Effects of Maxillary Protraction and Fixed Appliance Therapy on the Pharyngeal Airway

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ABSTRACT

Objective: To evaluate the long-term outcome of treatment with reverse headgear in patients with skeletal Class III malocclusion diagnosed as maxillary deficient.

Materials and Methods: Twenty-five patients (11 girls, 14 boys; mean age, 11.32 years) treated with a reverse headgear appliance were included in this study. Pretreatment, posttreatment, and 4-year follow-up cephalometric radiographs were obtained; linear, angular, and area measurements were performed. Comparison of treatment and observation changes was performed using a paired *t*-test.

Results: A significant increase was found in the forward movement of the maxilla, which was maintained 4 years after reverse headgear treatment. Treatment changes revealed significant increases in the sagittal dimensions and area of nasopharyngeal airway and remained significant at the end of the 4-year follow-up period. The oropharyngeal airway area increased nonsignificantly after the treatment, but significant increases occurred during the follow-up period.

Conclusions: In young individuals diagnosed with maxillary deficiency treated with reverse headgear, the nasopharyngeal airway dimensions were improved after the treatment, and favorable effects of the treatment remained over the posttreatment period of 4 years. (*Angle Orthod.* 2009; 79:660–667.)

KEY WORDS: Airway; Pharyngeal dimension; Reverse headgear treatment

INTRODUCTION

Skeletal Class III malocclusions can be defined as skeletal facial deformities characterized by a forward mandibular position with respect to the cranial base and/or maxilla. Studies have shown that the two-thirds of the skeletal Class III malocclusions in white individuals are due to maxillary hypoplasia or a combination of maxillary hypoplasia and mandibular prognathism.[1,2] To evaluate the success of orthodontic treatment in such cases, long-term posttreatment analysis is essential.

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In view of the high frequency of maxillary retrusion, maxillary advancement by reverse headgear has been considered a major treatment option in young patients.[3–5] The aim of these orthopedic approaches is to provide a more favorable environment for normal growth as well as an improvement in the occlusal relationship.[6,7] Several studies demonstrated the skeletal and dentoalveolar effects of maxillary protraction appliances, which were mainly the forward displacement of the maxilla, clockwise rotation of the mandible, protrusion of the upper incisors, and retrusion of the lower incisors.[8–11]

Previously, initial and short-term treatment response and long-term dentofacial adaptations to maxillary protraction treatment have been performed.[8,9,12–17] In addition, recent studies have revealed the beneficial treatment effects of maxillary protraction appliances on upper airway dimensions.[18–20] It has been reported that sagittal airway dimensions could be increased by the stimulation of forward maxillary growth. Only short-term treatment results have been reported on the relationships between maxillary protraction and airway size. However, long-term results are needed to evaluate if the improvement on the airway dimensions after

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maxillary protraction treatment induce stable changes until craniofacial growth is completed.

Thus, the purpose of this study was to investigate the long-term effects of treatment with reverse headgear in patients with anterior crossbite and a skeletal Class III malocclusion due to maxillary deficiency on the sagittal pharyngeal dimensions.

MATERIALS AND METHODS

The sample was composed of the lateral cephalometric radiographs of 25 children (11 girls, 14 boys) treated with a reverse headgear appliance and a removable intraoral plate on the lower arch with a minimum thickness sufficient to open the bite to an edge-to-edge incisal position, obtained retrospectively from the files of Class III subjects according to the following criteria: skeletal and dental Class III malocclusion with maxillary retrusion and normal mandible, optimal mandibular plane angle, an anterior crossbite with no functional shift, and no congenital anomalies in the medical history. The written informed consent forms of all patients were present in the files and were approved by the Research Ethics Committee of Gazi University School of Dentistry. Cephalometric radiographs were obtained before and after reverse headgear treatment, and follow-up radiographs were taken at approximately 4 years posttreatment.

