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Craniofacial morphology of Malay patients with obstructive sleep apnoea

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SUMMARY The aim of this study was to compare the skeletal and soft tissue patterns between obstructive sleep apnoea (OSA) patients and control group of non-OSA patients. Fifty Malays (32 males and 18 females) aged 18–65 years divided into two equal groups 25 (17 males and 8 females) with OSA and a control group 25 subjects (15 males and 10 females). Both groups were diagnosed using polysomnography. Nineteen variables related to craniofacial skeletal and soft tissue morphology were measured on lateral cephalometric films. Analysis of covariance was used to compare the means between the two groups.

The results showed that OSA subjects had a significant increase in body mass index (BMI) and neck circumference than the control group. The soft palate and tongue were longer and thicker in OSA patients. In addition, upper, middle, and lower posterior airway spaces were narrower, the hyoid bone was more inferior and posterior, and the cranial base flexure angle was significantly acute when compared with the control group. The findings indicate that craniofacial abnormalities play significant roles in the pathogenesis of OSA in Malay patients.

Introduction

Obstructive sleep apnoea (OSA) is a common disorder characterized by the intermittent reduction (hypopnoea) or cessation (apnoea) of breathing due to narrowing of the upper airways during sleep. The main symptom is daytime sleepiness. Sleep arousal is an important defence mechanism, which is induced by internal stimuli activation of the autonomic nervous system, also called subcortical arousals, which are reflected by abrupt cardiac changes, such as heart rate, arterial blood pressure, respiratory change, muscular, or galvanic skin responses (Scholle and Zwacka, 2001; McNicholas *et al.*, 2002). OSA may lead to premature death, hypertension, ischaemic heart disease, stroke, and road traffic accidents. The high prevalence of the syndrome and the morbidity and mortality thought to be associated with it have led to the view that sleep apnoea may be a major a public health hazard (Wright *et al.*, 1997).

Knowledge of craniofacial features of OSA subjects is important for treatment planning and prediction of treatment outcome. Many studies have investigated the craniofacial features of OSA subjects (Ono *et al.*, 1996; Isono *et al.*, 1997; Waite, 1998; Friedlander *et al.*, 2000; Sforza *et al.*, 2000; Benumof, 2001). Those authors found that the interaction between anatomy and muscle function of the upper airway is important in the understanding of OSA. Anatomic abnormalities of the craniofacial structures are considered to play an important role in the pathogenesis of OSA, which includes the soft palate, base of the tongue, mandibular retrognathia, low position of the hyoid bone, decrease in posterior airway space, increased tongue volume, and enlargement of palatal or adenoid tissue.

Cakirer *et al.* (2001) reported that the craniofacial morphology in Caucasians differed from Afro-American subjects with OSA and that brachycephaly was associated with an increased apnoea/hypopnoea index in Caucasians but not in Afro-Americans. Li *et al.* (1999), in a comparative study of Asian and Caucasian male patients with OSA, demonstrated that Asians were less obese despite the presence of severe OSA. Craniofacial morphology differences were also noted among OSA subjects of three major ethnic populations in Asia (Wong et *al.*, 2005). Malay subjects with moderate to severe OSA had a significantly shorter maxillary and mandibular length, whereas the hyoid bone was located more caudally in the moderate to severe Chinese subjects. Both features were suggested to be a diagnostic measurement for individual ethnic groups with OSA.

Since craniofacial features differ between ethnic populations, the specific characteristics of OSA for each population should be investigated. Hence, the aim of this research was to compare the difference in the craniofacial features of Malay patients with OSA and a non-OSA control group.

Subjects and methods

Ethical approval was obtained from the research and ethics committee of the Universiti Sains Malaysia (USM/PPSP®/Ethics Com./2005(161.3(1)).

A comparative cross-sectional study was conducted on 50 Malays subjects (32 males and 18 females) aged between 18 and 65 years. Informed consent was obtained from the patients. This study comprised 25 OSA (17 males and 8 females) and 25 non-OSA (15 males and 10 females) subjects. Both groups were diagnosed using polysomnography. These tests were used not only to diagnose sleep apnoea but also to determine its severity.

Subjects with a respiratory disturbance index (the number of apnoea and hypopnoea per hour of sleep) values greater than 5 comprised the study group, while those with values less than 5 were enrolled as the control group. Patients with psychiatric illness, who consumed alcohol (avoided for at least one week prior to the overnight sleep study) or who had uncontrolled systemic disease or craniofacial anomalies associated with syndromes, such as Crouzon, Apert, Treacher-Collins, and Robin sequence were excluded.

