Original Article

Cephalometric Analysis of Nonobese Snorers Either with or Without Obstructive Sleep Apnea Syndrome

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ABSTRACT

Objective: To determine if there is an indicator on the lateral cephalometric radiograph that can be used for the differential diagnosis of severe obstruct sleep apnea syndrome and simple snoring in nonobese young male adults.

Materials and Methods: The subjects were Taiwanese male patients with a complaint of snoring and/or sleep apnea, whose body mass index was less than 25 kg/m^2 and who were younger than 40 years old. Forty-six patients with severe obstructive sleep apnea and 36 patients with simple snoring were selected and underwent lateral cephalometric radiography, from which 24 linear and 34 angular measurements were calculated. Differences between the two groups were studied, and a discriminatory analysis was performed.

Results: Soft palate length, mandibular body length, tongue size, and distance from the hyoid bone to the mandibular plane were significantly larger in patients with severe obstructive sleep apnea syndrome. Of the original grouped cases, 76.5% were correctly classified using these five variables. The position of the hyoid bone in simple snorers was near the straight line from the third vertebra to the menton, whereas the position of the hyoid bone in severe obstruct sleep apnea syndrome patients was far below the line from the third vertebra to the menton.

Conclusion: The position of the hyoid bone relative to the line from the third vertebra to the menton can be used as an indicator for a diagnosis of severe obstruct sleep apnea syndrome in nonobese young male Taiwanese adults.

KEY WORDS: Nonobese; Obstructive sleep apnea syndrome; Simple snoring; Hyoid bone; Young male

INTRODUCTION

Obstructive sleep apnea syndrome (OSAS) is caused by recurrent upper airway obstruction during sleep, and it manifests as loud snoring, arterial oxygen desaturation, sleep fragmentation, and excessive daytime sleepiness.[1] OSAS affects 2% to 4% of the adult general population[2] and may be even more frequent in specific subgroups such as hypertensive[3] or heart failure patients.[4]

Several causes for OSAS have been suggested. It appears to result from a variable combination of anatomical and pathophysiological factors, some of which may be under genetic control.[5] Relaxation of the upper airway musculature has been studied in relation to OSAS.[6] Anatomic narrowing of the upper airway as a result of alterations in the craniofacial morphology or soft tissue enlargement, the Bernoulli effect, sleep posture, age, male gender, nasal obstruction, and adipose tissue in the pharynx have been suggested as etiologies of OSAS.[7–11]

There are several risk factors for OSAS, with the strongest being obesity and age.[10,11] The prevalence of OSAS increases with age, with a twofold to threefold higher prevalence in individuals older than 65

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years compared with those in middle age.[12] There is a relationship between a body mass index (BMI) of >26 kg/m^2 and OSAS.[13] Previous research suggested that there may be differences in the degree to which obesity and craniofacial anatomy serve as risk factors between Asians and Caucasians[14] and that the etiology of OSAS in obese patients may differ from that in nonobese patients.[15] It is still unclear whether there are anatomical differences in cephalometric measurements between severe-OSAS patients and patients simply suffering from snoring among nonobese young Asians.

This retrospective study was undertaken to compare the craniofacial and pharyngeal airway structures of severe OSAS patients with those of simple snorers using lateral cephalometric radiographs and to determine the risk factors for OSAS in a nonobese Taiwanese young adult population.

MATERIALS AND METHODS

The subjects of this retrospective study were Taiwanese adult male patients who visited the Ear, Nose, and Throat Department of National Taiwan University Hospital with complaints of snoring and/or sleep apnea. An institutional review board approval for the study was obtained at National Taiwan University Hospital before the study. Weight (kilograms) and height (meters) of all patients were recorded, and the BMI was calculated using the following formula: BMI (kg/m^2) = weight (kg)/height^2 (m^2). Only the patients whose BMI was <25 kg/m^2 and whose age was younger than 40 years were selected.

The subjects' sleep was monitored by overnight polysomnography. Apnea was defined as cessation of breathing for at least 10 seconds. Hypopnea is a decreased effort to breathe of at least 50% less than the baseline and with at least a 4% decrease in oxygen saturation. The respiratory disturbance index (RDI)[16,17] was calculated as the sum of the total events (apnea and hypopnea) per hour ([apnea + hypopnea]/sleep time). A diagnosis of OSAS was based on the RDI. Patients who snored but had an RDI of <5 were grouped into the simple-snoring group, while patients whose RDI was >40 were grouped into the severe OSAS group.

