

Cephalometric Indicator of Obstructive Sleep Apnea in Relation to Severity and Sites of Obstruction in Non-Obese Male Patients

Osama A Alsaddik^{1,*}, Fayez K Saleh² and Sara N Aksamawati³

¹Masters in Orthodontics, Beirut Arab University, Lebanon

²Professor of orthodontics in faculty of dentistry, Beirut Arab University, Lebanon

³Masters in Pediatric dentistry, Lebanese University, Lebanon

*Corresponding author: Osama A Alsaddik, Masters in Orthodontics, Beirut Arab University, Beirut, Lebanon, E-mail: osa954@hotmail.com

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Abstract

Obstructive Sleep Apnea (OSA) is characterized by episodic cessation of breathing during sleep. Upper airway patency is determined by an interactive role of anatomic and neuromuscular factors. Craniofacial skeletal and upper airway soft tissue morphology, obesity, sleep position represents a few of the determinant factors. Cephalometric characteristics for OSA patients include mandibular deficiency, bimaxillary retrusion, and reduced cranial base angle, decreased mandibular length and increased lower anterior facial height.

Treatment of OSA depends mainly on the severity and site of obstruction and is either surgical or non-invasive treatment.

Objective: The study evaluated the dentofacial characteristics of (OSA) patients in Lebanese non obese male population and compared them with normal group according to severity and sites of obstruction.

Materials and Methods: A total of 67 subjects were recruited for the study, 42 subjects were diagnosed with OSA by previous polysomnography tests at the American University in Beirut Medical Center Sleep Laboratory. 25 non-OSA subjects were recruited as controls. Based on Apnea-Hypopnea index (AHI) value, the patients were divided into mild-to-moderate and severe group. Cephalometric measurements and physical examination of the tonsils were used to classify the OSA patients into groups according to sites of obstruction. Cephalometric X-rays were taken and digitized for linear and angular values.

Results: Regarding severity groups, no statistically significant differences were observed in age, BMI, or angular measurements between the three severity groups except for the angular measurement (C3-H-Me). However, for linear measurements; the soft palate length, the soft palate thickness, Jarabak facial ratio; the distance between the PNS and point V; and the distance between the hyoid and the following : tongue base, mandibular plane and C3-Me were found significant.

As for sites of obstruction, no statistically significant differences were observed in angular measurements between the three groups except for C3-H-Me. However, the soft palate thickness, the distance between the PNS and point V; and the distance between the hyoid and the following: tongue base, mandibular plane and C3-Me were found significant.

Conclusion: This study revealed that certain Craniofacial and upper airway soft tissue characteristics exist in relation to severity of OSA and sites of obstruction. (C3-Me perpendicular to the hyoid bone) is a significant predictor of OSA in non-obese Lebanese male subjects.

Keywords: Sleep; Apnea; Lebanese; Cephalometric; Hyoid; Indicator; Obstructive; Non obese; Severity

Introduction

Obstructive Sleep Apnea syndrome (OSA) is characterized by episodic cessation of breathing during sleep. There is a controversy concerning the cause and effect of sleep apnea and certain abnormal craniofacial pattern. There are certain cephalometric characteristics for OSA patients in relation to severity and sites of obstruction and these include mandibular deficiency, bimaxillary retrusion, reduced

cranial base angle, decreased mandibular length; increased lower anterior facial height, inferiorly positioned hyoid, and elongated Soft Palate as revealed by Koubayashi, et al. [1] and Hou, et al. [2]. Previous studies by Bacon, et al. [3]; Kubota, et al. [4]; Lowe, et al. [5]; and Lowe, et al. [6] investigated facial characteristics of OSA patients in relation to severity and sites of obstruction and found that certain dentofacial characters could be used as diagnostic measures and aid in treatment planning of those patients. Since no cephalometric studies have been

conducted on obstructive sleep apnea on the Lebanese population and few studies have investigated the relationship between the dentofacial characteristics and obstructive sites in patients with OSA, this justified the conduct of the study since proper diagnosis is the key to understanding the etiology of OSA and the proper treatment plan.

Materials and Methods

A total of 67 subjects were recruited, 42 subjects were diagnosed with OSA by previous polysomnography test at the American University in Beirut Medical Center Sleep Laboratory. The polysomnography test was performed using overnight polysomnography including EEG (electroencephalography), ECG (electrocardiography), and EOG (electrooculography), sub mental EMG (electromyography), airflow, tracheal sound with microphone, arterial oxygen saturation (SpO₂), and respiratory effort. Additionally, 25 non-OSA control subjects were recruited from a pool of class I malocclusion patients from the Orthodontic Department at Beirut Arab University.

Inclusion: (All subjects including control)

- Lebanese males
- Age between 30 and 60 years
- Non-obese at the time of their recruitment: Body Mass Index (BMI) < 30. BMI is calculated as $[BMI = \text{weight (kg)} \div \text{height}^2 \text{ (m)}]$.

Exclusion

- Prior history of orthodontic treatment or craniofacial abnormality (applies for both OSA and non-OSA Subjects).
- Control patients with symptoms or features suggestive of OSA despite not doing PSG sleep study such as: snoring, nocturnal apnea, or excessive daytime sleepiness.

All participants signed a consent form after having an explanation on the subject, benefits, and minimal risk if any, when participating in our research study. Approval for the study was obtained from the ethics committee and IRB at the American University in Beirut Medical Center (AUBMC).

For every patient a lateral cephalometric X-ray was obtained in the Natural head position which is a standardized position of the head in an upright posture with the eyes focused on a point in the distance at eye level, which implies that the visual axis is horizontal. With the same machine and practitioner.

Every cephalometric X-ray was traced on acetate paper and then digitized by a scanner for landmark identification as shown in figure 1 and table 1; and measurement of linear and angular values, as shown in table 2, using the dentofacial Planner Program[®] was done.

Severity groups

The subjects were categorized into three severity groups based on their polysomnography test results specifically their AHI values as advocated by the American Academy of Sleep Medicine 2007 which indicates the number of respiratory irregularities per sleep hour and is calculated with this formula: $[(\text{total number of apneas} + \text{hypopneas}) / (\text{total sleep time in minutes})] \div 60$. An AHI index value exceeding 5 indicates the presence of OSA.