Digital lateral cephalometric radiographs were obtained for all subjects in a standardized head position with the patient's midsagittal plane parallel to the plane of the film and the central X-ray beam perpendicular to this plane. The head was centred in the cephalostat and orientated with the Frankfort plane parallel to the floor with the teeth in maximum intercuspation. All the radiographs were taken by a single radiographer using the Gendex Dental System (Hamburg, Germany). The body mass index (BMI) was calculated from the patient's height and weight in standard units (kilograms per metre square), and neck circumference was measured at the level of the thyroid cartilage.

Nineteen variables related to both craniofacial skeletal and soft tissue morphology were measured as angular (degrees) or linear (millimetres; Figures 1 and 2). These measurements represented the cranial base, maxilla, and mandible. The VixWin 2000 software program (Gendex Dental System), which is a Windows® application for general dental and maxillofacial diagnostic imaging, was used for measurement.

The lateral cephalometric radiographs were coded with identification numbers so that the operator (OBA) was blinded from identifying the patient group. Cephalometric landmarks for skeletal and soft tissues used are described in Table 1.

Polysomnography

The polysomnography was used to record a number of body functions during sleep including electrical activity of the brain, eye movement, muscle activity, heart rate, respiratory

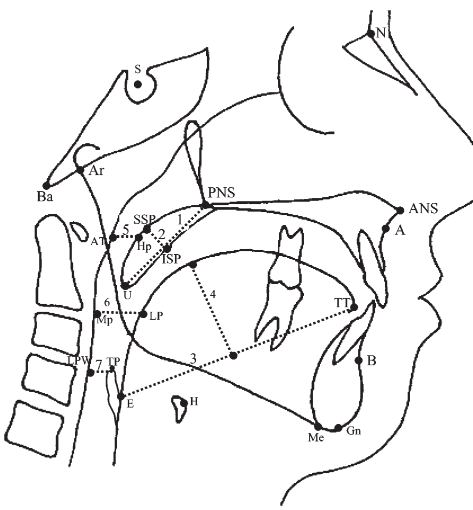

Figure 1 Soft tissue variables measured on the lateral cephalograms. 1, length of the soft palate (U–PNS): linear distance between point U and PNS; 2, thickness of the soft palate (SPP–ISP): the maximum dimension of the velum between its oral and nasal surfaces; 3, tongue length (TGL): linear distance between E and TT; 4, tongue height (TGH): linear distance along the perpendicular bisector of the E–TT line to the tongue dorsum; 5, upper posterior pharyngeal space (AT–Hp): antero-posterior distance of the nasopharynx; 6, middle posterior pharyngeal space (Mp–Lp): antero-posterior distance of the oropharynx; 7, lower posterior pharyngeal space (LWP–TP): antero-posterior distance of the hypopharynx.

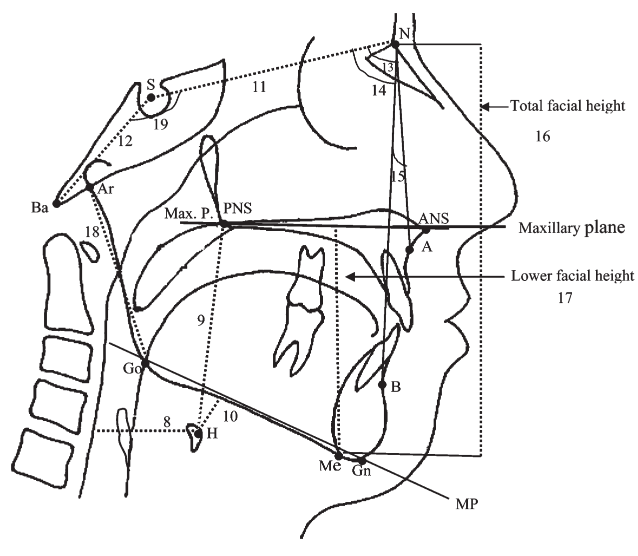

Figure 2 Skeletal variables measured on the lateral cephalograms. 8, the distance from hyoid bone to the posterior wall of the pharynx (H–PH); 9, distance from hyoid bone to PNS (H–PNS); 10, distance from the hyoid at right angles to the mandibular plane (H–MP); 11, anterior cranial base (S–N): length of the presellar anterior cranial base; 12, posterior cranial base (Ba–S): length of the postsellar part of the posterior cranial base; 13, maxillary protrusion (SNA): angle between sella, nasion to point A; 14, mandibular prognathism (SNB): angle between sella to nasion to point B; 15, maxillomandibular discrepancy (ANB): angle between A to nasion to point B; 16, total face height (N–Me): distance from nasion to menton; 17, lower anterior face height (ANS–Me): distance from menton perpendicular to the maxillary plane; 18, posterior face height (Go–Ar): distance form articular to gonion; 19, cranial base flexure angle: nasion–sella–basion (N–S–Ba).