A total of 82 patients (46 severe OSAS and 36 simple snoring) were selected for this study. All subjects included in this study had a full complement of permanent teeth except for third molars, no apparent craniofacial deformity, no history of orthodontic treatment, no history of pharyngeal airway surgery, and a clinically acceptable symmetry of the dental arches. Lateral cephalometric radiographs were obtained for all subjects using a standardized technique. The patient

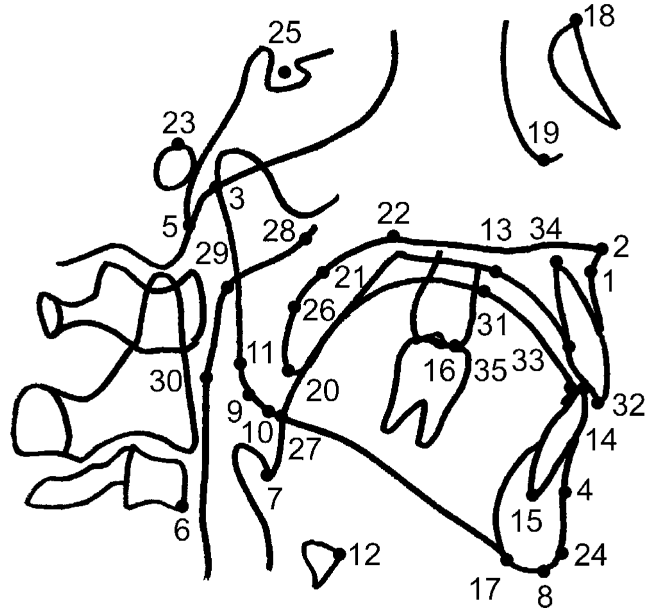

Figure 1. Reference points. 1: A; 2: ANS; 3: Ar; 4: B; 5: Ba; 6: C3 (the most anterior-inferior point of the third cervical vertebral body); 7: E (epiglottis); 8: Gn; 9: Go; 10: GoL (the most inferior point of the angle of the mandible); 11: GoP (the most posterior point of the angle of the mandible); 12: H (hyoid bone); 13: HP (the turning point of the curve of the hard palate); 14: L1; 15: L1R; 16: L6 (the mesial cusp tip of the mandibular first molar); 17: Me; 18: N; 19: Or; 20: point P (the tip of the soft palate); 21: PP (the most superior-posterior point of the soft palate); 22: PNS; 23: Po; 24: Pog; 25: S; 26: SAM (the point on the soft palate along the occlusal plane); 27: SAL (the point on the tongue along the mandibular plane); 28: SPU (the point on the pharyngeal posterior wall along the palatal plane); 29: SPM (the point on the pharyngeal posterior wall along the occlusal plane); 30: SPL (the point on the pharyngeal posterior wall along the mandibular plane); 31: TB (the most superior point of the tongue dorsum); 32: U1; 33: U1L (the point where the alveolar bone meets the cemento-enamel junction on the lingual surface of the upper central incisor); 34: U1R; 35: U6 (the mesial cusp tip of the upper first molar).

was seated with a natural head position and instructed to bring the posterior teeth into contact, close the mouth, and refrain from swallowing during cephalometry. One of the authors traced all the cephalometric radiographs and identified the 35 reference points (Figure 1) with no prior knowledge of the polysomnographic results. Tracing error was evaluated by retracing 10 randomly selected patients. The variance of the error was less than 2% of the total variance in the entire series.