In our research used the definition of Apnea as periods of no breathing while hypopnea means slow or shallow breathing in which the PSG reports the following:

- The peak signal excursions drop by $\geq 30\%$ of pre-event baseline using nasal pressure and PAP device flow.

- The duration of the $\geq 30\%$ drop in signal excursion is ≥ 10 seconds.
- There is a $\geq 3\%$ oxygen desaturation from pre-event baseline and/or the event is associated with an arousal.

The groups were as follow:

- Control or non-OSA subjects: AHI < 5
- Mild to moderate OSA: $5 \leq \text{AHI} < 30$
- Severe OSA: AHI ≥ 30

Obstructive site groups

We used the narrowest portion of the airway in the cephalometric radiograph taken in the awake upright subjects and physical examination of the tonsils to classify the OSA patients into groups according to sites of obstruction for further dentofacial characteristics description which may be one of the following as shown by Baik, et al. [7] and illustrated in figure 2:

1) Obstruction at the Retropalatal and Retroglossal region (Rp plus Rg group) in which the linear cephalometric values for Rp is calculated as the distance from Point (Sbtn) to Point (Phwn), and Rg as the distance from Point (U) to Point (ppw2), those two linear cephalometric values were used to classify the obstruction site groups if they both were less or equal to 6mm,

2) Obstruction at the Retropalatal region (Rp group) in which the linear cephalometric value for Rp (Sbtn-Phwn) is less or equal to 6mm, as shown in figure 2.

3) Obstruction due to tonsillar hypertrophy (tonsillar hypertrophy group). Classification in this group had 2 criteria. Patients were assigned to the tonsillar hypertrophy group when the appearance of their tonsils was Mackenzie's Class II or III (I: tonsils just visible beyond the palatal arch; II: intermediate enlargement; III: tonsils appearing to contact each other at the midline) as cited from Fukuda, et al. [8]; and when the values of cephalometric linear measurement (Sbtn-phwn) or (U-ppw2) exceeded 6mm on cephalometric X-ray.

The site of obstruction was further confirmed by the full night measurement of the oropharyngeal and esophageal pressure that we found in the patient's records since polysomnography will not be repeated for the purposes of this research.

Demographic and sleep data

Demographic and sleep data are summarized in table 3. The mean age and BMI of the control group were 31.4 years and 25.8 kg/m²; the mild to moderate OSA group, 42.8 years and 26.1 kg/m² with mean AHI of 18 ± 6.9 ; and the severe OSA group, 41.8 years and 26.6 kg/m² with mean AHI of 40.6 ± 5.3 respectively.

Matching: OSA patients will be (± 10 years) matched to the age of non OSA subjects. The relatively wide range in age matches is meant to allow for the single 25 subject non-OSA group to serve as an age match to the 2 OSA severity groups.

Additional Considerations at recruitment:

- Uniform sampling of the AHI range for each group were attempted to ensure that there is an even distribution of AHI values. This is needed for: (1) Quantitative correlation of Cephalometric data and OSA severity and (2) Multivariate modeling of AHI scores (MLR).
- Upon approaching these subjects, information about their current weight were collected to exclude the possibility of having a substantially altered BMI score from the previously conducted PSG study.

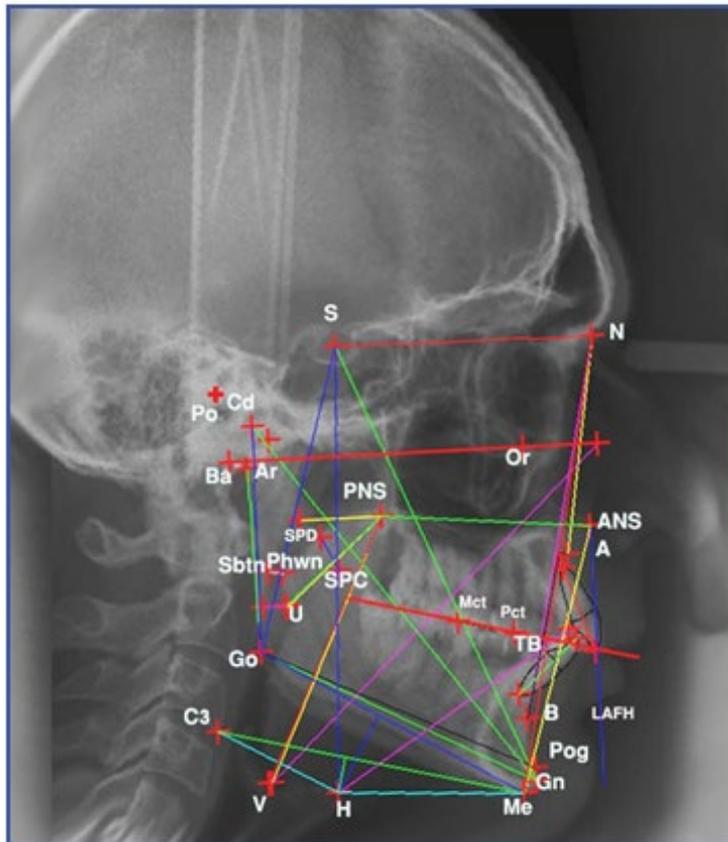


Figure 1: Angular and Linear measurements used in this study.