effort, airflow, and blood oxygen levels. These tests were used both to diagnose sleep apnoea and to determine its severity. All investigations were carried out in the sleep science laboratory of the Hospital of Universiti Sains Malaysia, based on a standard polysomnography (Somnologica 3 software, serial number F220041-PK, product code F-SP-100 revision 0410 and Embletta pds, version 1.0, Flaga hf.; Medical devices, Reykjavik, Iceland). The time required for analysis was approximately 7 hours 30 minutes. This test was performed for all patients during the normal period of sleep, i.e. 22:30 until 06:00. Monitors were attached to the surface of the scalp and other areas of the body to record the occurrence of apnoea and episodes of oxygen desaturation.

Study errors

To test the reproducibility of the measurements, 10 randomly selected lateral cephalograms from both the OSA and the control groups were remeasured after a period of 2 weeks by the same investigator. The differences between repeated measurements determined using a paired *t*-test showed no significant differences ($P > 0.05$). The degree of reproducibility of the measurements was calculated using the intraclass correlation coefficient. The measurements were almost nearly 1.00, which suggest that they were almost identical or with negligible errors.

Statistical analysis

Statistical analyses were undertaken using the Statistical Package for Social Services version 12.0 SPSS Inc. Chicago, Illinois, USA. Analysis of covariance test was used to compare craniofacial differences between the OSA and non-OSA groups, while gender differences were controlled. The level of significance was set at 0.05.

Results

Eight of the OSA patients were diagnosed with mild OSA, 12 with moderate OSA, and 5 with severe OSA. Table 2 summarizes the measurements of BMI and neck circumference between the OSA and non-OSA subjects. Significant differences in BMI and neck circumference were noted between the OSA and control group ($P < 0.001$). All OSA subjects had a higher BMI and neck circumference than the control group. OSA patients had a significantly wider and longer soft palate when compared with the control group ($P < 0.001$). The thickness as well as the length of tongue in OSA patients were significantly different ($P = 0.001$).

OSA patients showed a significant narrowing of the upper, middle, and lower posterior airway space when compared with the controls ($P < 0.001$) and a more inferior position of the hyoid bone to mandibular plane ($P = 0.001$).

Table 1 Cephalometric landmarks for skeletal and soft tissues.

Landmark	Definition
Point A	A point on the concavity between anterior nasal spine and the lowest point on the alveolar bone overlying the maxillary incisors.
Point B	A point on the anterior concavity of the mandibular symphysis.
Basion (Ba)	The median point of the anterior margin of the foramen magnum, located by following the image of the slope of the inferior border of the basilar part of the occipital bone.
Nasion (N)	The innermost point on the concavity between the frontal and nasal bones.
Posterior nasal spine (PNS)	Located at the intersection of the continuation of the pterygopalatinal fossa and the floor of the nose. It marks the posterior limit of the maxilla.
Sella (S)	The centre of the pituitary fossa of the sphenoid bone.
Hyoid (H)	The most superior point on the anterior surface of the body outline of the hyoid bone.
Gnathion (Gn)	The most antero-inferior point on the contour of the bony chin symphysis.
Gonion (Go)	A constructed point of the intersection of the ramus and mandibular planes.
Articulare (Ar)	The point of intersection of the images at the posterior border of the condylar process of the mandible and the inferior border of the basilar part of the occipital bone.
Menton (Me)	The lowest point on the symphyseal shadow of the mandible.
Mandibular plane (MP)	A line drawn between gonion and gnathion.
Maxillary plane	Points ANS and PNS joined by a line.
Vallecula (E)	The most antero-inferior point of the epiglottic fold.
Point ISP	The most prominent point on the inferior soft palate surface.
Point SSP	The most prominent point on the superior soft palate surface.
Point U	The tip of the uvula.
Point TT	The tip of the tongue.
Point AT	A point on the adenoid tissue of the posterior wall of the nasopharynx.
Point Hp	A point on the upper surface of the palatinal vellum of the anterior wall of the nasopharynx.
Point Lp	A point on the anterior wall of the oropharynx.
Point Mp	A point on the posterior wall of the oropharynx.
Point LPW	A point on the posterior wall of the hypopharynx.
Point TE	The tip of epiglottis.

Moreover, the distance of the hyoid bone to posterior nasal spine in OSA subjects was greater than in the control group ($P < 0.001$). Sagittally, the distance from hyoid bone to the posterior wall of the pharynx was less in the OSA group ($P = 0.007$).

