Original Article

Maxillary Protraction Appliance Effect on the Size of the Upper Airway Passage

Hüsamettin Oktay[a]; Esengül Ulukaya[b]

ABSTRACT

Objective: To test the hypothesis that maxillary protraction appliances (MPA) have no effect on the size of the upper airway passage and craniofacial structures in adolescent patients.

Materials and Methods: Twenty patients (5 male and 15 female; mean age 11.5 years) with skeletal Class III malocclusion were included in this study. The records of all patients who had maxillary protraction treatment and had lateral head radiographs taken before and after their protraction treatments were obtained from the files of treated cases. Treatment changes were determined by means of linear, angular, and area measurements. Data were analyzed statistically by means of paired *t*-test and correlation analysis.

Results: Significant increases were observed in the width and area of the pharyngeal airway. Significant increases also occurred in the sagittal growth of the maxilla, while a clockwise rotation and inhibition of sagittal growth were observed in the mandible.

Conclusions: The hypothesis was rejected. The size of the upper airway can be increased by means of MPA application.

KEY WORDS: Upper airway; Maxillary protraction; Nasopharynx; Pharyngeal size

INTRODUCTION

Patients with skeletal Class III malocclusions are characterized by a maxillary deficiency, maxillary retrusion, excessive mandibular growth, and mandibular protrusion. Clinically, these patients have a retrusive upper face and a protrusive lower face, causing a concave profile. The maxillary dental arch is usually smaller, and a reduced or negative overjet is present. It has been commonly accepted that treatment of a skeletal Class III malocclusion is one of the most difficult issues in orthodontics.[1,2] The treatment approaches for skeletal Class III malocclusions are growth modification for young patients and orthognathic surgery for adult patients. To apply a protracting force upon the maxilla and maxillary dentition at early ages is one of the most commonly used methods among orthodontists.[1–3]

Maxillary protraction appliances (MPA) have been used for the treatment of skeletal Class III malocclusions since 1960.[3] Numerous studies demonstrated that these appliances stimulate the forward displacement of the maxilla and reduce the forward displacement of the mandible. Clockwise rotation of the mandible, retroclination of the lower incisors, counterclockwise rotation of the palatal plane, and proclination of the upper incisors have been reported also.[4–13]

Many studies have investigated the effects of the MPA on the dentofacial structures and the soft tissues of the face,[1–13] but only a limited number of studies have been reported on the relationships between maxillary protraction and pharyngeal size.[14] Some of the studies related to the pharyngeal size and volume investigated the relationships between the mandibular advancement and airway dimensions.[15–18] Others studied the effects of different skeletal patterns on pharyngeal size.[19–23]

Pharyngeal size is very important for all subjects and especially for the patient with sleep apnea. The size of the nasopharynx may be of particular importance in determining whether the mode of breathing is predominantly nasal or oral. Oral breathers have to open their mouths and maintain an oral airway. Three

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Accepted: April 2007. Submitted: December 2006.

changes in posture are needed to accomplish this: lowering the mandible, positioning the tongue downward and forward, and extending the head. These postural changes could affect dentofacial growth and development.[24,25] In order to increase the pharyngeal airway, medical, surgical, or orthodontic treatments have been used in patients with oral respiration or sleep apnea. Surgical maxillomandibular advancement is a generally used method to increase the pharyngeal airway of the subjects with sleep apnea. The indications for this procedure are determined by cephalometric and polysomnographic studies.[26–28]

Özbek et al[19] studied the effects of functional-orthopedic treatment on oropharyngeal dimensions of growing patients with Class II malocclusion, and concluded that sagittal dimensions of the upper airway could be increased by functional treatment. Considering that mandibular growth has a definite influence on upper airway dimensions, one may speculate that stimulation of maxillary growth in growing subjects with a retrusive maxilla could also have beneficial effects on the upper airway dimensions.

The purpose of this study was to investigate the effects of maxillary protraction appliances on the size of the upper airway passage, and to determine if the size of pharynx is increased by maxillary protraction appliances.

