Cephalometric norms for the upper airway in a healthy North Indian population

Dipti Shastri, Pradeep Tandon, Amit Nagar, Alka Singh

Abstract

Objective: The aim was to obtain normative data for cephalometric measurements of the upper airway in the North Indian population. **Design:** Observational study. Setting: University department and teaching hospital out-patient clinic. **Subjects and Methods:** A total of 180 healthy patients were included out of which 90 were males (age range, 8-16 years), and 90 were females (age range, 8-16 years), with normal skeletal facial profile, no history of snoring, sleep apnea, upper airway disease, tonsillectomy or adenoidectomy, obesity, or pathology in the pharynx. Twenty cephalometric airway measurements, including size of the tongue, soft palate, nasopharynx, oropharynx, hypopharynx, and relative position of the hyoid bone and valleculae were obtained. Landmarks on cephalometric radiographs were digitized and measurements were made using a specially designed computer program. Error analysis of measurements was performed and comparison of measurements according to sex was made. **Results:** Significant sex dimorphism was seen for the majority of measurements, with the exception of minimal depth of the airway, oropharyngeal depth of the airway, and the soft palate angle with the hard palate. **Conclusion:** A minimum sagittal dimension of the upper airway was evident despite differences in measurements between sexes. Findings from this study should be a useful reference for the assessment of sleep apnea in the North Indian population.

Keywords: Cephalometry, North Indian, pharynx

Introduction

Cephalometric radiographs have been used for many years to evaluate facial growth and development.[1,2] Cephalometry enables analysis of dental and skeletal anomalies as well as soft tissue structures and form. Many studies have assessed the anatomic conformation of the upper airway with more sophisticated and expensive techniques, including cine-computed tomography (CT),[3] fluoroscopy,[4] acoustic reflection,[5] fiberoptic pharyngoscopy,[6] and magnetic resonance imaging.[7] Cephalometry is, however, less expensive, more useful, easily achieved with reduced radiation, and correlates with other investigations such as CT or somnofluoroscopy carried out during wakefulness or sleep.[8,9] Cephalometric measurements of the posterior airway space, although a two-dimensional analysis, have proved very reliable in diagnosing pharyngeal volumes.[10,11]

Posterior airway space, as measured by lateral cephalometric radiography, was highly correlated with measurements using three-dimensional CT scan, with a 92% accuracy in predictability.[12]

Many authors have used cephalometry for assessment of the airway in craniofacial syndromes,[13-16] in patients with obstructive sleep apnea (OSA),[11,16-23] and following orthognathic surgery,[24-29] and for evaluation of the airway in various dentofacial deformities.[30-32] Understanding of the upper airway in normal subjects can assist management of OSA syndrome and in identifying potential sites of obstruction of the upper airway after surgical correction of dentofacial deformities. Cephalometric measurements of the airway vary according to ethnic group and sex. Therefore, the purpose of this study was to carry out a systematic, cephalometric evaluation of the upper airway in a large group of normal subjects in order to establish cephalometric reference values of the upper airway in North Indian population.

Subjects and Methods

Subjects

Male and female North Indian subjects were selected from a large pool of patients attending the Faculty of Dental Sciences, King George's Medical University, Lucknow for dental treatment. Patients were interviewed and examined for the purpose of selection. The selection criteria included North

Departments of Orthodontics and Dentofacial Orthopaedics, Faculty of Dental Sciences, King George's Medical University, Lucknow, Uttar Pradesh, India

Correspondence: Dr. Dipti Shastri,
Department of Orthodontics and Dentofacial Orthopaedics,
Faculty of Dental Sciences, King George's Medical University,
Lucknow - 226 003, Uttar Pradesh, India.
E-mail: drdiptishastri@gmail.com

Indian, normal visual harmony of facial and skeletal profile, and normal dental occlusion (Class I), with 2-4 mm of overbite and intact dental arch. Exclusion criteria included previous orthodontic treatment or corrective jaw (Orthognathic) surgery, active periodontal disease, habitual snoring, habitual mouth breathing, obesity or assessed as clinically overweight, OSA, chronic respiratory disease, previous tonsillectomy and/or adenoidectomy, pathology in the area of study (e.g. nasopharyngeal carcinoma), and irradiation to the head and neck area.