Skeletal ages were determined from the hand-wrist radiographs.[21] All subjects were between PP_2 and MP_{3cap} developmental stages at the beginning of the treatment and between MP_3 union and Ru at the end of the follow-up period. The mean chronological age at the start of treatment was 11.32 $\pm$ 1.08 years. The magnitude of the protraction force was approximately 350 g per side and was delivered by elastics between the maxillary canines and lateral incisors, exerting a downward and forward pull 30° to the occlusal plane. The patients were instructed to wear the appliance 14 hours per day. The mean treatment time was 6.94 $\pm$ 0.91 months. Posttreatment cephalograms were obtained when positive overjet was achieved. After reverse headgear application, a second phase of orthodontic treatment with fixed appliances was used to maintain normal occlusion.

The lateral cephalometric radiographs of pretreatment (T_1), posttreatment (T_2), and follow-up period of 4 years (T_3) have been evaluated. Therefore, ($T_2 - T_1$) represented the treatment changes, ($T_3 - T_2$) the changes during the follow-up period, and ($T_3 - T_1$) the total changes during treatment and the follow-up period.

Lateral cephalometric radiographs were taken in the natural head position with a Trophy Instrumentarium Cephalometer (OP 100, Finland) at 70 KVp, 16 mA/s, with occlusal position as after a usual swallow. The lateral cephalometric radiographs were manually traced by the same researcher. The measurements obtained from the cephalograms were corrected for the standard magnification. Sixteen linear, six angular, and two pharyngeal area measurements were performed by the same researcher (Figure 1).

For the area measurements, the palatal line through ANS-PNS, the sphenoid line tangent to the lower border of sphenoid registered on basion, and the pterygomaxillary line perpendicular to the palate line registered on pterygomaxillare were traced on the cephalograms. The upper airway area was divided into two regions by the palatal line; the nasopharyngeal area (NA) and oropharyngeal area (OA). The palatal line and the base of epiglottis were accepted as the upper and lower borders of the oropharyngeal area (Figure 2). The area measurements were performed by NETCAD for Windows, V290b56, software program, which is an engineering drawing program used for topographic studies. For this purpose, photographs of the traced cephalograms were taken with a Sony DSC-T30 digital camera (7.2 megapixels, 3.0-in. hybrid LCD monitor; Japan) at standard conditions (film-negatoscope distance of 30 cm, macro on, auto flash, and 1.5× magnification). The photographs were transferred to the NETCAD program by a 1:1000 scale. The nasopharyngeal and oropharyngeal areas were digitized according to the specified points by two different authors to obtain maximum agreement and reliability when marking. The numerical values of the areas were determined by the program, and the derived numbers were designated as unit squares.

To evaluate the error in cephalometric tracing, 18 radiographs were randomly selected, retraced, and remeasured by the same author after 10 days. Method error coefficients for the measurements were within acceptable limits (range, 0.96–0.98).[22]

Statistical Analysis

Statistical evaluation was performed using SPSS for Windows, version 10.0 (Chicago, Ill). The treatment effects of reverse headgear appliance and changes during the follow-up period were evaluated by using a paired *t*-test. The level of significance was established as $P < .05$.

RESULTS

The means and standard deviations of each variable measured at the beginning (T_1), end of reverse headgear treatment (T_2), and follow-up period (T_3) are presented in Table 1. The treatment changes ($T_2 - T_1$), the changes during the follow-up period ($T_3 - T_2$), the total changes during treatment and the follow-up pe-