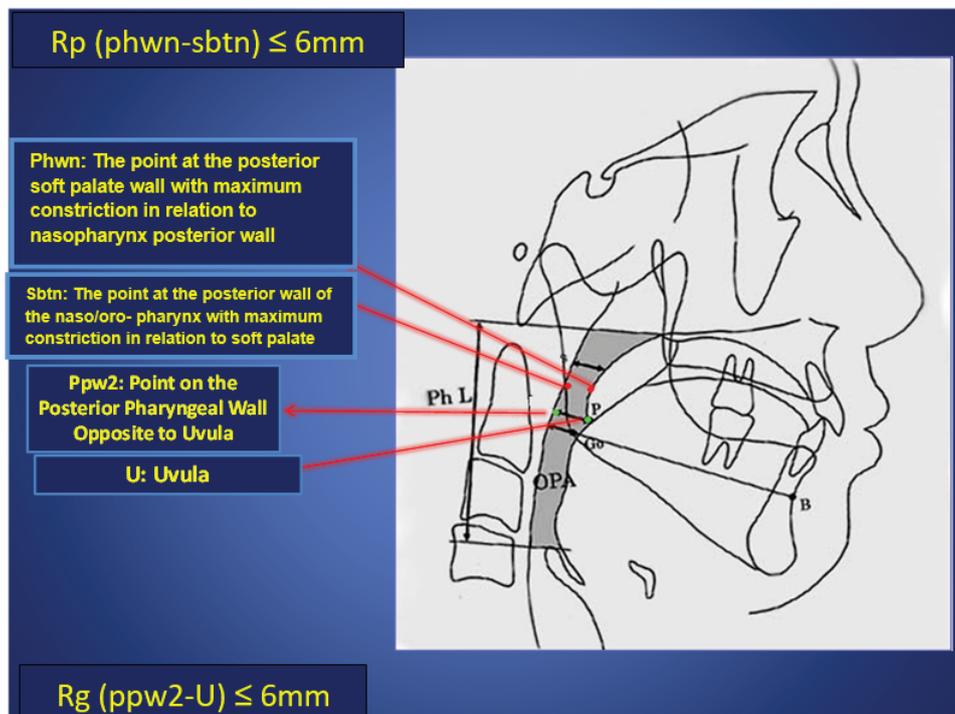


Figure 2: Retro-palatal and Retro-glossal Sites of Naso-pharyngeal and Oro-pharyngeal Obstruction.

Sample size calculation

Since there is no available data on the prevalence of dentofacial defects among OSA patients, or even data on the dentofacial characteristics of Lebanese OSA patients, a quick literature review was done to estimate the variation of means of the different Cephalometric measurements among the three different groups - as classified according to AHI scores. According to Chang and Shiao (2008), measurement of the distance of anterior superior hyoid to mandibular plane (MPH) among the four different groups was the following:

MPH means (± SD)	AHI<5	5 ≤ AHI<15(mild)	15 ≤ AHI<30(moderate)	AHI ≥ 30(severe)
	18.9 (± 9.8)	15.3 (± 5.9)	17.4 (± 4.5)	24.7 (± 11.5)

Based on the above difference in MPH means, an average in the mean difference in MPH of approximately 8.0 was taken with a standard deviation of 7.5 to calculate the sample size needed for comparison of the three different groups (ANOVA). Having a study

Table 1: Landmarks Definition.

Anterior Nasal Spine (ANS)	The anterior tip of the nasal spine at the lower margin of the anterior nasal opening.
Articulare (Ar)	The point of intersection of the posterior border of the condyle and the inferior border of the basilar part of the occipital bone.
Condylion (Cd)	The most superior point on the curvature of the condylar head. It is located as the most superior axial point of the condylar head rather than as the most superior point on the condyle.
C3	The most anteroinferior point on the curvature of the third vertebrae
Gnathion (Gn)	The most anteroinferior point on the contour of the bony chin symphysis. It is constructed by intersecting a line drawn perpendicular to the line connecting PG and ME.
Gonion (Go)	The constructed point where the ramus plane and the mandibular plane intersect
Hyoid (H)	The most superoanterior point on the body of the Hyoid bone.
Lower Incisor Apex	The root tip of the most anterior mandibular central incisor.
Lower Incisor Incisal Edge	The Incisal tip of the mandibular central incisor.
Menton (Me)	The most inferior point on the Symphysal outline of the mandible.
Nasion (N)	The most anterior point of the Nasofrontal suture or the most posterior point on the curve at the bridge of the nose.
Orbitale (Or)	The lowest point on the external border of the orbital cavity, tangent to the Frankfort plane.
Pogonion (Pg)	The most anterior point on the Symphysis. It is determined by a tangent through N.
Point A	The most posterior point on the labial surface of the maxilla between the anterior nasal spine and the dental alveolus.
Point B	The most posterior point from a line drawn from ID to PG on the anterior surface of the Symphyseal outline of the mandible.
Porion (Pr)	The most superior point of the external auditory meatus, tangent to the Frankfort plane.
PNS	The most posterior point at the sagittal plane on the dorsal surface of the maxilla.
Premolar Mesial Contact Point(PCT)	Established by the intersection of a line along the occlusal contact of the upper and lower premolars and a perpendicular line to it through the averaged anterior contact of the first maxillary premolars with the maxillary cuspid.
Sella Turcica	A constructed point representing the center of the pituitary fossa.
Upper Incisor Apex	The root tip of the maxillary central incisor.
Upper Incisor Incisal Edge	The Incisal tip of the maxillary central incisor
Upper Molar Mesial Cusp Tip(MCT)	The anterior cusp tip of the maxillary first molar.
Sbtn	The point at the posterior soft palate wall with maximum constriction in relation to Nasopharynx posterior wall
Phwn	The point at the posterior wall of the Naso/oro-Pharynx with maximum constriction in relation to soft palate
TB	Tongue Tip
SPC	The anterior point of the soft palate that has maximum convexity.
SPD	The posterior point of the soft palate that has maximum convexity in relation to Nasopharynx
Ppw2	Point on posterior pharyngeal wall opposite to the Uvula
U	The tip of the Uvula
V	Valeculia, the most posteroinferior base of the tongue
Mandibular plane	The plane from Point Go to Point Me
Frankfort Horizontal	The plane from point Orbitale to Point Porion

Table 2: Linear and angular Measurements definition.

Y-axis to SN	The angle between planes S-Me and S-N
Gonial angle	The angle between Point Go and Points Ar and Me
FMIA	Frankfort Mandibular Incisal Angle: the angle between Frankfort plane and mandibular incisal plane
Soft palate angulation	The angle between Point PNS and Points ANS and U
C3-H-Me	The angle between Point H to Points C3 and Me
Go - Gn	The distance from Point Gonion to Point Gnathion that measure mandibular length
ANS-Me(ALFH) / N-Me(ATFH)	The ratio between anterior lower facial height and anterior total facial height
PNS-U	The distance between Point Posterior nasal spine and Uvula
PNS-V	The distance between Point Posterior nasal spine and Valeculla
H-TB	The distance between hyoid bone and tip of the tongue
Sbtn-Phwn	The maximum constriction in the Nasopharynx
soft palate thickness	The distance between point SPC and point SPD
S-Go/N-Me %	Jarabak facial ratio: Ratio between points S and Go to N and Me
H perp. MP	The distance between a perpendicular from Point hyoid and mandibular plane
H perp. C3-Me	The distance between a perpendicular from Point hyoid and constructed plane from point C3 to Menton

Table 3: Demographic and sleep data.