Cephalometric analysis

Lateral cephalometric radiographs were taken using a standardized technique, with the jaw in centric relation and the teeth in occlusion, the lips relaxed, and the head in the natural head position. The subject stood with the sagittal plane parallel to the film and with bilateral ear rods gently inserted into the external auditory meatus to stabilize the head position during exposure. Two types of X-ray machines were used. The older was a General Electric GE 100 (General Electric Dental Systems, Milwaukee, US) and the films used were Kodak Ortho-G 24 × 30 (Eastman Kodak Company, Rochester, US). Distance from the anode to the mid-sagittal plane of the patient was 150 cm, while distance from the mid-sagittal plane to the film was 13 cm. The newer machine was a Philips Orthoralix SD (Philips Medical Systems, Monza, Italy) and the film used Kodak Ortho-G 15 × 30 (Eastman Kodak Company, Rochester, US). The mid-sagittal plane to film distance was 15 cm with this machine.

All films were processed under standardized conditions. The magnification factors of the lateral cephalometric radiographs taken with the older and newer X-ray machines were measured separately and corrected for the later cephalometric measurements on the processed films. The magnification factor was measured by the following formula: $M = (X' - X)/X$.

Where X is the radiopaque ruler used when the radiograph was taken, and X' is the figure measured from the magnified ruler on the radiograph.

Landmarks and measurements

The reference points and lines used in the analysis are shown in the Figure 1a and b and Table 1 provides a description of the landmarks used, while Tables 2 and 3 give descriptions of the measurements undertaken and the relevant abbreviations. The methods of measurement used were a modification of those used by Lyberg *et al.*,[20,21] and have been widely used in other studies.[22,23] Seventeen variables - including 12 linear distances, one angle, four-area measurements, and three ratios of area values were identified and calculated for each cephalometric radiograph on the basis of their clinical relevance in determining the patency of the nasopharyngeal, oropharyngeal, and hypopharyngeal airway space. The tongue
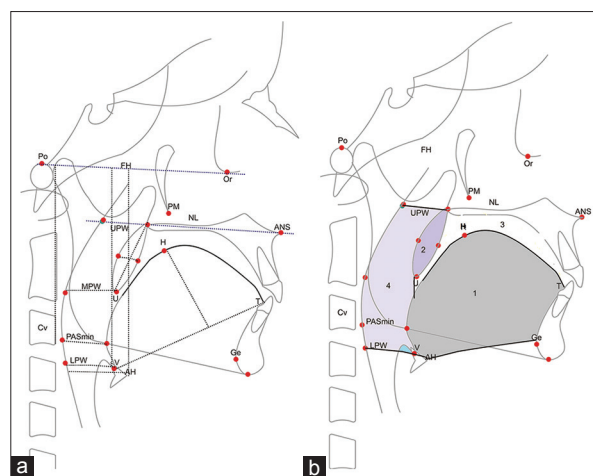

Figure 1: (a) Diagrammatic representation of the oronasopharynx (sagittal view) 1a Landmarks and reference lines used in the analysis of lateral cephalometric radiographs. (b) Area measurements used in the study

Table 1: Landmarks used in cephalometric analysis

AH	AH, the most anterior and superior point on the body of the hyoid bone, representing the inferior part of the tongue
ANS	ANS, the tip of the median, sharp bony process of the maxilla
CV	CV, the line overlying the anterior surface of the 2nd and 3rd CV was used
FH	FH plane, line joining the Or to the Po
GE	GE, representing the most posterior point of the mandibular symphysis and the antero-inferior part of the tongue
H	Superior part of the tongue, the most superior point of the tongue in relation to the line from V to T
LPW	LPW, intersection of the perpendicular line from V to the posterior pharyngeal wall
MPW	MPW, intersection of the perpendicular line from U to the posterior pharyngeal wall
NL	NL, line between the ANS and the PNS
Or	Or, the lowest point on the average of the left and right inferior borders of the bony orbit
PM	PM, the point at the junction of the pterygo-maxilla and the PNS
PNS	PNS, the most posterior point at the sagittal plane on the bony hard palate
Po	Po, the mid-point of the line connecting the most superior point of the external auditory canal on both sides
T	The tip of the tongue
U	Uvula, the tip of the uvula
UPW	UPW, point of intersection of the line perpendicular to the posterior pharyngeal wall from the PNS
V	Vallecula, the intersection of the epiglottis and the base of the tongue

