retention. Patients' anteroposterior jaw relationship and vertical heights were restored to normal values, as evidenced by cephalometric analysis.

The gonial angle was unchanged after facemask therapy, but decreased during the retention period. This change in the gonial angle may have contributed to the decrease in mandibular plane angle observed at T2. Gonial angle was also significantly influenced by the amount of forward maxillary growth from T1 to T2, and greater maxillary movement was associated with a decrease in the gonial angle. Gonial angle changes may be associated with facial height changes as posterior facial height significantly increased during the retention period while anterior facial height was unchanged. Tahmina et al.[13] reported that patients with unsuccessful chin cup therapy outcomes had larger gonial angles that increased over time. Cozza et al.[17] advocated the combined use of a facemask and a bite-block appliance in the mandibular arch for progressive closure of the gonial angle.

The maxilla rotated clockwise from T0 to T1 and counterclockwise from T1 to T2, but the mean change was approximately 1°, which was not clinically significant. Changes in SNA were also significantly correlated to maxillary rotations; patients with greater forward maxillary growth had greater clockwise rotation of the maxilla. This result was contrary to that of previous reports showing only counterclockwise rotations,[7,11] but the amount of maxillary rotation was minimal in our study as well as in previous studies.

A limitation of this study is that there was no control group of children with Class III malocclusion who had not been treated and had undergone only observation. However, this was not feasible for ethical reasons. The patients' age at the end of the retention period was 15.8 ± 2.2 years, and late mandibular growth may have occurred after the last follow-up period. As many of the predictor variables showed marginal nonsignificance, further studies with larger sample sizes and longer follow-up periods may provide more conclusive results.

CONCLUSIONS

An analysis of patients with Class III malocclusion treated with facemasks allowed the following conclusions to be drawn:

- Age was significantly associated with vertical changes induced by facemask therapy, and sex was not related to treatment outcomes.
- Vertical skeletal changes as a result of facemask therapy were significantly associated with the severity of the skeletal Class III malocclusion and mandibular plane angulation at the start of treatment and the amount of forward maxillary growth during the treatment and retention periods.

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