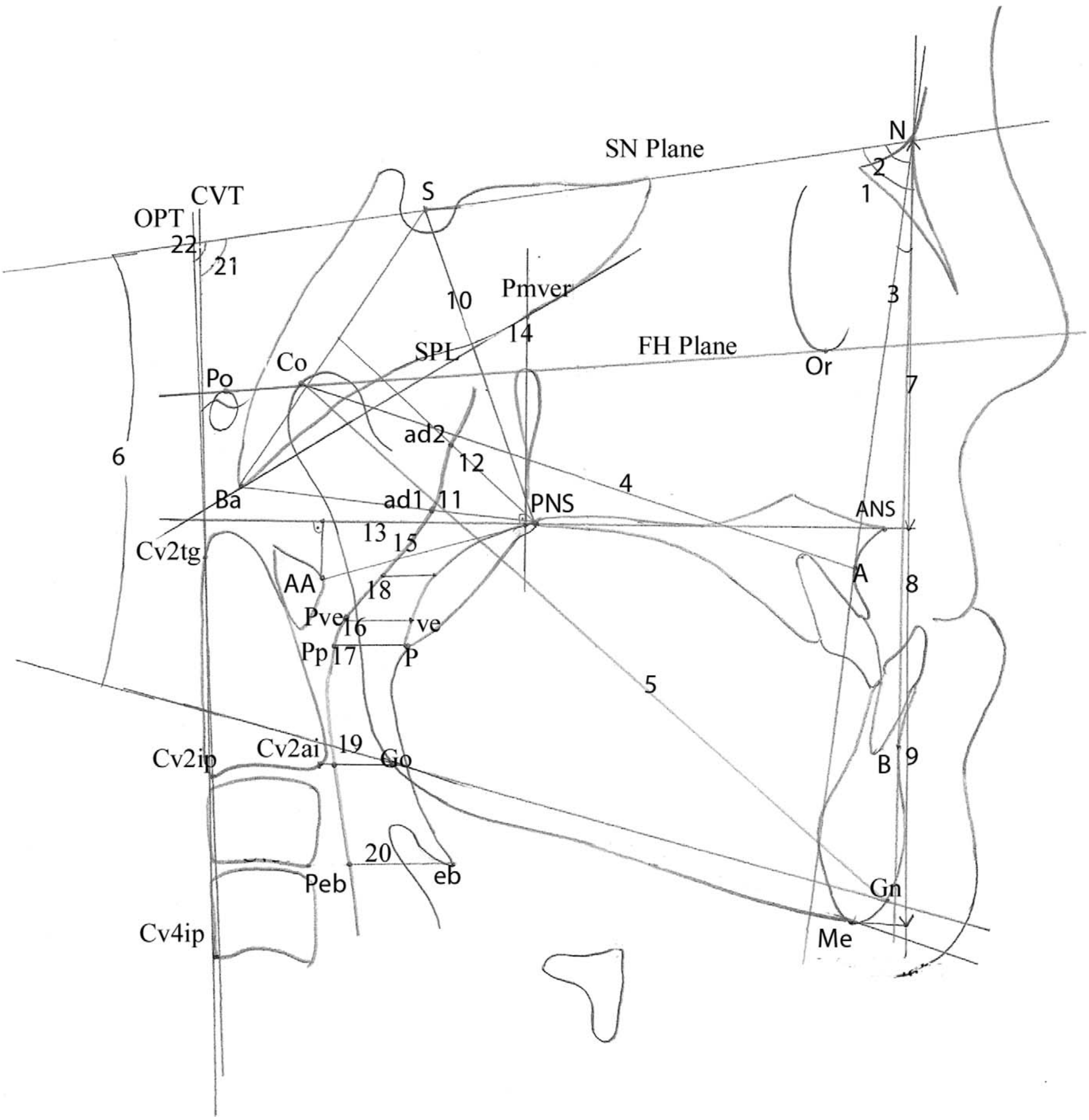

Figure 1. Cephalometric points, planes, and measurements used in the cephalometric analysis. 1, SNA; 2, SNB; 3, ANB; 4, Co-A; 5, Co-Gn; 6, SN-GoGn; 7, N-ANS; 8, ANS-Me; 9, N-Me; 10, S-PNS; 11, ad1-PNS (the distance from PNS to the pharyngeal wall along the line from basion [ba] to PNS); 12, ad2-PNS (the distance from PNS to the adenoid tissue along the line from PNS to the midpoint of the line intersecting ba to sella turcica); 13, AA′-Pm′ (the distance between the perpendicular intersections of anterior atlas and pterygmaxillary line along palatal line); 14, Pm′-SPL (sphenoid line tangent to lower border of sphenoid registered on basion); 15, AA-PNS; 16, ve-Pve (the distance of velum palatinum to the horizontal counterpart on the posterior pharyngeal wall along parallel line to Frankfurt horizontal); 17, MPS (the distance of the tip of the soft palate to the horizontal counterpart on the posterior pharyngeal wall along the parallel line to Frankfurt horizontal); 18, SPS (the distance of the midpoint of the line from PNS to tip of the soft palate [P] to the horizontal counterpart on the posterior pharyngeal wall along parallel line to Frankfurt horizontal); 19, IPS (the distance of the intersection points on the anterior and posterior pharyngeal wall through Cv2ai along the parallel line to the Frankfurt horizontal); 20, eb-Peb (the distance from the vallecula epiglottis to the horizontal counterpart on the posterior pharyngeal wall along the parallel line to the Frankfurt horizontal plane); 21, SN-CVT (the downward angle between the SN plane and the line through Cv2tg and Cv4ip); 22, SN-OPT (the downward angle between the SN plane and the line through Cv2tg and Cv2ip).