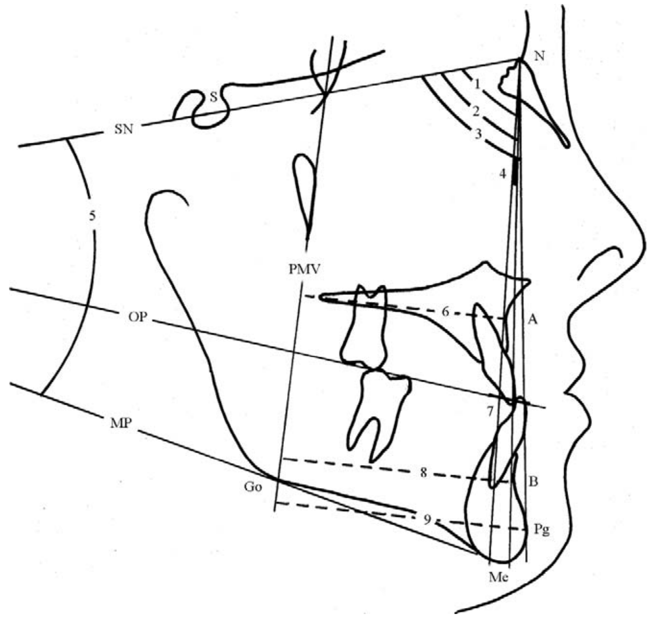

Figure 1. Linear and angular measurements used in this study: 1, SNA angle; 2, SNB angle; 3, SN-Pg angle; 4, ANB angle; 5, SN-GoGn angle; 6, PMV-A distance; 7, Wits appraisal; 8, PMV-B distance; 9, PMV-Pg distance.

MATERIALS AND METHODS

This retrospective study utilized the pretreatment and posttreatment lateral cephalometric radiographs of 20 patients, 15 female and 5 male, treated with Tübinger (Dentaurum 745-300, Ispringen, Germany) or Petit (GAC 17-100-20, Bohemia, NY) type face masks. The radiographs were selected from the treated patients in our department who met the inclusion criteria of skeletal and dental Class III malocclusions with maxillary retrusion, edge to edge incisor relationship or anterior crossbite, flat or concave facial profile, and no congenital anomalies or endocrine problems. Developmental stages of the subjects were determined from their hand-wrist radiographs according to Greulich and Pyle.[29] All subjects were in the period of pubertal growth spurt, and their mean chronological age was 11.5 ± 1.54 years at the beginning of the treatment.

In order to obtain a forward movement of the maxilla and maxillary dentition during the treatment period, elastic forces were applied between the face mask and the hooks which were soldered on the first molar and premolar bands and extended anteriorly to the canine teeth. The magnitude of the force was 600 grams at each side and its direction was 30° downward from the occlusal plane. The patients used their face masks 16 hours a day, and the treatment was continued until a normal overjet and Class I molar and canine relationships were obtained. The mean treatment time was 8 ± 2.5 months.

Treatment changes were determined from the pretreatment and posttreatment lateral cephalograms. The linear, angular, and area measurements used in this study are shown in Figures 1 and 2. In area measurement, Pm Vertical passing through ethmoid registration point and pterygomaxillary fissure inferior was used as the anterior border of the nasopharyngeal airway, and the ANS-PNS plane as the lower border. The ANS-PNS plane and the hy-cv3ia line were accepted as the upper and lower borders of the oropharyngeal air passage. In addition, the oropharyngeal airway was also divided into upper and lower parts by the occlusal plane. The upper part was named as oropharynx 1 and the other as oropharynx 2 (Figure 2). The area measurements were made by means of an electronic planimeter, Ushikata x-plan 360-i (Ushikata Mfg Co, Tokyo, Japan). Each area was measured three times successively, and the mean of the three measurements was used for statistical evaluation.