	Age	BMI mean	AHI, No./h
Control	31.48 ± 6.17	25.88 ± 0.79	
Mild to Moderate OSA	42.85 ± 8.57	26.17 ± 1.3	18 ± 6.91
Severe OSA	41.86 ± 9.3	26.65 ± 1.16	40.68 ± 5.31

power of 80% and type I error of 5%, we calculated a sample size of 20 subjects per group. (Analysis done by the Biostatistics Unit at the American University in Beirut-CRI).

The mild and moderate groups consisted of 20 subjects and, were therefore added together in one group with AHI range: ($5 \leq \text{AHI} < 30$); while the severe group consisted 22 subjects with AHI range: ($\text{AHI} \geq 30$).

Statistical methods for data analysis

Analysis was performed using the SPSS version 18.0 (IBM Corporation, Illinois, Chicago, USA) statistical package for Windows®. Data was tested for normal distribution using the Shapiro Wilk, and Lielliefors tests; and Levene's test for testing homogeneity of variances. Continuous variables will be expressed as mean ± standard deviation. Categorical variables were reported as frequencies and percentages. Standard descriptive statistics were determined. Univariate Analysis was conducted as appropriate using Fisher Exact test for categorical variables; and Welch's Robust and Kruskal Wallis tests for continuous variables. One way Analysis of Variance (ANOVA) test was used to evaluate the association between the different individual cephalometric measurements and OSA presence or severity (3 groups). Correlations between AHI scores and the cephalometric measurements (continuous) were also assessed (Pearson correlation).

Multivariate analyses were done as follows:

1-General Linear Model GLM: ANOVA with AHI score as dependent variable and each cephalometric measure as the independent variable.

2-Multiple linear regression analysis (MLR): MLR was also performed using backward elimination method to determine the cephalometric and other predictor variables that explain variations in AHI values in the Lebanese male population considering demographics. The model results were confirmed using the Forward

Selection and Stepwise Regression Methods. A p-value < 0.2 was used for initial inclusion in the multivariate modeling, and $p \leq 0.05$ was used for retaining variables in the final multivariate regression model. A p-value ≤ 0.05 (two sided) was used to indicate significance in all cases.

Results

Severity results

The significant variables found from normality testing as shown in table 4, were tested by: Fisher's ANOVA test; Welch's robust test; and Kruskal-Wallis test and no statistically significant differences were observed in angular measurements between the three groups except for the angular measurement (C3-H-Me). However, for linear measurements; the soft palate length, the soft palate thickness, Jarabak facial ratio; the distance between the PNS and point V; and the distance between the hyoid and the following: Tongue base, mandibular plane and C3-Me differences were found significant. For the eight variables that we found significant, we did not have equality in significances between the three severity groups, hence; those variables were compared two by two for further understanding of differences between the groups according to severity as shown in table 5.

Multiple linear regression analysis was done for AHI and the following variables: H perpendicular MP; soft palate angulation, PNS-U, H perpendicular C3-Me and Jarabak Facial Ratio. Only H perpendicular MP ($R_2=0.278$, $P<0.05$) and H perpendicular C3-Me ($R_2=0.508$, $P<0.05$) were significant. H perpendicular C3-Me showed the highest regression as shown in table 6 so it was tested for the appropriate model and showed a cubic figure in relation to AHI as shown in figure 3.

The findings of this study have shown that the position of the hyoid bone in mild to moderate OSA patients was below but near the straight line from the C3 to Me (mean: $7.5\text{mm} \pm 2.4$), whereas the position of the hyoid bone in severe OSA patients was far below this line (mean: $15.7\text{mm} \pm 4.7$). This was in agreement to the findings of Sakakibara, et al. [9]; Tsai, et al. [10]; and Kurt, et al. [11].

The results showed a low hyoid bone position in conjunction with a constricted posterior upper airway space (Sbtn-Phwn) in both severity groups (mild to moderate mean: $6.2\text{mm} \pm 2$; severe mean: $5.7\text{mm} \pm$

Table 4: Tests of normality for the angular and linear measurements between the control, mild-moderate and severe groups. Level of significance: $P < 0.05$.