The reference points were digitized as coordinates. The straight line that passes point Po and Or was designated the x-axis. The straight line vertical to the x-axis and passing at a right angle through point S was designated the y-axis. Twenty-four linear and 34 angular measurements were calculated from the coordinate values. Mean values of the x and y coordinates of all reference points as well as the mean values and

Table 1. Means and Standard Deviations of the Angular Measurements and Their *t*-Test Comparisons Between the Severe OSAS and Simple-Snoring Groups[a]

Angular Measurement, °	Severe OSAS		Simple Snoring		*t*-Test
	x̄	SD	x̄	SD	
FH to SN	2.04	3.95	1.12	4.07	ns
Palatal plane to FH	6.68	3.16	7.48	4.65	ns
Palatal plane to SN	8.74	3.98	8.62	4.18	ns
Occlusal plane to FH	13.77	4.14	14.81	6.24	ns
Occlusal plane to SN	15.83	5.36	15.93	5.31	ns
Mandibular plane to FH	32.25	6.92	31.96	8.20	ns
Mandibular plane to SN	34.30	7.78	33.09	7.51	ns
Occlusal plane to mandibular plane	18.48	5.81	17.14	4.75	ns
SNA	81.46	5.13	82.67	4.61	ns
SNB	78.78	3.86	79.88	3.86	ns
ANB	2.70	3.71	2.79	2.84	ns
A-B plane	−4.50	6.51	−4.43	3.68	ns
Convexity	3.77	8.37	4.51	6.52	ns
S-N-Pog	79.54	4.18	80.40	4.16	ns
Facial angle	81.60	3.67	81.52	4.57	ns
y-axis/FH	68.95	4.03	69.08	4.90	ns
y-axis/SN	71.00	4.45	70.22	3.90	ns
Ramus plane to FH	93.55	5.54	92.69	4.97	ns
Ramus plane to SN	95.60	4.94	93.80	5.10	ns
Saddle angle	126.27	6.41	127.07	4.64	ns
N-S-Ar	120.73	6.67	121.17	4.63	ns
Articular angle	154.87	7.48	152.63	6.51	ns
Gonial angle	118.70	7.57	119.27	6.22	ns
The three angle	394.30	7.78	393.09	7.51	ns
Upper gonial angle	45.34	4.01	45.93	3.25	ns
Lower gonial angle	78.23	5.51	78.33	5.06	ns
U1 to FH	108.95	8.25	107.99	7.40	ns
U1 to SN	106.89	8.14	106.88	6.20	ns
L1 to mandibular plane	96.23	7.08	96.95	8.03	ns
FMIA	51.52	7.28	51.08	4.30	ns
Interincisal angle	122.57	10.52	123.09	6.81	ns
Palatal shape	146.13	7.37	147.87	7.00	ns
Soft palate angulation	123.98	5.99	125.82	5.63	ns
Soft palate shape	136.22	5.37	134.54	4.23	ns

[a] OSAS indicates obstructive sleep apnea syndrome; articular angle, the measurement formed by connecting the S, Ar, and Go; the three angle, N-S-Ar + articular angle + gonial angle; upper gonial angle, measurement formed by connecting the Na, Go, and Ar; lower gonial angle, measurement formed by connecting the Na, Go, and Me; FMIA, measured at the intersection of the axis of lower central incisor and the FH plane; palatal shape, measurement formed by connecting the U1L, HP, and PNS; soft palate angulation, measurement formed by connecting the ANS, PNS, and point P; soft palate shape, measurement formed by connecting the PNS, PP, and point P; ns, not significant.

standard deviations for all measurements were calculated for both groups. An unpaired Student's *t*-test was used to determine whether significant differences were present between severe OSAS patients and simple snorers. To build a model of the severe OSAS group and simple-snoring group, multivariate discriminate analyses were carried out. All statistical analyses were performed using the Microsoft Excel statistical software package, and a 5% level of significance ($P < .05$) was used.

RESULTS

The mean age and BMI were 33 years and 24 kg/m^2 in the severe OSAS group and 32 years and 23 kg/m^2 in the simple-snoring group, respectively. The comparisons of angular and linear measurements between the severe OSAS and simple-snoring groups are given in Tables 1 and 2. No statistically significant difference was observed in age, BMI, or angular measurements between the severe OSAS and simple-snoring groups. However, the soft palate length, mandibular body length, distance from the base of the epiglottis to the tongue dorsum, tongue thickness, distance from the hyoid bone to the mandibular plane, and distance from the hyoid bone to C3-Me were significantly larger in the severe OSAS group than in the simple-snoring group.