Statistical Analysis

The effects of the maxillary protraction appliances on craniofacial structures and airway sizes were investigated by means of a paired *t*-test. To determine the possible relationships between the airway passage and the craniofacial variables, a correlation analysis

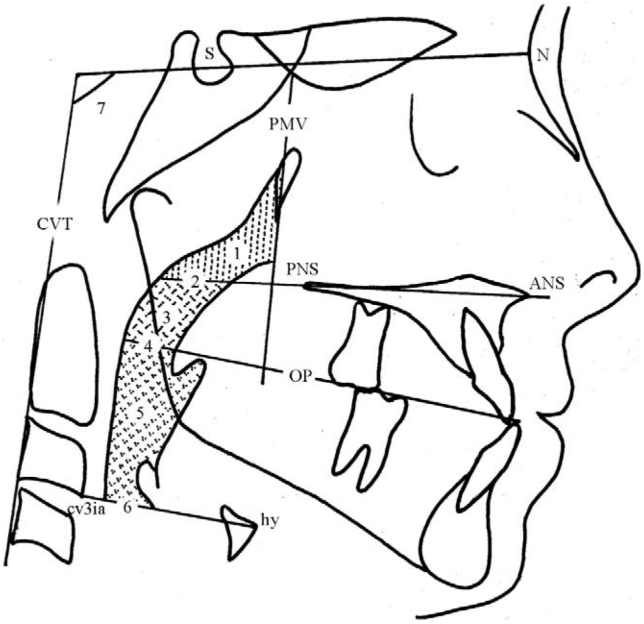

Figure 2. Linear and area measurements regarding the airway passage: 1, nasopharynx area; 2, upper pharyngeal width (UPW) at the level of palatal plane; 3, oropharynx 1 area; 4, middle pharyngeal width (MPW) at the level of occlusal plane; 5, oropharynx 2 area; 6, lower pharyngeal width (LPW) at the level of a line connecting cv3ia and hyoid points; 7, SN-CVT angle.

was applied to the measurement differences occurring with the protraction treatment.

RESULTS

The mean and standard deviation of each variable measured at the beginning (T_1) and end (T_2) of treatment and of the differences between them ($T_2 - T_1$)

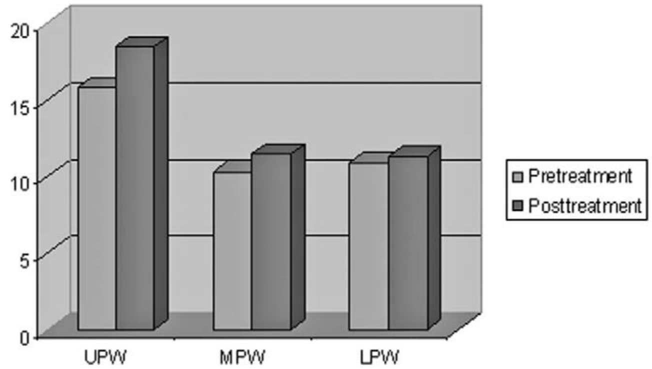

Figure 3. Upper, middle, and lower pharyngeal widths before and after maxillary protraction treatment.

are presented in Table 1. This table also presents the results of the paired *t*-test. As can be seen from Table 1, all measurements except three variables changed at a statistically significant level. The lower pharyngeal width, oropharynx 2 area, and SN-CVT angle indicating the craniocervical angulation did not change. The maxillary protraction appliances caused the maxilla to move forward and the mandible to rotate in a clockwise direction. As a consequence, SNA, ANB, and Sn-GoMe angles, PMV-A distance, and Wits appraisal increased, whereas SNB and SN-Pg angles and PMV-B and PMV-Pg distances decreased.

The airway passage showed upper and middle pharyngeal width increases at the significance levels of .01 and .05, respectively. Significant increases also were obtained in the measurements of the area of the nasopharynx and oropharynx 1 (Table 1). Insignificant increases were present in the lower pharyngeal width and oropharynx 2 areas. Figures 3 and 4 show the

Table 1. The Mean and Standard Deviation of the Parameters at the Beginning and End of the Maxillary Protraction and of the Differences Between Them as Well as the Results of Paired *t*-Test