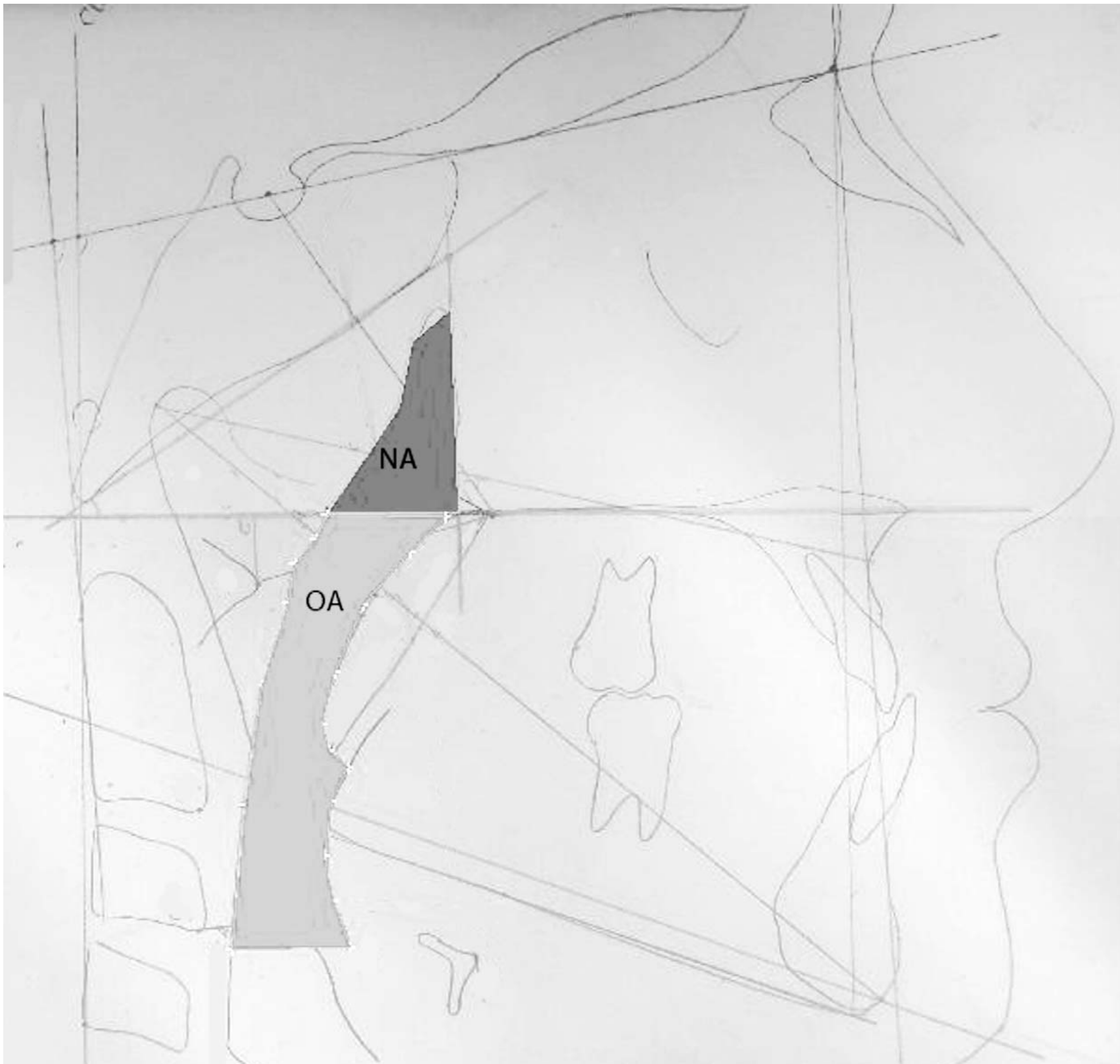

Figure 2. The nasopharyngeal (NA) and oropharyngeal area (OA) measurements.

riod ($T_3 - T_1$), and the comparison of the differences are presented in Table 2.

