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Dentofacial Characteristics of Chinese Obstructive Sleep Apnea Patients in Relation to Obesity and Severity

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ABSTRACT

Objective: To evaluate dentofacial characteristics in relation to obesity and degree of severity of obstructive sleep apnea (OSA) in male Chinese patients and to elucidate the relationship between demographic parameters (age, body weight, height, and body mass index [BMI]) cephalometric parameters and OSA in these subjects.

Materials and Methods: Lateral cephalograms of 121 Chinese male patients in natural head posture were obtained. Based on BMI value, the patients were divided into three groups. Based on apnea-hypopnea index (AHI) value, the patients were divided into a mild-to-moderate and a severe group.

Results: The hyoid position and soft palate length were significantly different among the three obesity groups. Soft palate length was significantly longer ($P < .01$) in the severe OSA group than in the mild-to-moderate OSA group. Tongue base was significantly more inferiorly placed ($P < .05$) in the severe OSA group than in the mild-to-moderate OSA group. Craniocervical extension was significantly increased ($P < .05$) in the severe OSA group. Statistically significant differences were found among the three obesity groups in mandibular length, mandibular body length, maxillary length, anterior cranial base length, and overbite. The multiple stepwise linear regression analysis identified body weight, lower posterior facial height, mandibular body length, craniocervical extension, and sella-hyoid distance as the significant predictive variables for AHI.

Conclusions: This study revealed the existence of craniofacial and upper airway soft tissue differences in relation to obesity and severity of OSA among male Chinese OSA patients. Body weight and certain cephalometric parameters were significant predictors of OSA in Chinese male subjects.

KEY WORDS: Obstructive sleep apnea, Cephalometrics, Obesity.

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INTRODUCTION Return to TOC

Obstructive sleep apnea (OSA) is a common disorder, but its pathogenesis is not fully understood. Several cephalometric differences between OSA patients and control samples have been reported. These include mandibular deficiency, bimaxillary retrusion, short cranial base, reduced cranial base angle, mandibular length, increased lower anterior facial height, maxillomandibular plane angle, craniocervical angulation, inferiorly positioned hyoid, and enlarged soft palate.[1–9]

In general, most Asian OSA patients seem to have a lower body mass index (BMI) than their Caucasian counterparts who possess a similar degree of OSA severity.[10–13] There may be differences in obesity and variability in the craniofacial anatomy as risk factors for OSA in these two groups.[13,14] Few English-language cephalometric studies on Chinese OSA subjects have been reported, particularly in relation to obesity and severity of OSA.[15–17] The aims of this study were to evaluate dentofacial characteristics in relation to obesity and degree of severity of OSA in male Chinese patients and to elucidate the relationship between demographic parameters (age, body weight, height, and BMI), cephalometric parameters, and OSA in these subjects.

MATERIALS AND METHODS Return to TOC

A total of 121 Chinese male patients with baseline lateral cephalometric radiographs were recruited for this study from a pool of 196 consecutive OSA patients (156 males and 40 females) referred for oral mandibular advancement device (MAD) therapy. Thirty-five of the excluded males were considered not suitable for MAD treatment and no baseline records were obtained. Patients' sleep apnea problems were confirmed by overnight polysomnography and OSA severity was determined by the apnea-hypopnea index (AHI) obtained from the sleep study. Baseline body weight and height were recorded for BMI calculation. Of the 121 patients, 4 patients did not have an AHI value and 16 patients did not have a BMI value. BMI was calculated as follows:

$$BMI = weight (kg) \div height^2 (m)$$

On the basis of BMI value, the patients were subdivided into three groups: (1) normal-weight (BMI < 25); (2) overweight (25 ≤ BMI < 30); and (3) obese (BMI ≥ 30). On the basis of AHI value, the patients were subdivided in two groups: (1) mild-to-moderate OSA (AHI < 30); and (2) severe OSA (AHI ≥ 30).

Cephalometric Radiograph and Statistical Analysis

Baseline lateral cephalometric radiographs were obtained with the patients standing upright in natural head posture. The cephalometric landmarks and measurements used in this study are outlined in Figure 1 and Table 1. Computer Assisted Simulation System for Orthognathic Surgery (CASSOS, SoftEnable Technology Limited, Hong Kong SAR China) computer software was used to digitize the lateral cephalometric radiographs, and all radiographs were digitized by the same operator.