	Pretreatment (T_1)		Posttreatment (T_2)		Difference ($T_2 - T_1$)		
Parameters	Mean	SD	Mean	SD	Mean	SD	Significance
SNA	76.70	2.95	78.9	3.00	2.17	1.13	***
SNB	79.30	3.34	77.9	3.26	−1.42	1.62	***
ANB	−2.62	1.76	1.02	1.09	3.65	1.56	***
Wits	−8.92	3.81	−3.05	2.57	5.87	3.86	***
SN-Pg	80.07	3.11	78.9	3.18	−1.10	1.74	*
SN-GoMe	37.67	4.80	38.95	5.10	1.27	2.26	*
PMV-A	49.67	3.18	51.00	2.91	1.32	1.65	**
PMV-B	61.05	5.92	56.50	5.82	−4.55	3.31	***
PMV-Pg	64.97	6.96	60.17	7.10	−4.80	3.89	***
SN-CVT	103.5	8.10	104.8	9.14	1.30	6.97	NS
UP-Width	15.80	3.43	18.47	4.90	2.67	3.33	**
MP-Width	10.37	2.62	11.47	3.66	1.10	2.59	*
LP-Width	10.90	4.01	11.37	3.29	0.47	3.37	NS
Nasopharynx	220.05	101.68	303.95	129.43	83.90	44.79	***
Oropharynx 1	193.65	62.18	248.40	101.19	54.75	62.43	**
Oropharynx 2	410.60	150.54	432.50	119.37	21.90	99.33	NS

* $P < .05$; ** $P < .01$; *** $P < .001$; NS, not significant.

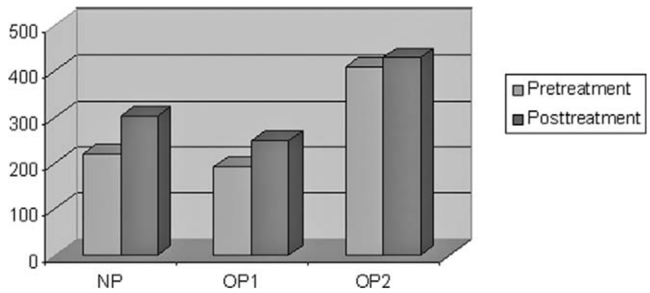

Figure 4. Area measurements of nasopharynx, oropharynx 1, and oropharynx 2 before and after maxillary protraction treatment.

changes caused by maxillary protraction treatment in the width and area measurements of the airway passage, respectively.

The results of the correlation analysis are presented in Table 2. No relationship was found between the differences of craniofacial variables and changes in the measurements of airway passage, except a correlation at a significance level of .05 was found between the oropharynx 2 area and the measurements of the Wits appraisal and SN-CVT angle.

DISCUSSION

Application of maxillary protraction appliances can produce good results in patients having skeletal Class III malocclusion with a maxillary deficiency, causing the maxilla and maxillary teeth to move forward and the mandible to move backward. These appliances are usually used during the prepubertal and pubertal growth periods, although they can also be used postpubertally.[4–13] In this study, the mean age of the patients was 11.5 ± 1.54 years, and all of them were in the period of the pubertal growth spurt.

Some authors[4–8,10,11] used the maxillary protraction appliances in conjunction with rapid maxillary expansion, and the others[9,12,13] treated their patients by maxillary protraction only. Rapid maxillary expansion was not applied to the patients in this study.

The duration of the daily application of face masks in the literature varied from 8 to 16 hours with a force between 400 and 1500 grams. The total treatment duration with these appliances varied from 4 to 16 months.[3–13] In the present study, the patients were requested to wear their face masks 16 hours a day, the forces applied to the maxillary dentition were approximately 600 grams on each side, and the mean treatment period was 8 ± 2.5 months.

The treatment changes were determined using lateral cephalometric radiographs. Cephalometric films have also been used in the other investigations carried out on pharyngeal size and growth.[30–31] It has been commonly accepted that there is a relationship between head posture and upper airway size.[14,23] Thus, the cephalometric head radiographs should be taken at natural head posture if the airway passage is to be investigated. The present study is a retrospective investigation, and the cephalometric films were taken by the usual methods. In order to determine whether the head position was the same during both of the projections, the SN-CVT measurement was used, and no statistically significant differences were found in head position measured on the first and second radiograms (Table 1). This result shows that the airway passage measurements were not affected by the positioning of the patients.