Treatment Changes ($T_2 - T_1$)

The maxilla moved forward, revealed by the significant increases in SNA angle and Co-A distance ($P < .001$). The findings indicate that reverse headgear appliance was associated with the increases in total and lower facial heights ($P < .001$).

The sagittal mandibular position (SNB), mandibular plane angle, Co-Gn distance, and upper anterior facial height did not change significantly after treatment.

The pharyngeal airway measurements illustrated that the nasopharyngeal height (S-PNS, Pm′-SPL; $P < .001$, $P < .05$, respectively), nasopharyngeal airway dimensions (ad1-PNS, ad2-PNS; $P < .05$), nasopharyngeal (NA) area ($P < .01$), and upper pharyngeal width (SPS; $P < .001$) revealed significant increases after treatment (Table 2).

Follow-up Period Changes ($T_3 - T_2$)

During the follow-up period, the skeletal pattern changes were such that both the maxilla and the mandible came more forward ($P < .001$, respectively). The facial height measurements continued to increase ($P < .001$, respectively) over this period. The mandibular plane angle decreased significantly, demonstrating the counterclockwise rotation of the mandible ($P < .01$).

All nasopharyngeal airway measurement changes were more pronounced, and the oropharyngeal area showed a significant increase ($P < .05$; Table 2).

Table 1. Means and Standard Deviations at the Beginning of Treatment (T_1), After Reverse Headgear Treatment (T_2), and at the End of the Follow-up Period (T_3)

	T_1		T_2		T_3	
	Mean	SD	Mean	SD	Mean	SD
Skeletal morphology						
SNA, °	77.56	2.84	80.50	3.25	82.06	3.70
SNB, °	80.14	3.09	80.04	3.57	81.50	4.05
ANB, °	−2.58	2.33	0.50	2.01	0.52	2.13
Co-A, mm	82.34	5.34	86.02	5.82	90.98	6.03
Co-Gn, mm	113.42	6.23	115.60	9.90	124.38	7.61
SN-GoGn, °	33.04	5.23	33.18	5.00	31.86	5.68
N-ANS, mm	53.06	3.21	53.62	2.96	56.42	2.58
ANS-Me, mm	64.18	6.56	67.52	5.90	71.52	7.17
N-Me, mm	117.26	8.35	121.32	7.15	127.88	8.40
Nasopharynx						
S-PNS, mm	48.52	2.72	50.42	2.75	53.16	3.34
ad1-PNS, mm	23.26	4.77	24.68	4.81	26.14	3.69
ad2-PNS, mm	18.58	3.76	19.82	4.44	22.78	3.38
AA′-Pm′, mm	28.20	3.49	28.92	3.57	29.62	3.56
Pm′-SPL, mm	30.24	3.01	31.46	2.76	33.44	3.86
NA Alan	57,871.24	19,641.90	68,618.08	20,609.33	84,040.64	19,880.01
Oropharynx						
AA-PNS, mm	32.10	2.55	32.86	3.01	33.92	3.18
ve-Pve, mm	8.68	2.24	8.82	2.23	8.98	1.74
MPS, mm	9.36	2.02	9.68	2.56	9.86	1.66
SPS, mm	11.96	1.78	13.26	1.94	13.60	2.11
IPS, mm	10.40	2.50	11.28	3.25	10.26	2.36
Eb-Peb, mm	13.90	3.50	15.02	3.04	15.18	3.97
OA Alan	136,099.96	28,092.74	147,879.36	35,842.38	170,296.44	39,210.17
Head posture						
SN-CVT, °	101.08	7.95	100.60	8.85	101.12	7.38
SN-OPT, °	96.70	8.07	95.62	8.58	95.22	7.64

Total Changes ($T_3 - T_1$)

The total differences in the skeletal morphology and the pharyngeal airway measurements during the treatment and at the end of the 4-year follow-up period remained statistically significant (Table 2).