AH: Anterior hyoid; ANS: Anterior nasal spine; CV: Cervical vertebrae; FH: Frankfort horizontal; GE: Genial tubercle; LPW: Lower pharyngeal wall; MPW: Middle pharyngeal wall; NL: Nasal line; Or: Orbitale; PM: Pterygo-maxillare; PNS: Posterior nasal spine; Po: Porion; UPW: Upper pharyngeal wall

Table 2: Description of linear measurements (mm) and angle measurement (degree) used

AH-CV	Position of hyoid bone in horizontal plane, from AH to CV and parallel to FH
AH perpendicular to FH	Position of hyoid bone in vertical plane, from AH perpendicular to FH
H perpendicular to VT	Tongue height, measured as perpendicular distance from H to VT line
NL/PM-U	Inclination of the long axis of the soft palate relative to the NL
PASmin	The shortest distance between the base of the tongue and the posterior pharyngeal wall, the narrowest sagittal airway space
PM-U	Length of soft palate, distance from PM to U
PM-UPW	Depth of nasopharyngeal airway space from PM to UPW
SPT	SPT, represents the maximal thickness of soft palate measured perpendicular to PM-U line
U-MPW	Depth of oropharyngeal airway space from U to MPW
V-CV	Position of V in horizontal plane, a line from V to CV and parallel to FH
V perpendicular to FH	Position of V in vertical plane, a perpendicular line from V to FH
V-LPW	Depth of hypopharyngeal airway space from V to LPW
VT	Length of tongue, measured as distance from V to T

AH: Anterior hyoid; CV: Cervical vertebrae; FH: Frankfort horizontal; NL: Nasal line; PM: Pterygo-maxillare; U: Uvula; UPW: Upper pharyngeal wall; SPT: Soft palate thickness; V: Vallecula; MPW: Middle pharyngeal wall; LPW: Lower pharyngeal wall

Table 3: Description of area measurements (mm²) and ratios used

NOPA	NOPA, the computed NOPA, including OA and the area defined by points PM, UPW, LPW and V along the posterior pharyngeal wall and the dorsal outline of the tongue including the SPA
OA	OA, the computed OA including TA and extending superiorly to the outline of soft and hard palate
SPA	SPA, the outline was defined along the anterior and posterior contour of the soft palate, the superior border was a line through PM perpendicular to the PM-U line
SPA/ (NOPA-OA)	Relationship between the soft palate and the difference between the NOPA and OAs (i.e., pharyngeal area)
TA	TA, the upper outline was defined by the dorsal contour of the tongue from V through H to T. The lower outline was reduced to a geometric polygon, of which the boundary was defined by line segments connecting the points V, AH, GE, and T
TA/OA	Relationship between the tongue and OA
TA+SPA/ NOPA	Relationship between combined tongue and SPAs and NOPA

NOPA: Naso-oropharyngeal area; OA: Oral area; SPA: Soft palate area; PM: Pterygo-maxillare; UPW: Upper pharyngeal wall; LPW: Lower pharyngeal wall; V: Vallecula; U: Uvula; TA: Tongue area

was measured in the sagittal length (VT), height (H⊥VT), and a defined sagittal area (tongue area [TA]). The soft palate was also measured in length (pterygo-maxillare uvula [PM-U]), thickness (soft palate thickness), and a defined sagittal area (soft palate area [SPA]). The width of the upper-airway space was measured in the sagittal plane at four levels: The nasopharynx (PM-upper pharyngeal wall [UPW]), oropharynx (U-middle pharyngeal wall [MPW]), hypopharynx (vallecula-lower pharyngeal wall [V-LPW]), and the region of minimal airway space (PASmin). The position of the soft palate was represented by the angle (nasal line [NL]/PM-U) between its long axis (PM-U) and the NL. In addition, the oral area (OA), nasopharyngeal area (NOPA), and three ratios of area values were calculated for further analysis.