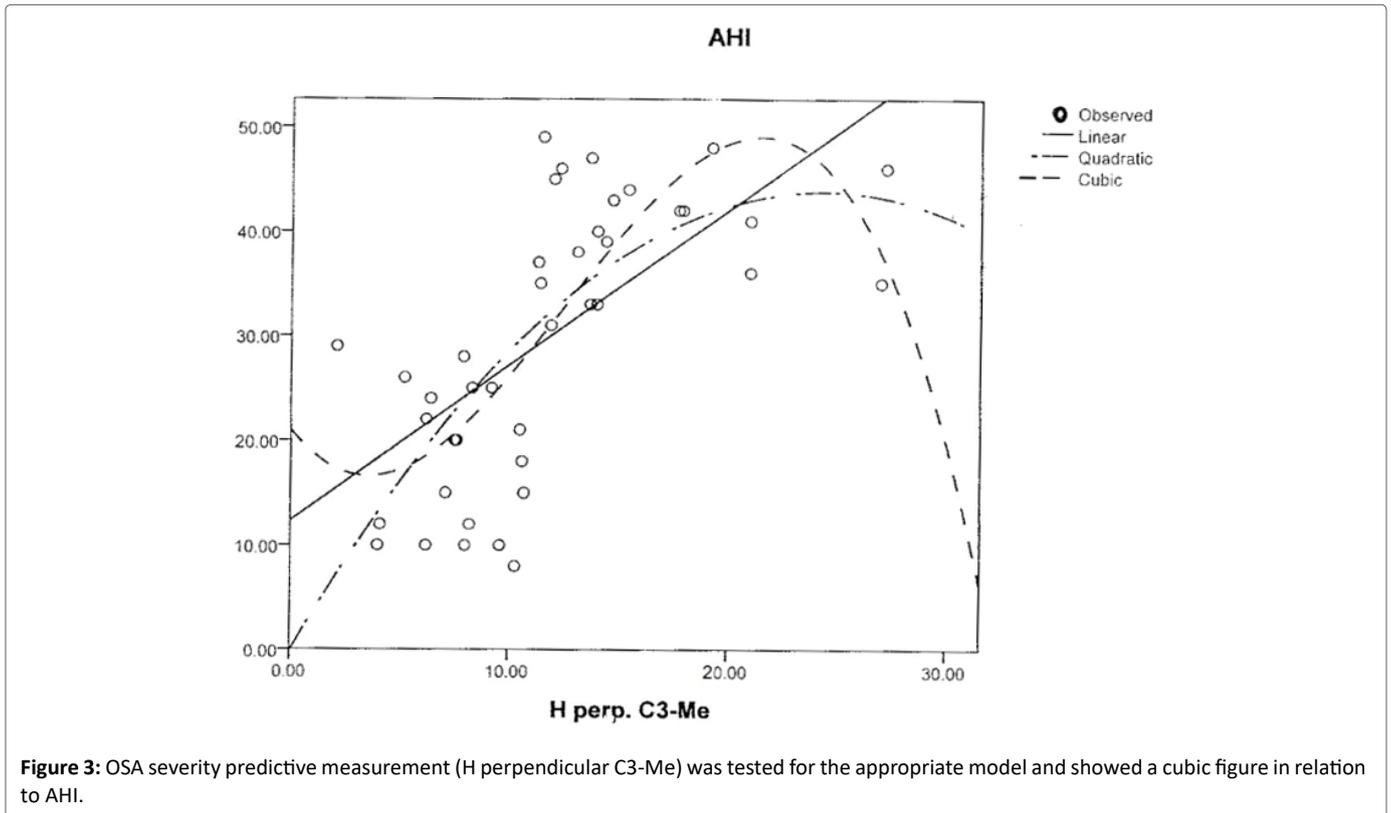
Variable	Group	Lilliefors Sig.	Judgment at 5%: Normality is	Shapiro-Wilk sign.	Judgment at 5%: Normality is
Y-axis to SN	Control	0.135	not rejected	0.582	not rejected
	Mild	0.2	not rejected	0.286	not rejected
	Severe	0.2	not rejected	0.837	not rejected
Gonial angle	Control	0.057	not rejected	0.402	not rejected
	Mild	0.048	rejected	0.044	rejected
	Severe	0.2	not rejected	0.347	not rejected
FMIA	Control	0.2	not rejected	0.424	not rejected
	Mild	0.2	not rejected	0.441	not rejected
	Severe	0.111	not rejected	0.262	not rejected
Soft palate angulation	Control	0.109	not rejected	0.148	not rejected
	Mild	0.2	not rejected	0.471	not rejected
	Severe	0.174	not rejected	0.461	not rejected
C3-H-Me	Control	0.2	not rejected	0.14	not rejected
	Mild	0.2	not rejected	0.899	not rejected
	Severe	0.026	rejected	0.072	not rejected
Go - Pg	Control	0.168	not rejected	0.263	not rejected
	Mild	0	rejected	0	rejected
	Severe	0.2	not rejected	0.891	not rejected
ANS-Me(ALFH) /N-Me(ATFH)	Control	0.2	not rejected	0.362	not rejected
	Mild	0.2	not rejected	0.397	not rejected
	Severe	0.032	rejected	0.154	not rejected
PNS-U	Control	0.2	not rejected	0.252	not rejected
	Mild	0.2	not rejected	0.544	not rejected
	Severe	0.2	not rejected	0.135	not rejected
PNS-V	Control	0.2	not rejected	0.559	not rejected
	Mild	0.2	not rejected	0.786	not rejected
	Severe	0.2	not rejected	0.512	not rejected
H-TB	Control	0.2	not rejected	0.337	not rejected
	Mild	0	rejected	0	rejected
	Severe	0.088	not rejected	0.209	not rejected
Sbtn-Phwn	Control	0.042	rejected	0.001	rejected
	Mild	0	rejected	0.001	rejected
	Severe	0.006	rejected	0.003	rejected
soft palate thickness	Control	0.2	not rejected	0.257	not rejected
	Mild	0.114	not rejected	0.333	not rejected
	Severe	0.087	not rejected	0.001	rejected
S-Go/N-Me % #321	Control	0.195	not rejected	0.464	not rejected
	Mild	0.2	not rejected	0.875	not rejected
	Severe	0.2	not rejected	0.918	not rejected
H perp. MP	Control	0.2	not rejected	1	not rejected
	Mild	0.2	not rejected	0.913	not rejected
	Severe	0.2	not rejected	0.661	not rejected
H perp. C3-Me	Control	0.2	not rejected	0.105	not rejected
	Mild	0.2	not rejected	0.394	not rejected
	Severe	0.005	rejected	0.001	rejected

Table 5: ANOVA tests for angular and linear measurements in severity groups. Level of significance at $P < 0.05$.

ANOVA by groups (Control, Mild, and severe)	Levene's Test for homogeneity of variances		Fisher's ANOVA Test		Welch's robust Test	Kruskal-Wallis Test
	Sig.	R-square	Sig.	Sig.	Sig.	
Y-axis to SN	0.972	0.045	0.231	0.224	0.282	
Gonial angle	0.173	0.001	0.972	0.962	0.877	
FMIA	0.565	0.007	0.789	0.8	0.772	
Soft palate angulation	0.19	0.007	0.795	0.777	0.818	
C3-H-Me	0.037	0.379	0	0	0	
Go-Pg	0.513	0.086	0.055	0.147	0.174	
ANS-Me(ALFH)/N-Me(ATFH)	0.118	0.041	0.266	0.293	0.308	
PNS-U	0.203	0.119	0.017	0.006	0.012	
PNS-V	0.488	0.4	0	0	0	
H-TB	0.146	0.387	0	0	0	
Sbbtn-Phwn	0.672	0.043	0.242	0.285	0.08	
Soft palate thickness	0.072	0.244	0	0	0	
S-Go/N-Me % #321	0	0.98	0	0	0	
H perp. MP	0.007	0.569	0	0	0	
H perp. C3-Me	0.007	0.536	0	0	0	

Table 6: Multiple comparisons between significant measurements and severity groups. Level of significance at $P < 0.05$.