Discriminate analysis was performed using the above-described five variables, and significant differences between groups were exhibited. Table 3 presents Fisher's linear discriminate function coefficients

Table 2. Means and Standard Deviations of the Linear Measurements and Their *t*-Test Comparisons Between the Severe OSAS and Simple-Snoring Groups[a]

Linear Measurement, mm	Severe OSAS		Simple Snoring		*t*-Test
	x̄	SD	x̄	SD	
Anterior cranial base length	63.68	3.12	62.70	4.36	ns
Posterior cranial base length	44.32	2.99	43.38	3.24	ns
Anterior facial height	118.36	6.94	116.08	6.95	ns
Posterior facial height	79.62	7.59	79.52	7.74	ns
Upper facial height	52.31	3.53	51.35	4.04	ns
Lower facial height	67.83	4.95	66.64	4.76	ns
Facial height ratio	0.67	0.07	0.69	0.07	ns
Maxillary length	47.35	2.77	47.93	3.46	ns
Mandibular body length	68.34	4.40	66.03	4.23	$P = .019$
Ramus height	46.98	5.38	48.46	6.14	ns
Sella to articulare	34.70	3.78	33.42	3.67	ns
Third vertebra to basion	61.38	4.25	60.41	3.40	ns
Third vertebra to hyoid bone	37.69	4.65	35.98	4.82	ns
Hyoid bone to mandibular plane	18.86	5.61	12.43	5.72	$P < .001$
Hyoid bone to C3-Me	8.97	5.62	4.86	3.52	$P < .001$
Base of epiglottis to hyoid bone	16.21	4.36	15.98	5.33	ns
Base of epiglottis to tongue dorsum	69.28	7.40	62.49	4.38	$P < .001$
Tongue thickness	65.03	7.56	59.01	4.18	$P < .001$
Soft palate length	39.29	4.64	35.96	3.58	$P < .001$
Soft palate thickness	7.07	2.25	7.66	1.71	ns
Upper pharyngeal space	21.60	3.33	21.76	3.09	ns
Middle pharyngeal space	6.50	2.20	6.39	3.18	ns
Lower pharyngeal space	10.27	8.56	8.71	3.80	ns
Airway space	11.95	3.10	10.62	3.65	ns

[a] OSAS indicates obstructive sleep apnea syndrome; anterior cranial base length, from S to Na; posterior cranial base length, from S to Ba; anterior facial height, from Na to Me; posterior facial height, from S to Go; upper facial height, from Na to ANS; lower facial height, from ANS to Me; facial height ratio, posterior facial height/anterior facial height; maxillary length, from ANS to PNS; mandibular body length, from Go to Me; ramus height, from Ar to Go; sella to articulare, from S to Ar; third vertebra to basion, from C3 to Ba; third vertebra to hyoid bone, from C3 to H; hyoid bone to mandibular plane, the perpendicular distance between H and the mandibular plane; hyoid bone to C3-Me, the perpendicular distance between H and the line from C3 to Me; base of epiglottis to hyoid bone, from E to H; base of epiglottis to tongue dorsum, from E to TB; tongue thickness, from H to TB; soft palate length, from PNS to point P; soft palate thickness, the perpendicular distance between PP and the line from PNS to point P; upper pharyngeal space, from PNS to SPU; middle pharyngeal space, from SAM to SPM; lower pharyngeal space, from SAL to SPL; airway space, from PP to SPU; and ns, not significant.

of the variables and constants and the classification results of the discriminate analysis.

The mean composite facial polygons are shown in Figure 2. Outlines of the soft palate and tongue are also shown with the lines that connect the related reference points. No statistically significant difference was observed in the x-coordinate values of any of the reference points; however, the y-coordinate values of the soft palate, epiglottis, and hyoid bone were significantly smaller in the severe OSAS group compared with the simple snoring group (Table 4).

Table 3. Fisher's Linear Discriminant Functions Coefficients and Classification Results of Discriminant Analysis

Discriminating Variable	Coefficient
Mandibular body length	.1507
Uvula length	.1678
Hyoid bone-tongue dorsum	−.1769
Hyoid bone-MP	.2366
Tongue base-tongue dorsum	.1667
Constant	−20.2172
F value	8.7578
P value	<.001
Mahalanobis' generalized distance	2.3062
Classification results, correctly classified	76.5%

DISCUSSION

Craniofacial anatomic risk factors are said to play a role in OSAS, together with the mechanism of upper airway compliance and muscle function. Several studies have recommended the use of cephalometric radiographs to characterize the craniofacial hard- and soft-tissue structures of patients with and without OSAS.[15,18–21]