The method used for the cephalometric analysis was based on the values obtained from two tracings carried out with an interval of at least 2 weeks. The mean values from the two tracings were used for statistical analyses, which were done using the SPSS 11.0 software package (SPSS, Chicago, ILL). Test for statistical significance was performed with one-way ANOVA for comparison among the normal-weight, overweight, and obese groups. Student's *t*-test was used for comparison between the mild-to-moderate and severe OSA groups. *P* values less than .05 were considered significant. Linear regression analysis with a forward selection stepwise procedure was used to evaluate the association between AHI (dependent factor) and age, body weight, height, BMI, and cephalometric variables in Figure 1 (independent factor).

Method Error

The method error study was carried out by repeating the digitization process for ten randomly-selected radiographs, again at an interval of at least 2 weeks. Mean values from the first and second tracings together with mean values from the third and fourth tracings were used for the method error determination. The method error was determined with the formula

$$SE = \sqrt{\sum d^2/2n}$$

where Σd^2 is the sum of the squared differences between the two mean values, and n is the number of double measurements.

For linear measurements the method error was determined as 0.4 mm ($P > .1$) and for angular measurements 0.5° ($P > .1$). Both of these were statistically insignificant. It can therefore be concluded that no systematic error occurred for landmark identification or cephalometric measurements.

Approval for the study was obtained from the ethics committee of the Faculty of Dentistry, University of Hong Kong.

RESULTS Return to TOC

There were significant differences in age, weight, BMI, and AHI among the three obesity groups (Table 2). The obese group was the youngest and had the highest AHI value. Between the mild-to-moderate and severe OSA groups, there were significant differences in weight, BMI, and AHI (Table 3). The severe OSA group was younger and more obese than the mild-to-moderate OSA group.

The hyoid bone position (Figure 1b) as measured from Rgn, MnPl, c4ia, and S was significantly different among the three obesity groups (Table 4). The hyoid bone was most inferiorly placed in the obese group, whereas it was most superiorly placed in the normal-weight group. There was no statistically significant difference in hyoid position between the mild-to-moderate and severe OSA groups (Table 5). As for tongue base position, statistically significant differences were found only in the PNS-V measurement between the mild-to-moderate OSA and severe OSA groups, where the tongue base was 3.0 mm more inferiorly placed in the severe OSA group ($P < .05$). No statistically significant difference in the tongue base position was found among the three obesity groups. For soft palate measurements, soft palate length (PNS-U) was significantly different for the three obesity groups, with the longest measurement in the obese group. It was also significantly longer in the severe OSA group than the mild-to-moderate OSA group ($P < .01$).

Craniocervical extension measurements (OPT/SN and c2sp.c4ip/SN angles) (Figure 1c) differed significantly between the mild-to-moderate and severe OSA groups (Table 5), but not among the three obesity groups (Table 4). The mean OPT/SN angle in severe OSA group was 3°, ($P < .05$) higher than that found in the mild-to-moderate OSA group. The mean c2sp-c4ip-SN angle in the severe OSA group was also 3°, higher than that found in the mild-to-moderate OSA group ($P < .05$).

The only significant difference in the measurements of the craniofacial structures between the mild-to-moderate and severe OSA groups was in lower posterior facial height (LPFH) (Table 5) where the mean was 1.8 mm ($P < .05$) longer in the severe OSA group. There were statistically significant differences in mandibular length (Cd-Gn), mandibular body length (Go-Me), maxillary length (ANS-PNS), sella-nasion length (S-N), overjet, and overbite between the three obesity groups. The obese group had the greatest Cd-Gn, Go-Me, ANS-PNS, and S-N, whereas the normal-weight group had the shortest lengths for these measurements. For overjet and overbite, the normal-weight group had the most protrusive teeth and deepest bite among the three groups.

For all the OSA patients, the multiple stepwise linear regression model for AHI ($R^2 = 0.434$, $P < .001$) identified the body weight (partial $R^2 = 0.162$, $P < .001$), mandibular body length (partial $R^2 = 0.114$, $P < .01$), LPFH (partial $R^2 = 0.076$, $P < 0.01$), c2sp-c4ip-SN angle (partial $R^2 = 0.044$, $P < .01$) and S-H (partial $R^2 = 0.038$, $P < .05$) as the significant predictive variables (Table 6).