Variable	Multiple Comparisons				
	Difference	Mean Difference	Sig.	95% Confidence Interval	
				Lower Bound	Upper Bound
C3-H-Me	Control - Mild	1.684	0.89	-7.088	10.456
	Control - Severe	20.518	0	11.97	29.066
	Mild - Severe	18.834	0	9.799	27.868
PNS-U	Control - Mild	-2.494	0.318	-6.597	1.609
	Control - Severe	-4.892	0.013	-8.891	-0.894
	Mild - Severe	-2.398	0.367	-6.624	1.828
PNS-V	Control - Mild	-6.953	0.01	-12.496	-1.41
	Control - Severe	-14.697	0	-20.099	-9.295
	Mild - Severe	-7.744	0.005	-13.453	-2.035
H-TB	Control - Mild	-8.121	0.004	-13.943	-2.299
	Control - Severe	-14.991	0	-20.664	-9.319
	Mild - Severe	-6.87	0.021	-12.866	-0.875
Soft palate thickness	Control - Mild	-2.291	0.004	-3.939	-0.643
	Control - Severe	-2.861	0	-4.468	-1.255
	Mild - Severe	-0.57	0.701	-2.268	1.127
S-Go/N-Me % #321	Control - Mild	-65.402	0	-68.773	-62.031
	Control - Severe	-66.75	0	-70.035	-63.466
	Mild - Severe	-1.349	0.622	-4.82	2.123
H perp. MP	Control - Mild	-4.91	0.004	-8.407	-1.413
	Control - Severe	-12.988	0	-16.396	-9.58
	Mild - Severe	-8.078	0	-11.68	-4.476
H perp. C3-Me	Control - Mild	-1.229	0.568	-4.126	1.668
	Control - Severe	-9.489	0	-12.312	-6.667
	Mild - Severe	-9.489	0	-11.244	-5.277



2.3) in comparison to controls (mean: 6.9mm ± 2.5) which was similar to the findings of Kurt, et al. [11].

The angle (C3-H-Me) was significantly decreased with severity compared to controls and that strengthens the relation of OSA severity and position of the hyoid bone (mild to moderate mean: 158.5 deg. ± 8.5; severe mean: 139.7 deg. ± 11.8). This was in agreement with Jamieson, et al. [12] and Tsai, et al. [13].

The results of this study have shown significant increase in soft palate length between the mild-to-moderate group (mean: 38.7mm ± 7.4), severe group (41.1mm ± 4.8) and controls (mean: 36.2mm ± 4.8). A strong relation was found between OSA severity and soft palate length. Since there is tendency for the tone of the lingual and pharyngeal musculature to decrease during sleep and for the tongue and soft palate to fall backward in the supine position; therefore, we hypothesize that elongation of the soft palate in our study probably may have resulted from long-term vibration of the soft tissue by recurrent obstruction of the upper pharyngeal airway during sleep similar to the findings of Lyberg, et al. [14] and Hou, et al. [15].

The present findings revealed that the two OSA severity groups tongue base (PNS-V) was in a more inferior position in relation to control subjects (control mean: 68.9mm ± 7.3; mild to moderate: 75.9mm ± 7.1; severe mean: 83.6mm ± 8.6). The tongue mass (H-TB) was significantly increased with severity when compared to controls. (control mean: 62.7mm ± 6.3; mild to moderate mean: 70.8mm ± 7.0; severe mean: 77.7mm ± 9.2), this means that in the two severity groups, 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 as was shown by Lyberg, et al. [14] and Tsai, et al. [10]. 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.

The results of this study have also showed that the palate thickness was significantly higher with the severity of OSA in the mild to moderate group (mean: 12.1mm ± 2.7) and severe group (mean: 12.6mm ± 2.7) in comparison to control group (mean: 9.8mm ± 1.4) but showed no significant difference between the mild to moderate and severe group indicating the role of soft palate thickness in collapse of the upper airway, which was in agreement with the findings of Tangugsorn, et al. [16] and Kurt, et al. [11].

As for the facial pattern, we used the Jarabak Facial Ratio (the percentage of the anterior and posterior facial proportions) which is obtained by the formula posterior facial height/ anterior facial height × 100. Anterior facial height is measured from Nasion to Menton and the posterior facial height is measured from Sella to Gonion. Values between 62-65% indicate a well balanced face, a higher percentage is seen in hypo divergent cases (short faces), whereas lower percentage is suggestive of hyper divergent cases (Long faces).

We found a hyper divergent facial type (excessive vertical development of the posterior facial height) for the two severity groups in comparison to controls (we found decreased Jarabak facial ratio (S-Go/N-Me%): controls mean: 70 ± 0; mild to moderate mean: 66.1 ± 5.7; severe mean: 67.4 ± 6.1) which was in accordance with the findings of Tsai, et al. [13] in which greater lower anterior facial height was related to an overall increase in OSA severity in men; and severity of the OSA was related to the lower anterior portion in men (inferiorly positioned chin and hyoid bone) in which a larger Y-axis implies more downward mandibular growth and is related to greater lower facial height. This was further investigated by Hou, et al. [15] that documented several alterations in the craniofacial structure of 121 male patients with OSA, including posteriorly positioned maxilla and

Table 7: Tests of Normality by sites of obstruction. P value of significance: P<0.05.