The face masks affected both the maxilla and mandible. Elastic forces applied to the upper dentition stimulated the forward growth of the maxilla and moved the maxillary teeth forward, while the reciprocal forces acting on the mandible caused a clockwise rotational effect. Significant increases were observed in the SNA angle ($P < .001$) and PMV-A measurement ($P < .01$). This demonstrated the sagittal movement of the upper jaw, while significant decreases occurred in the SNB angle and PMV-B distance ($P < .001$). These results are compatible with the results regarding maxillary protraction in the literature.[4–13]

Table 2. The Results of Correlation Analysis Between the Craniofacial and Pharyngeal Variables[a]

	UPW	MPW	LPW	Nasopharynx	OP 1	OP 2
SNA	−0.137	0.154	−0.331	0.029	0.033	−0.209
SNB	−0.024	0.036	−0.081	0.055	0.205	0.055
ANB	−0.071	0.087	−0.131	−0.026	−0.171	−0.156
Wits	0.207	0.162	−0.425	−0.044	0.221	−0.498*
SN-Pg	−0.017	−0.015	−0.186	0.058	0.219	−0.077
SN-GoMe	0.161	0.044	−0.139	−0.111	−0.108	−0.269
PMV-A	0.042	0.096	−0.041	0.188	−0.011	0.032
PMV-B	0.048	0.017	0.302	0.217	−0.000	0.368
PMV-Pg	0.122	0.109	0.143	0.113	−0.025	0.127
SN-CVT	0.237	0.248	0.436	0.163	−0.003	0.456*

[a] UPW indicates upper pharyngeal width; MPW, middle pharyngeal width; LPW, lower pharyngeal width; OP 1, oropharynx 1; OP 2, oropharynx 2.

* $P < .05$.

Some studies investigated the effects of growth and development on airway passage dimensions.[32–36] Other studies investigated the pharyngeal size in the subjects having different ANB angles and rotational patterns.[15,37] Taylor et al[34] carried out a longitudinal study on 16 male and 16 female subjects to describe the pattern of bony and soft tissue growth of the oropharynx. They concluded that a greater rate of change in the soft tissue measurements of the posterior pharyngeal wall occurred between 6 to 9 years and 12 to 15 years, and that growth increments were very small between 9 and 12 years. Because the mean age of the subjects in the present study was 11.5 years and the mean treatment time was 8 months, it was thought that the changes in pharyngeal measurements related with growth were at a negligible level, and thus a control group was not included to this study.

Ceylan and Oktay[15] reported that the pharyngeal airway size was influenced by the changes in ANB angle, and that the oropharyngeal area decreased in the subjects with an increased ANB angle. Akcam et al[37] found a decrease in the upper airway dimensions of the subjects having posterior mandibular rotation. This reveals a close relationship between the upper airway passage and the positioning of the jaws.

Most of the studies in the literature, which investigated the effects of the changes in intermaxillary relationships on the airway size and dimensions, have been carried out on patients with obstructive sleep apnea and on subjects treated by mandibular protraction appliances or surgical techniques. Özbek et al[19] found that the upper airway dimensions of skeletal Class II patients increased with the use of functional orthopedic treatment. Fransson et al[18] applied mandibular protraction appliances to 44 obstructive sleep apnea and 21 snoring patients for 2 years, and obtained an increase in the pharyngeal airway resulting from the mandibular protrusion.

In this study maxillary protraction appliances were applied, and significant distances and increments in area were observed in the upper part of the airway space, especially at the nasopharynx. Likewise, Hiyama et al[14] found that maxillary growth induced by protraction treatment had a significant positive effect on the superior upper airway dimension. Based on their findings, they suggested that facilitating maxillary growth in growing patients during maxillary protraction treatment could contribute to an increase in the upper airway dimensions and improve the respiratory function of patients with maxillary hypoplasia.

Athanasiou et al[38] surgically repositioned the mandible in a group of mandibular prognathism patients, and observed that this rapid change did not alter the size of the airway passage. They explained this finding with postoperative reflex alterations in the pharyngeal muscular mechanism. It should be remembered that the alterations caused by nonsurgical orthodontic methods come into existence over a long time, and thus the reflexes naturally reorientate.