DISCUSSION Return to TOC

The demographic data from this study (Table 2) show that the obese group was more severely affected by OSA (increased AHI). Previous studies have also found an association between obesity and OSA.[11,18] The BMI grouping (Table 2) and AHI grouping (Table 3) show statistically significant differences in BMI and weight, but not in height, indicating that weight is a more important factor in determining the statistical significance of BMI. Furthermore, in the multiple stepwise linear regression analysis, body weight was found as the dominant significant predictor of AHI.

This study noted that OSA tended to occur at a younger age in the obese group, but previous studies have indicated that the prevalence of

OSA seems to increase in midlife, with higher prevalence among older age groups.[19,20] The risk of OSA is much higher with increased obesity, and this probably explains why an earlier occurrence of OSA was observed in the obese group in this study (Table 2). Because obesity involving all age groups is becoming an increasingly serious problem in many affluent societies, particularly the United States,[21] it is likely that a growing number of young obese people will be affected by OSA in these societies in the years to come.

This study found that normal-weight OSA patients had significantly greater anteroposterior facial compression than obese OSA patients (Table 4). This manifested as a shorter mandible (mandibular length and body length), shorter maxilla (maxillary length), and shorter anterior cranial base length (SN length). These cephalometric findings are consistent with the results of some earlier studies.[17,22–24]

The multiple stepwise linear regression analysis revealed that the mandibular body length was a significant predictor for AHI in this study (Table 6). In another study on Chinese subjects, it was found that retroposition of the mandible was associated with OSA, particularly with more severe OSA.[25] Some studies have also reported that normal-weight OSA patients have more craniofacial structure abnormalities than their obese counterparts, whereas obese OSA patients tend to have more normal craniofacial structures but more upper airway soft tissue abnormalities.[22–24,26]

The hyoid bone is important as anchorage for the tongue muscles, and its position partly affects the shape, size and position of the tongue. Previous studies have shown that the hyoid bone is more inferiorly positioned in OSA patients than in non-OSA subjects.[1,2,6] However, other studies found that the difference in the position of the hyoid bone in nonobese and obese OSA patients was not significant.[22,24] By contrast, this study revealed that the hyoid bone was more inferiorly positioned in obese OSA patients. One explanation for this finding might be that the BMI of the obese OSA group in this study (Table 2) was higher than that found in the two earlier studies.[22,24] This might have resulted in increased fat deposition in the upper airway soft tissues, forcing the hyoid bone into a more inferior position. The inferior position of the hyoid bone in turn gave the tongue a more upright position, and more tongue mass occupied the hypopharyngeal area.[8] Multiple stepwise linear regression analysis of this study found that the position of hyoid bone from sella was a significant predictor of AHI (Table 6). Similarly, a recent study on Chinese subjects also reported the inferior hyoid position as one of the cephalometric parameters associated with OSA.[25]

The increased soft palate length of the obese OSA patients in this study could be related to fat deposits caused by increased obesity. Previous studies have also shown upper airway soft-tissue abnormalities such as increased soft palate length in obese OSA patients.[22,24,26,27] The results of this study suggest that the increased soft palate length and inferiorly positioned hyoid bone in obese OSA patients could make them more prone to airway obstruction.

As for the mild-to-moderate OSA group vs the severe OSA group, significant differences were found in soft palate length and tongue base position, but not in hyoid bone position. The severe OSA group had a longer soft palate length and the tongue base was in a more inferior position. These features in the severe OSA group indicate that more soft palate and tongue masses would occupy the upper airway space, and this in turn could make the upper airway more prone to obstruction and might partly account for the increased OSA severity in this sample.