Variable	Group	Lilliefors Sig.	Judgment at 5%: Normality is	Shapiro-Wilk sig.	Judgment at 5%: Normality is
Y-axis to SN	RP+Rg	0.2	not rejected	0.751	not rejected
	Rt	0.2	not rejected	0.999	not rejected
	RP	0.2	not rejected	0.347	not rejected
Gonial angle	RP+Rg	0.107	not rejected	0.065	not rejected
	Rt	0.2	not rejected	0.579	not rejected
	RP	0.2	not rejected	0.587	not rejected
FMIA	RP+Rg	0.029	rejected	0.073	not rejected
	Rt	0.2	not rejected	0.662	not rejected
	RP	0.2	not rejected	0.482	not rejected
Soft palate angulation	RP+Rg	0.176	not rejected	0.314	not rejected
	Rt	0.2	not rejected	0.999	not rejected
	RP	0.2	not rejected	0.162	not rejected
C3-H-Me	RP+Rg	0.2	not rejected	0.639	not rejected
	Rt	0.2	not rejected	0.587	not rejected
	RP	0.2	not rejected	0.83	not rejected
Go - Pg	RP+Rg	0.2	not rejected	0.152	not rejected
	Rt	0.006	rejected	0	Rejected
	RP	0.2	not rejected	0.043	Rejected
ANS-Me(ALFH)/N-Me(ATFH)	RP+Rg	0.108	not rejected	0.181	not rejected
	Rt	0.2	not rejected	0.264	not rejected
	RP	0.2	not rejected	0.603	not rejected
PNS-U	RP+Rg	0.2	not rejected	0.719	not rejected
	Rt	0.2	not rejected	0.998	not rejected
	RP	0.2	not rejected	0.297	not rejected
PNS-V	RP+Rg	0.2	not rejected	0.823	not rejected
	Rt	0.162	not rejected	0.11	not rejected
	RP	0.2	not rejected	0.656	not rejected
H-TB	RP+Rg	0.2	not rejected	0.455	not rejected
	Rt	0.111	not rejected	0.126	not rejected
	RP	0.058	not rejected	0.021	Rejected
Sbtn-Phwn	RP+Rg	0.2	not rejected	0.296	not rejected
	Rt	0	rejected	0	Rejected
	RP	0.2	not rejected	0.514	not rejected
soft palate thickness	RP+Rg	0.2	not rejected	0.248	not rejected
	Rt	0.151	not rejected	0.103	not rejected
	RP	0.2	not rejected	0.246	not rejected
S-Go/N-Me % #321	RP+Rg	0.2	not rejected	0.474	not rejected
	Rt	0.2	not rejected	0.035	rejected
	RP	0.2	not rejected	0.64	not rejected
H perp. MP	RP+Rg	0.068	not rejected	0.066	not rejected
	Rt	0.2	not rejected	0.863	not rejected
	RP	0.2	not rejected	0.368	not rejected
H perp. C3-Me	RP+Rg	0.2	not rejected	0.996	not rejected
	Rt	0.2	not rejected	0.733	not rejected
	RP	0.2	not rejected	0.354	not rejected

Table 8: ANOVA tests for angular and linear measurements between sites of obstruction groups. P value of significance: P<0.05.

ANOVA/All groups/by Localization	Levene's test for homogeneity of variances	Fisher's ANOVA Test		Welch's robust Test	Kruskal-Wallis Test
		R-square	Sig.	Sig.	Sig.
Variable	Sig.				Sig.
Y-axis to SN	0.052	0.085	0.178	0.078	0.142
Gonial angle	0.849	0.011	0.81	0.807	0.698
FMIA	0.011	0.016	0.732	0.774	0.978
Soft palate angulation	0.067	0.059	0.308	0.31	0.278
C3-H-Me	0.219	0.265	0.002	0.023	0.022
Go - Pg	0.269	0.057	0.321	0.324	0.605
ANS-Me(ALFH)/N-Me(ATFH)	0.268	0.026	0.596	0.532	0.657
PNS-U	0.355	0.025	0.614	0.509	0.672
PNS-V	0.754	0.254	0.003	0.018	0.017
H-TB	0.09	0.216	0.009	0.017	0.025
Sbtn-Phwn	0	0.502	0	0	0
Soft palate thickness	0.706	0.062	0.286	0.43	0.409
S-Go/N-Me % #321	0.657	0.058	0.313	0.336	0.299
H perp. MP	0.356	0.322	0.001	0.009	0.007
H perp. C3-Me	0.042	0.392	0	0.008	0.005

Table 9: Multiple comparisons between significant measurements and sites of obstruction groups. P value of significance: P<0.05.

Multiple Comparisons					
Variable	Difference	Mean Difference	95% Confidence Interval		
			Sig.	Lower Bound	Upper Bound
C3-H-Me	RP+Rg - Rt	-6.259	0.309	-16.52	4.002
	RP+Rg - RP	13.476	0.038	0.65	26.302
	Rt - RP	19.735	0.002	6.909	32.56
PNS-V	RP+Rg - Rt	-2.776	0.554	-9.258	3.705
	RP+Rg - RP	-12.032	0.002	-20.134	-3.929
	Rt - RP	-9.255	0.022	-17.357	-1.153
H-TB	RP+Rg - Rt	-6.071	0.114	-13.295	1.154
	RP+Rg - RP	-11.715	0.008	-20.745	-2.685
	Rt - RP	-5.644	0.292	-14.674	3.386
Sbtn-Phwn	RP+Rg - Rt	-3.2	0	-4.481	-1.919
	RP+Rg - RP	-0.69	0.551	-2.291	0.911
	Rt - RP	2.51	0.001	0.909	4.111
H perp. MP	RP+Rg - Rt	-1.212	0.78	-5.593	3.17
	RP+Rg - RP	-9.365	0	-14.842	-3.889
	Rt - RP	-8.154	0.002	-13.63	-2.677
H perp. C3-Me	RP+Rg - Rt	0.729	0.884	-3.023	4.482
	RP+Rg - RP	-8.438	0	-13.128	-3.747
	Rt - RP	-9.167	0	-13.858	-4.476

mandible, a steep mandibular plane, and high upper and lower facial heights. In contrary to those findings, Kurt, et al. [11] found a hypo divergent tendency in the OSA group in comparison to controls.

Sites of obstruction

The comparison of angular and linear measurements using tests of normality for sites of obstruction groups are given in table 7. The significant variables were then tested by: Fisher's ANOVA test; Welch's robust test; and Kruskal-Wallis test as shown in table 8. No statistically significant differences were observed in angular measurements between the three groups except for C3-H-Me. However linear

measurements of soft palate thickness, the distance between the PNS and point V; and the distance between the hyoid and the following: tongue base, mandibular plane and C3-Me were found significant.

For those six variables that we found significant, we did not have equality in significances between the three obstruction sites groups, hence; those variables were compared two by two for further understanding of differences between the groups according to obstruction sites as shown in table 9.

In our study, we have found that the Retrotonsillar group had longer faces in comparison to the Retropalatal group (Retrotonsillar group

Table 10: Intra Class Correlation for reliability of measurements. P value of significance: $P < 0.05$.

ANOVA					
		Sum of Squares	df	Sig.	ICC
Gonial angle	Between Groups	725.983	19	0	0.999516
	Within Groups	0.185	20		
	Total	726.168	39		
H perp. MP	Between groups	1074.181	19	0	0.999794
	Within Groups	0.116	20		
	Total	1074.297	39		

mean: $67.4\text{mm} \pm 5.5$; Retropalatal group mean: $68.8\text{mm} \pm 5.2$) which was in accordance with the findings of Baik, et al. [7].