All lateral cephalometric radiographs were scanned by an HP ScanJet 4C scanner (HP, Guangzhou, China). The image was visualized on a 1280 × 1024 noninterlaced monitor. The landmarks were digitized, and the Frankfort plane was used as the horizontal plane during the measurements. Linear, angular, area, and ratio variables were measured and analyzed by computer software designed for that purpose.[33] The digitization and measurements were performed by the same investigator.

The magnification factor was taken into account for each cephalometric radiograph. The computer used in this study was an IBM compatible 486/66 D2 CPU-based personal computer with 16 MB RAM.

Reliability and error analysis
A random sample of 30 scanned cephalometric tracings were selected and digitized. The measurements were completed twice on two separate occasions, 4 weeks apart, by the same investigator. The mean value of the variables measured on each of the two occasions was compared using paired *t*-test to detect any systematic error in measurements made.

Statistics
Cephalometric variables for male and female subjects were compared using the Student's *t*-test and *P* value less than 5% was considered as significant. The statistical package used was the Statistical Package for Social Science (Windows version 6.0; SPSS Inc., Chicago, US).

Results

A total of 90 males and 90 females were included in the study. Males ranged in age from 8 to 16 years, and females from 8 to 16 years. The results of the error analysis found no significant difference between any of the paired measurements. The values for cephalometric airway measurements in males and females are compared in Table 4.

Table 4: Comparison of results of cephalometric analysis of the upper airway in male and female subjects

Measurement	Mean±SD (*n*=90)		P value
	Male	Female	
VT	74.0±4.4	68.8±4.1	<0.001
H perpendicular to VT	40.9±3.1	35.9±4.9	<0.001
PM-U	38.3±1.9	35.6±1.7	<0.001
SPT	11.1±1.4	9.5±1.4	<0.001
PM-UPW	27.9±2.5	25.1±1.3	<0.01
U-MPW	10.9±2.8	10.1±2.4	1
V-LPW	19.7±2.6	16.5±3.1	<0.01
PASmin	11.1±3.2	10.5±2.8	0.89
V perpendicular to FH	92.2±6.4	79.9±5.3	<0.001
V-CV	24.0±2.9	21.4±2.8	<0.001
AH perpendicular to FH	94.4±6.4	79.5±5.8	<0.001
AH-CV	38.4±3.0	33.2±2.9	<0.001
NL/PM-U	129.4±5.3	128.9±5.2	0.47
TA	2845.1±214.8	2335.5±244.5	<0.001
SPA	283.1±44.1	223.3±35.8	<0.001
OA	3194.4±267.9	2714.7±231.0	<0.001
NOPA	4146.0±316.2	3455.9±316.6	<0.001
TA/OA	0.8855±0.05	0.8645±0.07	0.13
TA+SPA/NOPA	0.7347±0.04	0.7185±0.05	0.27
SPA/(NOPA-OA)	0.2773±0.06	0.2681±0.05	0.58

SD: Standard deviation; H: Height; SD: Standard deviation; PM: Pterygo-maxillare; U: Uvula; SPT: Soft palate thickness; UPW: Upper pharyngeal wall; MPW: Middle pharyngeal wall; V: Vallecula; LPW: Lower pharyngeal wall; FH: Frankfort horizontal; CV: Cervical vertebrae; AH: Anterior hyoid; NL: Nasal line; SPA: Soft palate area; OA: Oral area; NOPA: Naso-oropharyngeal area; TA: Tongue area

Fourteen of the 20 measurements demonstrated a significant difference according to sex and overall, larger values was recorded for male subjects. The measurements for which no significant differences were seen between males and females included NL/PM-U, U-MPW depth, PASmin, and the three ratios of the area measurements TA/OA, (TA + SPA)/NOPA, and (SPA/NOPA-OA).

Discussion

This study contained a group of North Indian subjects based on their clinically normal facial profile and dental occlusion, and the absence of any reported abnormality of the upper airway. The cephalometric measurements of the upper airway in this group are thus appropriate to use as normative data for future comparison. In that study, cephalometric measurements of 180 normal subjects were analyzed to determine normative data for the North Indian populations. These researchers used the same measurement method as the current study and reported similar results.