DISCUSSION

This study evaluated the effects of reverse headgear appliance on the skeletal morphology and airway passage after treatment and over the follow-up period. Since the patients were still in an active growth period at the end of the reverse headgear treatment, the follow-up cephalograms were achieved at early adulthood. To our knowledge, there has been no previous report on the long-term effects of maxillary protraction on sagittal pharyngeal airway dimensions. Early treatment is commonly indicated for these type of malocclusions because, if left untreated, there will be a substantial percentage of patients seeking orthognathic surgery in adulthood. There are studies in the literature in which Class I control groups have been used, but the dentoalveolar and skeletal growth trends in Class III subjects may reveal differences. A Class III control group is advantageous, but it is difficult to find and not ethical to confine a longitudinal Class III control material. For this 4-year follow-up study, no control group was available because it was extremely difficult to obtain such untreated Class III patients in the long term.

Several studies demonstrated that reverse headgear treatment stimulated the forward displacement of the maxilla and reduced the forward displacement of the mandible.[8–10,23,24] The present results revealed that forward movement of the maxilla was significant, and the backward positioning of the mandible was statistically nonsignificant after treatment. The mean differences in the Co-A distance were likely to be significant, and forward movement of the maxilla was evident and more pronounced in the follow-up period. Therefore, the maxilla continued to grow forward after treatment, which was maintained in the long-term observation. This is in accordance with the findings of previous long-term studies.[15,25] Ngan et al[26] found that the maxilla continued to move forward in the treated subjects, similar to the controls.

The improvement in the maxillomandibular relation-

Table 2. Comparison of the Mean Differences at the Start (T_1), End of Treatment (T_2), and Follow-up Period (T_3)

	Mean Differences ($T_2 - T_1$)	SD	*P*	Mean Differences ($T_3 - T_2$)	SD	*P*	Mean Differences ($T_3 - T_1$)	SD	*P*
Skeletal morphology									
SNA, °	2.94	1.78	***	1.56	2.17	***	4.50	2.82	***
SNB, °	−0.10	1.85	ns	1.46	1.88	***	1.36	2.80	*
ANB, °	3.06	1.39	***	0.04	0.85	ns	3.01	1.57	***
Co-A, mm	3.68	3.24	***	4.96	4.50	***	8.64	4.06	***
Co-Gn, mm	2.18	5.95	ns	8.78	8.39	***	10.96	6.68	***
SN-GoGn, °	0.14	1.09	ns	−1.32	2.15	**	−1.18	2.63	*
N-ANS, mm	0.56	2.36	ns	2.08	2.35	***	3.36	2.45	***
ANS-Me, mm	3.34	2.87	***	4.00	3.62	***	7.34	4.04	***
N-Me,l mm	4.06	4.13	***	6.56	5.01	***	10.62	5.61	***
Nasopharynx									
S-PNS, mm	1.09	1.40	***	2.74	2.35	***	4.64	2.68	***
ad1-PNS, mm	1.42	2.99	*	1.46	2.52	**	2.88	3.15	***
ad2-PNS, mm	1.24	2.06	*	2.96	3.08	***	4.02	3.44	**
AA′-Pm′, mm	0.72	2.55	ns	0.70	1.70	*	1.42	2.42	**
Pm′-SPL, mm	1.22	2.83	*	1.98	3.15	**	3.02	3.14	***
NA Alan	10,746.90	1646.00	**	15,422.60	1881.00	***	26,169.40	2009.00	***
Oropharynx									
AA-PNS, mm	0.76	1.80	*	1.06	1.74	**	1.82	2.18	***
ve-Pve, mm	0.14	2.57	ns	0.12	1.91	ns	0.26	2.88	ns
MPS, mm	0.26	2.63	ns	0.22	2.22	ns	0.48	2.57	ns
SPS, mm	1.03	1.65	***	0.38	1.78	ns	1.68	1.84	***
IPS, mm	0.88	3.57	ns	−1.02	2.83	ns	−0.14	3.12	ns
eb-Peb, mm	1.12	3.00	ns	0.16	3.65	ns	1.28	4.30	ns
OA Alan	11,779.40	4084.00	ns	22,417.08	4655.00	*	34,196.50	5179.00	**
Head posture									
SN-CVT, °	−0.48	9.56	ns	0.52	10.30	ns	0.04	8.56	ns
SN-OPT, °	−1.08	9.40	ns	−0.40	10.40	ns	−1.48	8.58	ns