The findings of the present study revealed that the hyoid bone position was more inferiorly placed in the Retropalatal group (mean: 18.9 ± 6.4) in comparison to the Retropalatal plus Retroglossal group (mean: 10.5 ± 3.4), and Retrotonsillar group (mean: 9.8 ± 4.4), contrary to the findings of Baik, et al. [7] in which inferior position of the hyoid bone was most pronounced in the Retropalatal plus Retroglossal group but was also found in the Retropalatal and Retrotonsillar groups as well.

The Upper airway space assessment demonstrated that it was narrowest in the Retropalatal plus Retroglossal group (mean: $4.5\text{mm} \pm 0.9$) in comparison to Retropalatal group (mean: $5.2\text{mm} \pm 0.6$), and Retrotonsillar group (mean: $7.7\text{mm} \pm 2.2$) which was in accordance to the findings of Baik, et al. [7].

The findings of our research have shown that the tongue base measurement (PNS-V) was significantly lower in the Retropalatal group (mean: $88.5\text{mm} \pm 9.3$) in comparison to the Retrotonsillar group (mean: $79.3\text{mm} \pm 7.5$) and Retropalatal plus Retroglossal group (mean: $76.5\text{mm} \pm 7.3$). The Retropalatal group showed thicker tongue mass (H-TB) than the Retropalatal plus Retroglossal group which was in contrary to the findings of Baik, et al. [2] in which the Retropalatal plus Retroglossal group showed thicker tongue mass in comparison to Retropalatal and Retrotonsillar groups.

Measurements error

The measurements error study was carried out by repeating the tracing and measurements of twenty randomly selected Cephalograms, again at an interval of two weeks. We used Intra Class correlation to test the Gonial angle measurement and H perpendicular C3-Me linear measurement that yielded $ICC=0.99$. Both of these measurements error were statistically insignificant as shown in table 10. Therefore, it can be concluded that no systematic error occurred for landmark identification or cephalometric measurements.

Discussion

The craniofacial anatomical risk factors, mechanism of upper airway compliance and muscle function play a role in OSA. However, many other etiological factors contribute to OSA including anatomic narrowing of the upper airway as a result of alterations in the craniofacial morphology or soft tissue enlargement, sleep posture, age, male gender, nasal obstruction, and adipose tissue in the pharynx have been suggested as etiologies of OSA by Battagel, et al. [17] and Tsai, et al. [10].

A Systematic Review by Guarda-Nardini, et al. [18] on the predictive value of anatomy based parameters in treatment for Obstructive Sleep Apnea with Intraoral Splint Devices have found that the mandibular plane angle and the distance between hyoid bone and mandibular plane have a predictive value for mandibular advancement devices (MAD) effectiveness in OSA patients. However, the relative weak inconsistent cephalometric data suggested that decisions based solely on these factors cannot be recommended and that other risk factors (e.g: age, sex, BMI) should be taken into consideration.

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 non-obese adults.

The relative position of the hyoid bone with both the mandible and vertebra; which is more accurate and easier than using the distance from the hyoid bone to the mandibular plane alone, was used in this study because 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 as was shown by Tsai, et al. [13].

Concerning severity groups; Regression analysis showed that an inferiorly positioned hyoid bone is the most likely to be expected in patients with severe OSA and that the cephalometric variable (H perpendicular C3-Me) is an effective cephalometric indicator of OSA in Non Obese Males.

As for Sites of Obstruction; the Retropalatal plus Retroglossal and Retrotonsillar groups were more prevalent in our OSA sample than Retropalatal obstruction which was not in accordance to the findings of Baik, et al. [7] in which the Retropalatal obstructive type was the most common of all of the obstructive types of OSA.

The results of our study suggest that the Retropalatal and Retroglossal obstructions have to be examined carefully when a patient with OSA presents with a certain level of skeletal Class II tendency. To relieve obstruction at the Retroglossal site, site-specific surgery (reduction of the base of the tongue and other procedures) may be effective. Furthermore, it is hypothesized that mandibular advancement therapy such as therapy with an oral appliance or orthognathic surgery would be effective as advocated by Fujita, et al. [19]. Airway obstruction in patients with OSA may be caused by a lack of airway-dilating muscle activity and tissue compliance against the intraluminal negative pressure and gravity on inspiration. Among the airway-dilating muscles, the geniohyoid, genioglossus, and mylohyoid muscles are the main large muscles. They are attached to the body and symphysis of the mandible, tongue, and hyoid bone. Thus, retrognathia or micrognathia results in posterior displacement of the tongue, an inferior position of the hyoid bone, and narrowing of the airway, which can predispose to the obstruction of the upper airway.

Conclusion

The following conclusions could be drawn:

- The distance from a line from the C3-Me perpendicular to the hyoid bone on lateral cephalometric radiographs may be used as a cephalometric indicator in severe OSA patients and aid in better understanding of the obstruction site mechanism in non-obese Lebanese men. Based on the result of the regression analysis, inferiorly positioned hyoid bone is most likely to be expected in patients with severe OSA.

- The Jarabak facial ratio showed a hyper divergent facial type and increase in the posterior facial height for the two severity groups in comparison with controls.
- The Retrotonsillar group had longer faces in comparison to the Retropalatal group.
- Palate length and thickness were significantly higher with severity of the OSA which was also revealed by our results in the mild to moderate and severe group in comparison to control group
- Retrotonsillar and Retropalatal plus Retroglossal obstruction sites were more prevalent in our sample.
- The two OSA severity groups tongue base was in a more inferior position in relation to control subjects.

Recommendations

Further studies to investigate the effect of the sites of obstruction in OSA on dentofacial morphology is needed with larger number of subjects and using better method design in the localization of obstruction sites.

We suggest that the Retropalatal and Retroglossal obstructions have to be examined carefully when a patient with OSA shows a certain level of skeletal Class II tendency.

Limitations

In regard to the sites of obstruction classification from the cephalometric radiograph; more reliable and powerful methods using MRI or supine Cephalometric imaging could have been used to better determine the site of obstruction since the narrowest portion of the airway on a 2D film in an awake upright subject may not be the same as the actual position of obstruction in a sleeping supine sleep apneic patient.

Another limitation is in the Retrotonsillar group site of obstruction, we did not measure the Palatine Tonsil size rather than the constriction in the area behind the tonsil so that may have not well determined the Tonsillar hypertrophy precisely.

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