In this study, the variables which did not demonstrate sex dimorphism were: PM-UPW, PASmin depth, and the ratio of

TA/OA. This last finding is difficult to explain since one would not expect to see sex dimorphism of angle measurements or ratios. In the current study, all measurements bar six demonstrated sex dimorphism. The exceptions were NL/PM-U, U-MPW depth, PASmin, and all three ratios of area measurement. The two further variables that did not demonstrate sex dimorphism was the U-MPW depth and PAS min. These latter measurements are directly related to the patency of the airway, being the predominant levels at which the pharyngeal airway is reported to narrow in OSA.[10,12] Furthermore, oropharyngeal depth is the most variable measurement in the pharyngeal airway. Several studies in patients with OSA have demonstrated a significant reduction in two-dimensional and three-dimensional measurements at the oropharyngeal level, although this was not a consistent finding across subjects.[16,17,34] Two further measurements of clinical relevance to the patency of the airway are the PM-UPW depth and the V-LPW depth. It is evident from this study that although the majority of airway measurements demonstrate sex dimorphism, those that are most important to the patency of the airway are not dimorphic. This suggests that a minimal sagittal dimension of the upper airway is required for a normal patency.

Bacon *et al.*[35] used 40 normal subjects aged between 20 and 26 years (mean age, 23.7 years) as a control group in the cephalometric evaluation of pharyngeal obstructive factors in patients with OSA. These researchers reported the mean soft palate length in the male control group to be 38.7 mm (standard deviation [SD], 3.2 mm). Riley *et al.*[11] reported a normal soft palate length in Caucasian males of 37.0 mm, while our results indicate a soft palate length of 34.3 mm (SD, 3.9 mm). Hochban and Brandenburg,[34] in a cephalometric evaluation of OSA, reported the following measurements from their control group of Caucasian males (mean age, 43 years): Length of the soft palate, 45.1 mm; thickness of the soft palate, 12.2 mm; angle of the soft palate to the palatal plane, 54.5°; hypopharyngeal depth of the airway, 22 mm; and tongue length, 87 mm.

Lyberg *et al.*[20,21] performed cephalometric analysis of patients with OSA and reported the norms obtained from the control group of Caucasian males (*n* = 10; mean age, 23.6 years). They reported a magnification factor of approximately 6% but did not correct for this in their measurements.

Neither of the studies conducted by Lyberg *et al.*[20,21] included females as control subjects. Cephalometric norms for nasopharyngeal measurements were also reported by Poole *et al.*[36] Norms were calculated for various ages (6 and 16 years) and both sexes, and found to vary according to age and sex.

In establishing norms, however, these researchers used a random sample of patients for whom the presence or absence of nasopharyngeal obstruction was not known. In addition,

all measurements were at the level of the nasopharynx and in the horizontal plane only, limited representation of the upper airway as a whole.

Thus, although a small number of studies have made cephalometric analyses of upper-airway measurements, these had notable limitations and reported results are not directly comparable to the current study for the following reasons:

1. The majority of investigations did not use a control group and hence lacked reference measurements for the norms. Rather, comparisons between two or more abnormal groups were made (such as OSA with postsurgical groups) in order to identify changes in upper-airway measurements

2. The magnification factor in many of these investigations was either not considered or not reported

3. The majority of studies did not include female control subjects, as most studies related to OSA which predominantly occurs in males.[37]

This limits comparison of measurements across studies, the results of which cannot be presumed to be applicable for the diagnosis of abnormalities in the North Indian population

In the current study, detailed cephalometric analysis of the upper airway was conducted, with due consideration of the magnification error for each cephalometric radiograph. The findings showed that there were significant differences between males and females in the size of the tongue, soft palate, nasopharynx, hypopharynx, and oral cavity, and in the relative position of the vallecula and the hyoid bone.

Conclusion

Cephalometric norms for the pharyngeal airway in the North Indian population have been established in this study.

Significant sex dimorphism was evident for measurements other than oropharyngeal depth of the airway, minimal depth of the airway, and the soft palate angle, suggesting that a minimal sagittal dimension is needed for a normal patency of the upper airway. Data derived from this study should thus prove useful as a reference for the assessment of OSA and other conditions in the North Indian population.

