ORIGINAL ARTICLE

Predictive Morphometric Model Value Estimation and its Correlation with Severity of Obstructive Sleep Apnoea in a Mixed Indian Population: A Pilot Study

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Abstract

Background: The morphometric model (MM) provides a rapid, accurate and reproducible method for predicting whether patients in an ambulatory setting are at risk for obstructive sleep apnoea (OSA).

Introduction: The aim of this study was to estimate mean MM scores in a mixed Indian population and to investigate its correlation with the severity of OSA as determined by apnoea/hypopnoea index (AHI).

Materials and Methods: A total of 60 subjects were included in the study and were divided into two groups of 30 subjects each; Group 1: Patient group; Group 2: Control group. A comparative cross-sectional study design was employed and MM value as suggested by Kushida *et al*. was estimated by applying their clinical rule. To determine the correlation between OSA severity as indicated by AHI and MM values, linear and multiple regression models were applied.

Results: The comparison of MM values between OSA and non-OSA groups showed an extremely statistically significant difference. There was no significant correlation between the severity of OSA and MM values in this sample of Indian OSA patients.

Conclusions: The results of this study could facilitate the early recognition of OSA and support the available diagnostic setup.

Keywords: Obstructive sleep apnoea, morphometric model, apnoea/hypopnoea index, polysomnography, clinical rule, predictors

Introduction

Even though obstructive sleep apnoea (OSA) is fairly common, it often remains undiagnosed in primary care practice. The failure to recognise the syndrome is in part due to limited availability of diagnostic facilities, which make the patients with OSA heavy users of health care resources, not only at the time of diagnosis, but also for years prior to diagnosis. While overnight polysomnography (PSG) is considered the 'gold standard' for the diagnosis of OSA, the need for accurate, quantitative diagnostic criteria is further supported by the significant cost incurred with routine PSG. However, the lack of a simple, non-invasive, repeatable method has been an obstacle for the early recognition of OSA patients.

Although sleep laboratories have been set up in various centres in India, the availability of this service is

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very limited. The limited number of facilities available restricts the proper identification of OSA and may lead to underestimation of the magnitude of the problem and under-treatment, with undesirable public and personal health consequences. Common symptoms of the condition have limited predictive value in identifying patients with OSA[1]. The morphometric model (MM) is a useful screening test to investigate the possibility of OSA in patients during initial office visits. The most commonly used predictive model is the MM given by Kushida *et al*. of the Stanford Sleep Disorders Clinic and Research Centre, California (hereafter referred to as the Stanford Morphometric Model:SMM), which provides a rapid, accurate and reproducible method for predicting whether patients in an ambulatory setting are at risk for OSA[2]. This clinical MM was tested on Caucasian patients, where it was found that patients with values equal to or more than 70 typically had OSA. There is no data available on the applicability of the predictive model to Indian subjects.

We carried out a pilot study with the aim of estimating mean SMM scores in a mixed Indian population and its correlation with the severity of OSA as determined by apnoea/hypopnoea index (AHI). The results of this study could facilitate the early recognition of OSA and support the available diagnostic setup. Based on the intraoral findings, orthodontists may request a polysomnographic evaluation when OSA is suspected and the final diagnosis of sleep disorder; its severity and the evaluation of comorbidities are made by a physician according to polysomnographic findings.

Materials and Methods

This multi-disciplinary study was undertaken at the Division of Orthodontics and Dentofacial Orthopedics, Armed Forces Medical College, Pune, Maharashtra, India. The research protocols were reviewed and approved by the Institutional Ethical Committee of the Hospital. Informed consent under witness was obtained from each participant at enrolment after each subject was explained the nature and purpose of the study. To detect a clinically significant difference with 80% power, $\acute{a}$=0.05 and a ratio between two groups of 1:1, 60 adult Indians aged 18 years and above were recruited for this study[3]. A comparative cross-sectional study design was employed. The total of 60 subjects included in the study was divided into two groups of 30 subjects each; Group 1: Patient (test) group; Group 2: Control group.

The patient sample (test group) consisted of 30 randomly selected PSG-diagnosed OSA patients referred by the Department of Respiratory Medicine, Military Hospital, Cardio-Thoracic Centre, Pune, India, for the analysis of craniofacial morphology. PSG performed was level I, using a 16-channel polygraph (SleepScan Analysis VISION, Bio-logic Systems Corp, USA). For the purpose of this study, only one variable, the number of apnoeas and hypopnoeas, was utilised. There was no prior knowledge of the patient to be seen and there was no regular pattern of days to examine the patients. For the test group, the patients who satisfied the following criterion were included in the study: aged 18 years and above; polysomnographic evidence of OSA (defined as an AHI of $\geq$ 5/h of sleep); and the presence of at least 10 teeth in each arch.