No significant difference was observed in the maxillary ($P = 0.415$) and mandibular ($P = 0.107$) positions between OSA subjects and controls. In addition, there was no significant difference in maxillomandibular discrepancy ($P = 0.380$). Lower ($P = 0.415$) and posterior ($P = 0.772$) face heights showed no significant differences between OSA and control subjects. There was also no significant difference in total face height ($P = 0.415$). The cranial base flexure angle was significantly different between the OSA and control groups ($P < 0.001$). In contrast, anterior ($P = 0.892$) and posterior ($P = 0.087$) cranial base lengths showed no significant difference. The measurements are summarized in Table 3.

Discussion

The results of this study demonstrate that BMI and neck circumference were significantly greater in this Malay OSA group than in the controls. Obesity played a major factor in the aetiology of OSA patients. This is in agreement with the findings of Dixon *et al.* (2002) who reported that an increase in BMI was associated with an increase risk of OSA by approximately 10-fold. Furthermore, neck circumference reflects the obesity of the upper airway region, which alters the structure of the upper airway due to fat deposition in the neck region. Ferguson *et al.* (1995) reported that patients with OSA have a large neck compared with non-OSA subjects.

The OSA patients in this study showed significantly longer and thicker soft palates, which occupied more space in the oropharyngeal area. Schwab *et al.* (1995) contributed this enlargement to continuous trauma due to snoring and the continuous vibration of the soft palate causing

Table 2 Measurements of body mass index (BMI) and neck circumference between the obstructive sleep apnoea (OSA) subjects and the control group. ANCOVA, analysis of covariance.

Measurement	OSA adjusted mean* (95% CI), *n* = 25	Control adjusted mean* (95% CI), *n* = 25	Mean difference (95% CI)	*F* statistic (df)	*P* value (ANCOVA)
BMI	29.65 (27.22–32.05)	23.36 (20.94–25.77)	6.28 (2.86–9.70)	13.63 (1.48)	<0.001
Neck circumference	16.14 (15.58–16.69)	14.08 (13.52–14.63)	2.06 (1.27–2.84)	27.64 (1.48)	<0.001

*Adjusted for gender.

Table 3 Measurements of hard and soft tissues between the obstructive sleep apnoea (OSA) subjects and control group.

Measurements	OSA adjusted mean* (95% CI), *n* = 25	Control adjusted mean* (95% CI), *n* = 25	Mean difference (95% CI)	*F* statistic (df)	*P* value (ANCONA)
SPI	38.60 (34.37 to 42.84)	29.26 (25.131 to 33.40)	9.34 (3.53 to 15.14)	10.47 (1.47)	0.002
SPW	11.58 (10.62 to 12.53)	9.00 (8.06 to 9.93)	2.57 (1.26 to 3.89)	15.67 (1.47)	<0.001
TI	91.48 (86.54 to 96.42)	81.49 (76.67 to 86.31)	9.99 (3.22 to 16.76)	8.81 (1.47)	0.005
TW	39.74 (37.24 to 42.23)	33.83 (31.39 to 36.27)	5.90 (2.47 to 9.33)	12.01 (1.47)	0.001
SPAS	8.18 (7.14 to 9.21)	11.71 (10.70 to 12.73)	−3.53 (−4.95 to −2.11)	25.03 (1.47)	<0.001
MPAS	9.62 (8.32 to 10.21)	12.93 (11.66 to 14.21)	−3.31 (−5.10 to −1.52)	13.83 (1.47)	<0.001
LPAS	11.62 (10.33 to 12.91)	15.89 (14.61 to 17.18)	−4.27 (−6.06 to −2.48)	23.05 (1.47)	<0.001
SNA	86.34 (84.84 to 87.84)	85.50 (84.03 to 86.96)	0.84 (−1.21 to 2.90)	0.67 (1.47)	0.415
SNB	84.44 (82.89 to 86.00)	82.70 (81.18 to 84.22)	1.741 (−0.39 to 3.87)	2.70 (1.47)	0.107
ANB	3.16 (2.59 to 3.74)	2.823 (2.26 to 3.38)	0.346 (−0.44 to 1.13)	0.78 (1.47)	0.380
Lower face height	70.03 (65.55 to 74.51)	67.64 (63.27 to 72.02)	2.38 (−3.75 to 8.52)	0.61 (1.47)	0.438
Posterior face height	59.02 (55.48 to 62.57)	58.31 (54.79 to 61.83)	0.713 (−4.20 to 5.62)	0.08 (1.46)	0.772
Total face height	124.99 (118.86 to 131.12)	124.40 (118.41 to 130.38)	0.59 (−7.81 to 8.99)	0.02 (1.47)	0.888
SN	69.00 (66.08 to 71.91)	69.27 (66.42 to 72.12)	−0.27 (−4.26 to 3.72)	0.01 (1.47)	0.892
SBa	43.14 (40.25 to 46.03)	46.58 (43.76–49.41)	−3.44 (−7.40 to 0.51)	3.05 (1.47)	0.087
N–S–Ba	122.05 (121.12 to 122.98)	127.58 (126.67 to 128.49)	−5.52 (−6.80 to −4.24)	75.76 (1.47)	<0.001
H–MP	39.74 (37.24 to 42.23)	33.83 (31.39 to 36.27)	5.90 (2.47 to 9.33)	12.01 (1.47)	0.001
H–PNS	82.964 (78.112 to 87.81)	65.26 (60.52 to 70.00)	17.69 (11.04 to 24.35)	12.04 (1.47)	<0.001
H–PH	33.02 (35.20 to 39.89)	33.02 (30.73 to 35.32)	4.51 (1.30 to 7.73)	7.98 (1.47)	0.007