* $P < .05$; ** $P < .01$; *** $P < .001$; ns, nonsignificant.

ship indicated by the ANB angle was significant at the time of the present treatment and, because of the forward movement of the mandible, the change in ANB angle was nonsignificant in the follow-up period. The current changes that occurred with the reverse headgear appliance demonstrated a nonsignificant alteration of mandibular growth, but a significant anterior rotation of the mandible was observed during the follow-up period. This result was in contrast to the findings of Oktay and Ulukaya[18] and Hiyama et al.[20] They reported that the mandible revealed a significant clockwise rotation after maxillary protraction. Their sample demonstrated different growth patterns with a tendency to high angle, which might be considered in evaluating the discrepancy between studies. Ngan et al[24] declared downward and backward rotation in the mandible at the follow-up period of maxillary protraction and expansion treatment. Gallagher et al[9] reported that follow-up after protraction treatment revealed a clockwise rotation of the maxilla and a normal growth of the mandible.

The occlusion was maintained in a favorable arrangement, and the development of relapse was prevented probably because of the second-phase orthodontic treatment. Previously, a more hipodivergent skeletal pattern or skeletal deep-bite tendency have been considered as favorable signs for the prognosis of early Class III malocclusion treatments.[15,27] It was reported that the clockwise rotation of the mandible after the protraction treatment is associated with a higher relapse tendency at the observation period.[28]

In this study, the lower anterior and total facial heights increased significantly after the treatment, and the increases in the follow-up period were more pronounced, which is in accordance with previous studies.[25] Moreover, Bacetti et al[29] found that the lower facial height continued a less pronounced increase in the long term.

Most of the studies in the literature investigated the effects of maxillary protraction appliance on dentofacial structures.[8–11,30] So far, a limited number of studies have been published on the relationships between maxillary protraction and pharyngeal airway dimensions.[18–20] Oktay and Ulukaya[18] declared that the size of the upper airway can be increased by the maxillary protraction treatment. Sayınsu et al[31] evaluated the effects of maxillary expansion and protraction on the sagittal airway and found that the nasopharyngeal airway size increased with treatment. Hiyama et al[20] found an increase in the upper airway dimensions after maxillary protraction treatment and suggested that this therapy might improve the respiratory function of patients with maxillary retrusion. Their results showed that greater forward maxillary growth was associated with a greater increase in the upper airway dimensions. Likewise, a previous study demonstrated the improvement in nasopharyngeal and oropharyngeal airway dimensions after protraction of the maxilla together with maxillary expansion.[19] Current results revealed significant increases in pharyngeal measurements, especially at the nasopharynx, in accordance with these studies.[18–20,31] It was declared that 17 untreated Class III subjects showed negligible changes in the upper-airway dimensions during a 9.8-month observation period. Therefore, the increase in the upper airway dimension could be related to the increased maxillary growth induced by protraction treatment.[19]

As far as we can determine, the effect of Class III orthopedic treatments on the airway size is limited by the treatment results. This study provides information regarding the long-term effects of reverse headgear treatment on pharyngeal dimensions. As there is a potential risk for unfavorable growth in Class III patients even after early treatment with reverse headgear,[9,25,32,33] the patients were observed at the time when facial growth was close to complete. The findings of this study demonstrated that during the follow-up period, the nasopharyngeal airway changes remained statistically significant, being more pronounced than in the treatment period.

The present results concerning airway evaluations are based on the two-dimensional cephalometric measurements, which cannot completely predict clinical efficiency because of the limitations of two-dimensional cephalometric assessments. However, such examinations provide beneficial information related to the airway changes. Future studies could provide more beneficial input by including three-dimensional–based cephalometric analysis.

CONCLUSION

- Treatment of maxillary deficiency with reverse headgear improved the nasopharyngeal and oropharyngeal airway dimensions initially, and the beneficial effect of the treatment, especially at the nasopharynx, was maintained at long-term follow-up.

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