Most patients with OSAS are middle-aged men with evidence of obesity or craniofacial abnormalities.[22] In general, the facial skeleton is reduced in depth anteroposteriorly due to shortening of the skull base, maxilla, and mandible.[15,23,24] One study[15] reported that anatomic abnormalities may be more of an underlying problem in nonobese OSAS patients, while soft-tissue

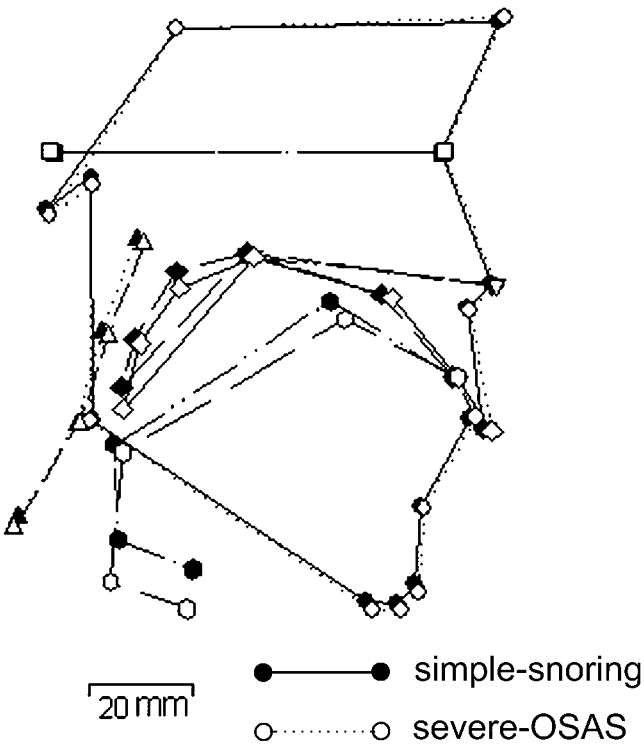

Figure 2. The mean composite facial polygons.

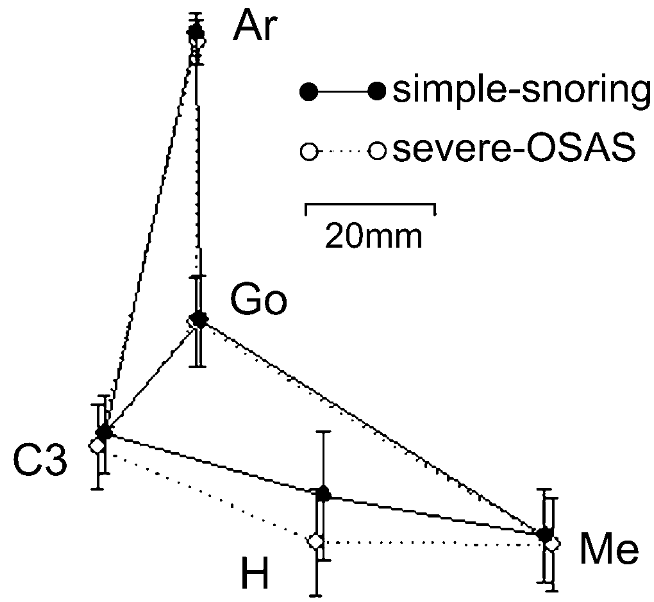

Figure 3. Superimposition of the standard deviations of the mean position and y-coordinate values of the hyoid bone relative to the C3 and the mandible.

variables have a much greater influence in obese OSAS patients. However, data in the literature are inconsistent, such that studies evaluating cephalometric anomalies in patients with OSAS have found no clear-cut morphological characteristics.[25] In addition, a recent study showed that gender and racial variations are present in cephalometric parameters.[26]

Because the structural relationship between the hard and soft tissues of the upper airway is confounded by obesity, which independently remains an important factor for increasing apneic activity, it is important to know which craniofacial parameters are risk factors for nonobese young adults. For Asian men, a BMI exceeding 27 kg/m^2 is defined as being obese.[27] This study demonstrated the cephalometric parameters of craniofacial characteristics that can be used as indicators of OSAS severity in nonobese young Taiwanese male adults.