References

1. Steiner CC. Cephalometrics in clinical practice. Angle Orthod 1959;29:8.
2. Khouw FE, Proffit WR, White RP. Cephalometric evaluation of patients with dentofacial disharmonies requiring surgical correction. Oral Surg Oral Med Oral Pathol 1970;29:789-98.
3. Haponik EF, Smith PL, Bohlman ME, Allen RP, Goldman SM, Bleecker ER. Computerized tomography in obstructive sleep apnea. Correlation of airway size with physiology during sleep and wakefulness. Am Rev Respir Dis 1983;127:221-6.
4. Suratt PM, Dee P, Atkinson RL, Armstrong P, Wilhoit SC. Fluoroscopic and computed tomographic features of the pharyngeal airway in obstructive sleep apnea. Am Rev Respir Dis 1983;127:487-92.
5. Bradley TD, Brown IG, Grossman RF, Zamel N, Martinez D, Phillipson EA, et al. Pharyngeal size in snorers, nonsnorers, and patients with obstructive sleep apnea. N Engl J Med 1986;315:1327-31.
6. Remmers JE, deGroot WJ, Sauerland EK, Anch AM. Pathogenesis of upper airway occlusion during sleep. J Appl Physiol Respir Environ Exerc Physiol 1978;44:931-8.
7. Rodenstein DO, Dooms G, Thomas Y, Liistro G, Stanescu DC, Culée C, et al. Pharyngeal shape and dimensions in healthy subjects, snorers, and patients with obstructive sleep apnoea. Thorax 1990;45:722-7.
8. Maltais F, Carrier G, Cormier Y, Sériès F. Cephalometric measurements in snorers, non-snorers, and patients with sleep apnoea. Thorax 1991;46:419-23.
9. Pepin JL, Ferretti G, Veale D, Romand P, Coulomb M, Brambilla C, et al. Somnofluoroscopy, computed tomography, and cephalometry in the assessment of the airway in obstructive sleep apnoea. Thorax 1992;47:150-6.
10. deBerry-Borowiecki B, Kukwa A, Blanks RH. Cephalometric analysis for diagnosis and treatment of obstructive sleep apnea. Laryngoscope 1988;98:226-34.
11. Riley R, Guilleminault C, Herran J, Powell N. Cephalometric analyses and flow-volume loops in obstructive sleep apnea patients. Sleep 1983;6:303-11.
12. Riley RW, Powell NB. Maxillofacial surgery and obstructive sleep apnea syndrome. Otolaryngol Clin North Am 1990;23:809-26.
13. Friede H, Lopata M, Fisher E, Rosenthal IM. Cardiorespiratory disease associated with Hallermann-Streiff syndrome: Analysis of craniofacial morphology by cephalometric roentgenograms. J Craniofac Genet Dev Biol Suppl 1985;1:189-98.
14. Figueroa AA, Glupker TJ, Fitz MG, BeGole EA. Mandible, tongue, and airway in Pierre Robin sequence: A longitudinal cephalometric study. Cleft Palate Craniofac J 1991;28:425-34.
15. Gallagher DM, Hyler RL, Epker BN. Hemifacial microsomia: An anesthetic airway problem. Oral Surg Oral Med Oral Pathol 1980;49:2-4.
16. Lowe AA, Gionhaku N, Takeuchi K, Fleetham JA. Three-dimensional CT reconstructions of tongue and airway in adult subjects with obstructive sleep apnea. Am J Orthod Dentofacial Orthop 1986;90:364-74.
17. Lowe AA, Santamaria JD, Fleetham JA, Price C. Facial morphology and obstructive sleep apnea. Am J Orthod Dentofacial Orthop 1986;90:484-91.
18. Jamieson A, Guilleminault C, Partinen M, Quera-Salva MA. Obstructive sleep apneic patients have craniomandibular abnormalities. Sleep 1986;9:469-77.
19. Guilleminault C, Riley R, Powell N. Obstructive sleep apnea and abnormal cephalometric measurements. Implications for treatment. Chest 1984;86:793-4.
20. Lyberg T, Krogstad O, Djupesland G. Cephalometric analysis in patients with obstructive sleep apnoea syndrome. I. Skeletal morphology. J Laryngol Otol 1989;103:287-92.
21. Lyberg T, Krogstad O, Djupesland G. Cephalometric analysis in patients with obstructive sleep apnoea syndrome: II. Soft tissue morphology. J Laryngol Otol 1989;103:293-7.
22. Tangugsorn V, Skatvedt O, Krogstad O, Lyberg T. Obstructive sleep apnoea: A cephalometric study. Part I. Cervico-craniofacial skeletal morphology. Eur J Orthod 1995;17:45-56.
23. Tangugsorn V, Skatvedt O, Krogstad O, Lyberg T. Obstructive sleep apnoea: A cephalometric study. Part II. Uvulo-glossopharyngeal morphology. Eur J Orthod 1995;17:57-67.
24. Yu LF, Pogrel MA, Ajayi M. Pharyngeal airway changes associated with mandibular advancement. J Oral Maxillofac Surg 1994;52:40-3.
25. Farole A, Mundenar MJ, Braitman LE. Posterior airway changes associated with mandibular advancement surgery: Implications for patients with obstructive sleep apnea. Int J Adult Orthodon Orthognath Surg 1990;5:255-8.