*Adjusted for gender.

morphological and functional changes. Furthermore, vibration injury can cause mucosal oedema by further reducing upper airway patency. The increased muscular stiffness of the soft palate also suggests that its tissues undergo morphological and functional changes. The latter fact is supported by the histological findings of the uvular and soft palate muscles in snoring and apnoeic patients obtained at biopsy following uvulopalatopharyngoplasty (Veldi *et al.*, 2004).

The results of the present study showed a significantly longer length and thickness of the tongue in OSA patients, which occupied more space in the oropharyngeal area, resulting in narrowing of the airway. Moreover, in the supine position, the tongue falls back posteriorly and obstructs the hypopharyngeal space. Thus, the larger the tongue, the more likely obstruction of the airway.

The hyoid in the OSA patients was more inferiorly positioned compared with the control group. Since the hyoid bone serves as anchorage for the tongue muscles, infero-posterior displacement will pull the muscle of the tongue into a downward and backward position resulting in a greater tongue mass in OSA patients (Nelson and Hans, 1997; Battagel *et al.*, 2000; Do *et al.*, 2000; Hui *et al.*, 2003; Chang and Shiao, 2008). However, Wong *et al.* (2005) found that the hyoid bone was located more caudally in Chinese moderate to severe OSA subjects but only when compared with Malays and Indians.

The upper, middle, and lower airway spaces showed the narrowest dimensions in OSA patients in the current study. Isono *et al.* (1997) and Lyberg *et al.* (1989) reported that abnormalities of the soft tissues such as the tongue or soft palate volume that surround the pharyngeal airway can contribute to a decrease in the size of the pharyngeal airway because the upper airway is a soft tube without bony support.

No significant difference in maxillomandibular discrepancy was observed between the OSA and control groups. However, Sakakibara *et al.* (1999) found a significant difference in maxillary and mandibular positions between obese and non-obese Japanese OSA patients. They noted a decreased bony pharynx width, which might reflect a retroposition of the maxilla and mandible. This narrowed bony inlet of the pharyngeal airway represents an inherited risk factor for the development of airway obstruction.

No significant differences were found in lower anterior, posterior, or total face height between the OSA and control groups. This is in agreement with the study of Sforza *et al.* (2000) who found no significant differences in lower and total face heights between obese and non-obese OSA patients of the same height.

OSA patients had a more acute cranial base flexure angle as well as narrower upper, middle, and lower airway spaces than the control group. The posterior wall of the pharynx is attached to the cranial base at the pharyngeal tubercle. Having an acute cranial base, will decrease the antero-posterior length of the pharynx and will cause anterior displacement of the posterior pharyngeal wall (Steinberg and Fraser, 1995). Because the upper airway is a 'soft tube' without bony support, any changes in the cross-sectional area, including the lateral and antero-posterior diameter, can affect the upper airway (Tsuiki *et al.*, 2004). The results of the present study showed that the angle between the anterior and posterior segments of the cranial base was diminished resulting in the cervical spine and posterior pharyngeal wall being further forward thus reducing the space available for the airway. With regard to the effect of age, i.e. only one patient in the present sample with OSA was aged 65 years while the rest of the sample was 18 to 54 years old, resulting in the extended age range, however, this did not significantly influence the results.

Conclusions

Malay OSA patients generally had significant hard and soft tissue differences when compared with non-OSA subjects. Thus, craniofacial abnormalities play a significant role in the pathogenesis of OSA.

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