Since narrowing may be present in various segments of the upper airway, knowledge of its location is central to an understanding of the pathogenesis of OSAS.[28,29] In contrast to previous studies, our results indicated that there was no statistically significant difference in any portion of the upper pharyngeal airway space between severe OSAS patients and simple snorers. Therefore, the cephalometric craniofacial features that possibly reflect structural narrowing of the upper airway, which contributes directly to the pathogenesis of upper airway obstruction in OSAS, were not found in the nonobese subjects of this study.

In comparison with simple snorers in this study, nonobese patients with severe OSAS were characterized by a greater tongue thickness, an inferiorly positioned hyoid bone, a greater mandibular body length, and a longer soft palate. In the supine position, the tongue falls back posteriorly due to gravity and obstructs the oropharyngeal space. This posterior encroachment by the tongue is counteracted only by the tone of the genioglossal muscle. Thus, the thicker the tongue is, the more likely obstruction of the airway will occur during sleep.

Table 4. Means and Standard Deviations of the Y-Coordinate Values of the Soft Palate, Epiglottis, and Hyoid Bone and Their *t*-Test Comparisons Between the Severe OSAS and Simple-Snoring Groups

	OSAS		Snoring		
Y-Coordinate Value	x̄	SD	x̄	SD	*t*-test
PP (the most superior-posterior point)	−50.37	4.84	−47.28	5.49	$P = .008$
P (tip of soft palate)	−74.03	5.47	−69.70	5.60	$P < .001$
E (epiglottis)	−107.63	8.94	−99.37	11.63	$P < .001$
H (hyoidale)	−112.92	8.85	−105.22	10.67	$P < .001$