Only two correlations were at a statistically significant level ($P < .05$) (Table 2). The correlations between Wits appraisal and oropharynx 2 and between SN-CVT and oropharynx 2 were as expected because the upper border of the oropharynx 2 was the occlusal plane and head posture was related to pharyngeal space. The fact that no correlation was found between measurement differences of the airway passage and craniofacial variables included in this study indicated that other factors might be acting on the airway measurements.

CONCLUSIONS

- Maxillary protraction caused the upper airway dimensions to increase in patients with a retrusive maxilla.
- No correlation was found between the pharyngeal measurements and most of the investigated craniofacial variables.

REFERENCES

1. Dellinger EL. A preliminary study of anterior maxillary displacement. *Am J Orthod.* 1973;63:509–516.
2. Kambara T. Dentofacial changes produced by extraoral forward force in the Macaca irus. *Am J Orthod.* 1977;71:249–277.
3. Nanda R. Protraction of maxilla in rhesus monkeys by controlled extraoral forces. *Am J Orthod.* 1978;74:121–141.
4. Baik HS. Clinician results of the maxillary protraction in Korean children. *Am J Orthod Dentofacial Orthop.* 1995;108:583–592.
5. Nygan P, Hägg U, Yiu C, Mervin D, Wei SHY. Soft tissue and dentoskeletal profile changes associated with maxillary expansion and protraction headgear treatment. *Am J Orthod Dentofacial Orthop.* 1996;109:38–49.
6. Gallagher RW, Miranda F, Buschang PH. Maxillary protraction: treatment and post treatment effects. *Am J Orthod Dentofacial Orthop.* 1998;113:612–619.
7. Baccetti T, McGill JS, Franchi L, McNamara JA Jr, Tollaro I. Skeletal effects of early treatment of Class III malocclusion with maxillary expansion and face-mask therapy. *Am J Orthod Dentofacial Orthop.* 1998;113:333–343.
8. Macdonald KE, Kapust AJ, Turley PK. Cephalometric changes after the correction of Class III malocclusion with maxillary expansion/face-mask therapy. *Am J Orthod Dentofacial Orthop.* 1999;116:13–24.
9. Yüksel S, Üçem TT, Keykubat A. Early and late facemask therapy. *Eur J Orthod.* 2001;23:559–568.
10. Kim JH, Viana MAG, Graber TM, Omerza FF, BeGole EA. The effectiveness of protraction face mask therapy: a meta-analysis. *Am J Orthod Dentofacial Orthop.* 1999;115:675–685.
11. Filho OGS, Magro AC, Filho LC. Early treatment of the Class III malocclusion with maxillary expansion and maxillary protraction. *Am J Orthod Dentofacial Orthop.* 1998;113:196–203.