The craniocervical extension has also been related to the severity of OSA.[6,7,28] The craniocervical extension measurements made in this study (OPT/SN and c2sp.c4ip/SN) showed that the head posture differed significantly between the mild-to-moderate OSA group and the severe OSA group. Severe OSA patients had a more extended craniocervical angulation than did mild-to-moderate OSA patients, similar to findings noted in other studies.[6,7,28] The increased craniocervical angle in the OSA patients was a physiological adaptation aimed at maintaining airway adequacy.[7] This probably represents a compensatory physiological adaptation to lift away the base of the tongue and the soft palate from the posterior pharyngeal wall, thereby alleviating the obstruction and maintaining airway adequacy.[7] In addition, in this study multiple stepwise linear regression analysis confirmed that the c2sp.c4ip/SN measurement is one of the significant predictor for AHI.

CONCLUSIONS Return to TOC

- Obesity and craniofacial and soft tissue abnormalities may aggravate the severity of OSA syndrome in Chinese male subjects.
- Body weight and certain cephalometric parameters are significant predictors of OSA in Chinese male subjects.

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Table 1. Cephalometric Landmarks and Measurements Used in Figure 1

Variable	Definition
Landmark	
S	Center of the sella turcica.
N	Nasion, the deepest point in the concavity of the nasc
Ba	Basion, the most inferior point on the anterior margin
Po	Porion, the most superior point of the bony external a
Or	Orbitale, the most inferior point on the infraorbital mar
ANS	Anterior nasal spine.
PNS	Posterior nasal spine.
A	A point, the deepest point in the concavity of the ante rior nasal spine and the alveolar crest.
B	B point, the deepest point in the concavity of the ante alveolar crest and pogonion.
Is	Upper incisor tip.
Ii	Lower incisor tip.
Ms	Mesial buccal cusp tip of upper first molar.
Cd	Condylion, the most posterosuperior point of the conc
Go	Gonion, the most posterioinferior point on the angle o
Gn	Gnathion, the most anteroinferior point on the bony cl
Me	Menton, the most inferior point on the body chin.
Rgn	Retrognathia, the most posterior point of symphysis.
U	The tip of the uvula.
V	Vallecula, the most posteroinferior base of the tongue
H	The most superior and anterior point on the body of tl
c2sp	The most superior posterior point of the second cervi
c2ip	The most inferior posterior point of the second cervic
c4ia	The most inferior anterior point of the fourth cervical v
c4ip	The most inferior posterior point of the fourth cervical
FH	Frankfort horizontal plane, the line joining Po and Or.
MnPl	Mandibular plane, the line joining Me and Go.
MxPl	Maxillary plane, the line joining PNS and ANS.
Upper occlusal plane	The line joining Is and Ms (take the second molar if tl take the premolar if both molars are missing).
OPT	Odontoid process tangent, the line joining c2sp and c
Hyoid position	
Rgn-H (mm)	The distance between Rgn and H.
H-MnPl (mm)	The perpendicular distance from H to the MnPl.
H-c4ia (mm)	The distance between H and c4ia.
S-H (mm)	The distance between S and H.
Tongue base position	
PNS-V (mm)	Length of pharynx, the distance between PNS and V.
V-FH (mm)	Vertical position of V, the perpendicular distance betw tal plane.
V-c4ia (mm)	Horizontal position of V, the distance between V to c4 zontal plane.
Soft palate	
PNS-U (mm)	Soft palate length, the distance between PNS and U.
Soft palate angle (°)	The angle between soft palate length (U-PNS) and M
Craniocervical extension	
OPT-SN (°)	The angle between the OPT and the sella-nasion (S-I
c2sp-c4ip-SN (°)	The angle between the c2sp-c4ip line and the S-N lin

Table 1. Continued

Variable	Definition
Craniofacial structures	
NSBa (°)	Skull base angle, the angle between the nasion-sella on (S-Ba) line.
SNA (°)	The angle between the S-N line and the Nasion-A (N-
SNB (°)	The angle between the S-N line and the Nasion-B (N-
ANB (°)	The angle between the N-A line and the N-B line.
MnPl/SN (°)	Mandibular plane angle, the angle between the MnPl
MxPl/SN (°)	Maxillary plane angle, the angle between the MxPl ar
Overjet (mm)	The distance between the Is and Ii, parallel to the up upper incisor is in front of the lower incisor, negativ the upper incisor).
Overbite (mm)	The distance between Is and Ii, perpendicular to the u if there is overlapping, negative if there is open bite
Upper posterior facial height (UPFH) (mm)	The distance from S to MxPl, along the S-Go line.
Lower posterior facial height (LPFH) (mm)	The distance from MxPl to Go, along the S-Go line.
Total posterior facial height (TPFH) (mm)	The distance from S to Go.
Upper anterior facial height (UAFH) (mm)	The distance from N to MxPl, along the N-Me line.
Lower anterior facial height (LAFH) (mm)	The distance from MxPl to Me, along the N-Me line.
Total anterior facial height (TAFH) (mm)	The distance from N to Me.
Mandibular length (mm)	The distance between Cd and Gn.
Ramus length (mm)	The distance between Cd and Go.
Body length (mm)	The distance between Go and Me.
Maxillary length (mm)	The distance between ANS and PNS.
Anterior cranial base length (SN) (mm)	The distance between S and N.