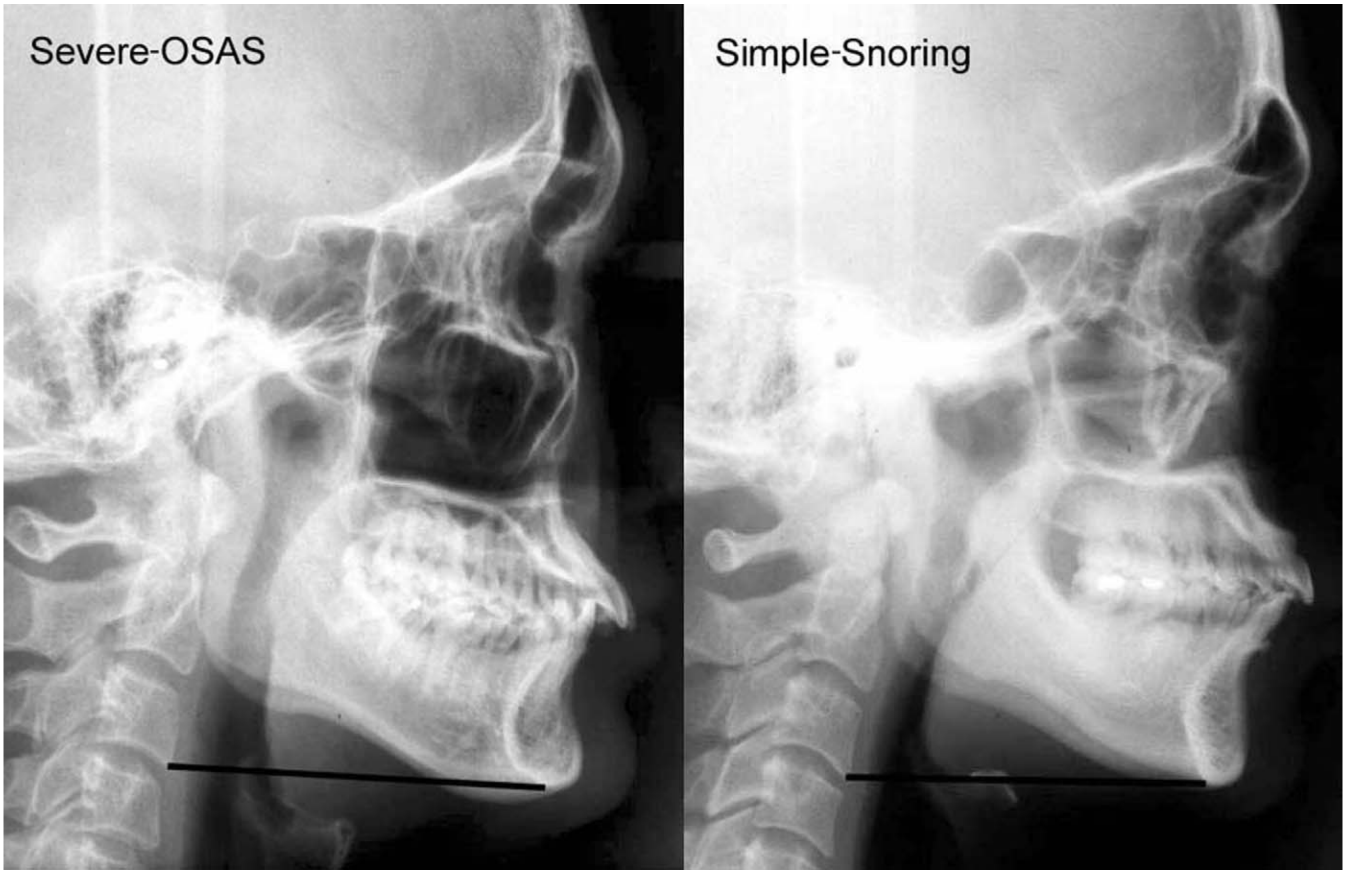

Figure 4. The line from the C3 to the Me on lateral cephalometric radiographs.

The position of the hyoid bone serves as a central anchorage for the tongue muscles and determines the position of the tongue. A lower hyoid bone might be a compensatory mechanism to alleviate the increased airway resistance caused by a reduced airway space, or it might be the result of a greater tongue mass. A downward and forward position of the hyoid was noted in children with enlarged tonsils and adenoids.[30] Children with an obstruction in the upper airway region adopt a more anterior head position with increased craniocervical stretching.[31,32] With this altered habitual head posture, the position and the tone of the supra- and infrahyoid muscles change; the hyoid adopts a downward and forward position relative to the mandible.[33]

A longer mandibular body length in the OSAS group in this study might be the result of a greater tongue mass, because growth of the mandibular body is related to development of the tongue.[34] There is a tendency for the tone of the lingual and pharyngeal musculature to decrease during sleep and for the tongue and soft palate to fall back in the supine position. Therefore, elongation of the soft palate in this study probably resulted from long-term vibration of the soft tissue by recurrent obstruction of the upper pharyngeal airway during sleep.

Because the tongue dorsum, epiglottis, and soft palate are soft tissues that are sometimes unclear on routine cephalograms, a hard-tissue hyoid bone that can be easily identified on radiographs might make a better indicator for differentiating the two groups. A previous study[35] reported that the position of the hyoid bone was consistently above and near the line from the C3 to the Me from the primary to the early permanent dentition in normal Taiwanese subjects. A longitudinal study[36] investigating the hyoid bone position of adult men revealed that the hyoid bone changes to a more inferior position with increasing age.

Another longitudinal study[37] indicated that gonion and the second cervical vertebra body were anatomically interrelated. Therefore, to understand the positional changes in the same patient and to compare the hyoid bone position among different patients, it seems that the use of the relative position of the hyoid bone with both the mandible and vertebra may be a more accurate and easier method than using the distance from the hyoid bone to the mandibular plane. In addition, the perpendicular distance from the hyoid bone to the mandibular plane may be influenced by the anteroposterior position of the hyoid bone: it increases when the hyoid bone is positioned posteriorly and decreases when the hyoid bone is positioned anteriorly. Figure 3 shows the superimposition of the standard deviations of the mean position and y-coordinate values of the hyoid bone relative to the C3 and the mandible for both groups. Figure 4 shows that the perpendicular distances from the hyoid bone to the mandibular plane were comparable in both groups; however, the position of the hyoid bone in simple snorers was below but near the straight line from the C3 to the Me, whereas the position of the hyoid bone in severe OSAS patients was far below this line. To summarize our results, it is suggested that the line from the C3 to the Me on lateral cephalometric radiographs may be used as a clinical guideline for diagnosing severe OSAS in nonobese young Taiwanese men.

CONCLUSION

- The position of the hyoid bone relative to a line from the third vertebra to menton can be used as an indicator for a diagnosis of severe OSAS in nonobese young male Taiwanese adults.

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