12. Sung SJ, Baik HS. Assessment of skeletal and dental changes by maxillary protraction. *Am J Orthod Dentofacial Orthop.* 1998;114:492–502.
13. Yavuz I. *Cephalometric Evaluation of the Effects of Tubinger Face Mask in the Girls Who Have Completed Statural Growth* [PhD thesis]. Erzurum, Turkey: Ataturk University Health Science Institute Department of Orthodontics; 2001.
14. Hiyama S, Suda N, Suzuki MI, Tsuiki S, Ogawa M, Suzuki S, Kuroda T. Effects of maxillary protraction on craniofacial structures and upper airway dimension. *Angle Orthod.* 2002;72:43–47.
15. Ceylan I, Oktay H. A study of the pharyngeal size in different skeletal patterns. *Am J Orthod Dentofacial Orthop.* 1995; 108:69–75.
16. Liu Y, Lowe AA, Fleetham JA, Park YC. Cephalometric and physiologic predictors of the efficacy of an adjustable oral appliance for treating obstructive sleep apnea. *Am J Orthod Dentofacial Orthop.* 2001;120:639–647.
17. Baik UB, Suzuki M, Ikeda K, Sugawara J, Mitani H. Relationship between cephalometric characteristics and obstructive sites in obstructive sleep apnea syndrome. *Angle Orthod.* 2002;72:124–134.
18. Fransson AMC, Tegelberg Å, Svenson BAH, Lennartsson B, Isacsson G. Influence of mandibular protruding device on airway passages and dentofacial characteristics in obstructive sleep apnea and snoring. *Am J Orthod Dentofacial Orthop.* 2002;122:371–379.
19. Özbek M, Memikoğlu UT, Gögen H, Lowe AA, Baspinar E. Oropharyngeal airway dimensions and functional-orthopedic treatment in skeletal Class II cases. *Angle Orthod.* 1998; 68:327–336.
20. Hiyama S, Ono T, Ishiwata Y, Kuroda T. Changes in mandibular position and upper airway dimension by wearing cervical headgear during sleep. *Am J Orthod Dentofacial Orthop.* 2001;120:160–168.
21. Schwab RJ, Gupta KB, Gefter WB, Metzger LJ, Hoffman EA, Pack AI. Upper airway and soft tissue anatomy in normal subjects and patients with sleep disordered breathing. *Am J Respir Crit Care Med.* 1995;152:1673–1689.
22. Solow B, Siersbæk-Nielsen S, Greve E. Airway adequacy, head posture, and craniofacial morphology. *Am J Orthod.* 1984;86:214–223.
23. Pracharktam N, Hans MG, Strohl KP, Redline S. Upright and supine cephalometric evaluation of obstructive sleep apnea syndrome and snoring subjects. *Angle Orthod.* 1994; 64:63–74.
24. Preston B. The upper airway and craniofacial morphology. In: Graber TM, Vanarsdall RL, Vig KWL, eds. *Orthodontics: Current Principles and Techniques.* St Louis, Mo: Elsevier Mosby; 2005:128–136.
25. Proffit WR, Fields HW. The etiology of orthodontic problems. In: Proffit WR, Fields HW, eds. *Contemporary Orthodontics.* St Louis, Mo: CV Mosby; 1986:112–113.
26. Hochban W, Brandenburg U, Peter JH. Surgical treatment of obstructive sleep apnea by maxillomandibular advancement. *Sleep.* 1994;17:624–629.
27. Conradt R, Hochban W, Brandenburg U, Heitmann J, Peter JH. Long-term follow-up after surgical treatment of obstructive sleep apnea by maxillomandibular advancement. *Eur Respir J.* 1997;10:123–128.
28. Hochban W, Conradt R, Brandenburg U, Heitmann J, Peter JH. Surgical maxillofacial treatment of obstructive sleep apnea. *Plast Reconstr Surg.* 1997;99:619–626.
29. Greulich WW, Pyle SP. Radiographic atlas of skeletal development of the hand and wrist. Stanford, Calif: Stanford University Press; 1966:95–110;159–172.
30. Rubin R. Effects of nasal airway obstruction on facial growth. *Ear Nose Throat J.* 1987;66:44–53.
31. Jakhi SA, Karjodkar FR. Use of cephalometry in diagnosing resonance disorders. *Am J Orthod Dentofacial Orthop.* 1990;98:323–332.
32. Handelman CS, Osborne G. Growth of the nasopharynx and adenoid development from one to eighteen years. *Angle Orthod.* 1976;46:243–259.
33. Linder-Aronson S, Leighton BC. A longitudinal study of the development of the posterior nasopharyngeal wall between 3 and 16 years of age. *Eur J Orthod.* 1983;5:47–58.
34. Taylor M, Hans MG, Strohl KP, Nelson S, Broadbent BH. Soft tissue growth of the oropharynx. *Angle Orthod.* 1996; 66:393–400.
35. Jeans WD, Fernando DCJ, Maw AR, Leighton BC. A longitudinal study of the growth of the nasopharynx and its contents in normal children. *Br J Radiol.* 1981;54:117–121.
36. Preston CB, Tobias PV, Salem OH. Skeletal age and growth of the nasopharynx in the sagittal plane: a cephalometric study. *Semin Orthod.* 2004;10:16–38.
37. Akcam MO, Toygar U, Wada T. Longitudinal investigation of soft palate and nasopharyngeal airway relations in different rotation types. *Angle Orthod.* 2002;72:521–526.
38. Athanasiou AE, Toutountzakis N, Mavreas D, Ritzau M, Wenzel A. Alterations of hyoid bone position and pharyngeal depth and their relationship after surgical correction of mandibular prognathism. *Am J Orthod Dentofacial Orthop.* 1991;100:259–265.