26. Hochban W, Brandenburg U, Peter JH. Surgical treatment of obstructive sleep apnea by maxillomandibular advancement. Sleep 1994;17:624-9.
27. Greco JM, Frohberg U, Van Sickels JE. Cephalometric analysis of long-term airway space changes with maxillary osteotomies. Oral Surg Oral Med Oral Pathol 1990;70:552-4.
28. Greco JM, Frohberg U, Van Sickels JE. Long-term airway space changes after mandibular setback using bilateral sagittal split osteotomy. Int J Oral Maxillofac Surg 1990;19:103-5.
29. Wenzel A, Williams S, Ritzau M. Relationships of changes in craniofacial morphology, head posture, and nasopharyngeal airway size following mandibular osteotomy. Am J Orthod Dentofacial Orthop 1989;96:138-43.
30. Dahl E, Kreiborg S, Jensen BL, Fogh-Andersen P. Comparison of craniofacial morphology in infants with incomplete cleft lip and infants with isolated cleft palate. Cleft Palate J 1982;19:258-66.
31. McWilliam J. Hypoplasia of the middle third of the face-a morphological study. Angle Orthod 1976;46:260-7.
32. Fields HW, Warren DW, Black K, Phillips CL. Relationship between vertical dentofacial morphology and respiration in adolescents.

Am J Orthod Dentofacial Orthop 1991;99:147-54.
33. Xia J. Quantitative analytic system of velopharyngeal function. Shanghai J Bioeng 1992;10:16-9.
34. Hochban W, Brandenburg U. Morphology of the viscerocranium in obstructive sleep apnoea syndrome: Cephalometric evaluation of 400 patients. J Craniomaxillofac Surg 1994;22:205-13.
35. Bacon WH, Turlot JC, Krieger J, Stierle JL. Cephalometric evaluation of pharyngeal obstructive factors in patients with sleep apneas syndrome. Angle Orthod 1990;60:115-22.
36. Poole MN, Engel GA, Chaconas SJ. Nasopharyngeal cephalometrics. Oral Surg Oral Med Oral Pathol 1980;49:266-71.
37. Gislason T, Almqvist M, Eriksson G, Taube A, Boman G. Prevalence of sleep apnea syndrome among Swedish men: An epidemiological study. J Clin Epidemiol 1988;41:571-6.

New features on the journal's website

Optimized content for mobile and hand-held devices

HTML pages have been optimized of mobile and other hand-held devices (such as iPad, Kindle, iPod) for faster browsing speed.
Click on **[Mobile Full text]** from Table of Contents page.
This is simple HTML version for faster download on mobiles (if viewed on desktop, it will be automatically redirected to full HTML version)

E-Pub for hand-held devices

EPUB is an open e-book standard recommended by The International Digital Publishing Forum which is designed for reflowable content i.e. the text display can be optimized for a particular display device.
Click on **[EPub]** from Table of Contents page.
There are various e-Pub readers such as for Windows: Digital Editions, OS X: Calibre/Bookworm, iPhone/iPod Touch/iPad: Stanza, and Linux: Calibre/Bookworm.

E-Book for desktop

One can also see the entire issue as printed here in a 'flip book' version on desktops.
Links are available from Current Issue as well as Archives pages.
Click on 📖 View as eBook