Table 2. Demographic Data of Normal-Weight (n = 38; 36%), Overweight (n = 43; 41%), and Obese (n = 24; 23%) Male OSA Patients

	Normal-Weight			Overweight			Obes	
Variable	Mean	SD	Range	Mean	SD	Range	Mean	SD
Age (y)	48.7	10.3	20.5–66.6	47.1	9.2	27.8–71.4	42.6	7.7
Body weight (kg)	67.8	5.8	59.1–86.5	77.4	5.8	65.5–92.0	104.5	25.3
Height (cm)	171	0.1	159–195	170	0.1	156–178	171	0.1
BMI (kg/m²)	23.2	1.7	16.0–24.9	26.9	1.4	25.0–29.9	35.7	8.1
AHI	24.4	16.0	4.7–70.1	28.5	18.5	3.3–65.3	45.8	24.2

[a] OSA indicates obstructive sleep apnea; BMI, body mass index, and AHI, apnea-hypopnea index; * $P < .05$

Table 3. Demographic Data of Mild-to-Moderate (n = 64; 55%) and Severe (n = 53; 45%) Male OSA Patients

	Mild-to-Moderate			Severe		
Variable	Mean	SD	Range	Mean	SD	Ra
Age (y)	46.1	11.5	20.5–79.2	47.2	8.5	27.8
Body weight (kg)	74.8	10.8	61.5–113.0	86.6	24.5	59.1
Height (cm)	170	0.1	158–181	171	0.1	156
BMI (kg/m²)	25.9	3.6	19.4–40.5	29.7	7.9	16.0
AHI	15.7	7.6	3.3–29.9	49.2	16.1	30.0

[a] OSA indicates obstructive sleep apnea; BMI, body mass index, and AHI, apnea-hypopnea index; ** $P < .0$

Table 4. Cephalometric Comparison of Normal-Weight (n = 38), Overweight (n = 43), and Obese (n = 24) Male OSA Patients

Variable	Normal-Weight		Overweight		Obese	
	Mean	SD	Mean	SD	Mean	S
Hyoid position						
Rgn-H (mm)	42.4	4.6	43.9	6.0	48.0	4
H-MnPl (mm)	22.6	4.9	23.5	5.4	26.4	5
H-c4ia (mm)	45.2	4.2	45.9	4.9	49.8	5
S-H (mm)	128.6	7.8	130.7	6.7	132.4	9
Tongue base position						
PNS-V (mm)	84.1	6.2	85.3	6.4	87.7	7
V-FH (mm)	107.3	6.7	109.4	6.4	110.4	8
V-c4ia (mm)	107.3	6.7	109.4	6.4	110.4	8
Soft palate						
PNS-U (mm)	47.0	4.3	47.5	3.7	50.2	4
Soft palate angle (°)	125.9	4.8	126.1	5.6	124.7	5
Craniocervical extension						
OPT-SN (°)	110.7	8.1	109.8	7.2	113.5	6
c2sp.c4ip-SN (°)	113.3	7.1	112.6	6.2	115.7	6
Craniofacial structures						
NSBA (°)	128.3	5.5	127.3	5.7	130.3	6
SNA (°)	81.0	4.3	82.4	4.2	82.3	4
SNB (°)	77.2	4.0	78.4	3.8	79.3	4
ANB (°)	4.0	2.8	4.0	3.0	3.0	2
MnPl/SN (°)	36.6	6.5	34.3	7.3	35.4	5
MxPl/SN (°)	10.6	3.1	9.5	3.9	10.8	3