The control group consisted of 30 randomly selected adults attending the dental outpatient department, with an Angle's Class I molar relation and no history of sleep obstructed breathing. The control group was matched with the patient sample to the best extent possible for age, gender, height and weight. For the control group, the subjects who satisfied the following criterion were included in the study: aged 18 years and above; subjects with Angle's Class I occlusion, Epworth Sleepiness Scale (ESS) score <9 (to exclude daytime sleepiness); no reported snoring by family members and the presence of at least 10 teeth in each arch. Snoring frequency, snoring intensity and ESS were used as a questionnaire for selection of subjects in the control group.

The exclusion criteria for both groups were as follows: edentulous subjects; subjects with hypothyroidism; subjects with history of orthodontic treatment; subjects with history of reconstructive/orthognathic surgery; subjects with craniofacial deformity, such as cleft lip and D or palate; subjects with history of pharyngeal surgery and subjects with patient-specific disorders (such as neuromuscular disorders).

Each of the groups consisted of 19 men and 11 women. Data collection was divided into three sections as follows:

a. Medical and sleep history including an ESS.
b. Clinical examination with anthropomorphic recordings of the subject's height, weight and neck circumference (NC). NC in centimetres was measured with a tape measure, at the level of the cricothyroid cartilage in upright awake subjects. For

each subject, obesity was expressed as body mass index (BMI)[4].

c. Study model analysis: Measurements were taken from the maxillary and mandibular study models using a pair of digital calipers (Workzone, Global tronics GmbH & Co, Germany), with a resolution of 0.01 mm.

Upper and lower dental arch study models were obtained with alginate impression material and dental stone. The following measurements were recorded on the study models[2,5]. All the measurements were carried out by the principal investigator.

1. Maxillary intermolar width (Mx): Distance between the mesiobuccal cusp tips of the crowns of the maxillary right and left permanent first molars (Figure 1).

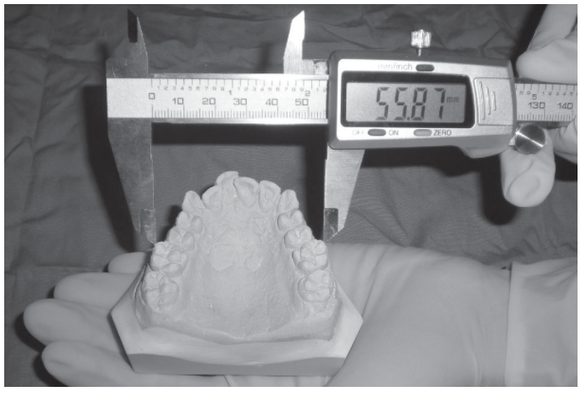


Figure 1: Measurement of maxillary intermolar width on study model.

2. Mandibular intermolar width I (Mn): Distance between the mesiobuccal cusp tips of the crowns of the mandibular right and left permanent first molars (Figure 2).

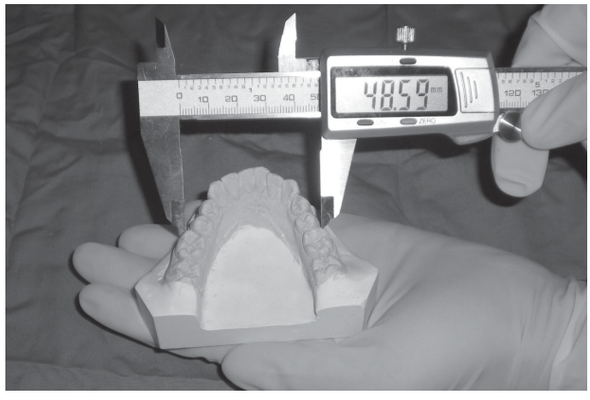


Figure 2: Measurement on mandibular intermolar width on study model

3. Overjet (OJ): Horizontal overlap of the crowns of the maxillary and mandibular central incisors, in millimetres.

4. Palatal height (*P*): To standardise measurement of palatal depth/height, models were trimmed until the distal contact point of the upper first molars showed up on the edge. Distance from the mid-deepest part of the palate to the line connecting the left and right distolingual cusp tips of the upper first molars was taken as palatal depth (Figure 3).

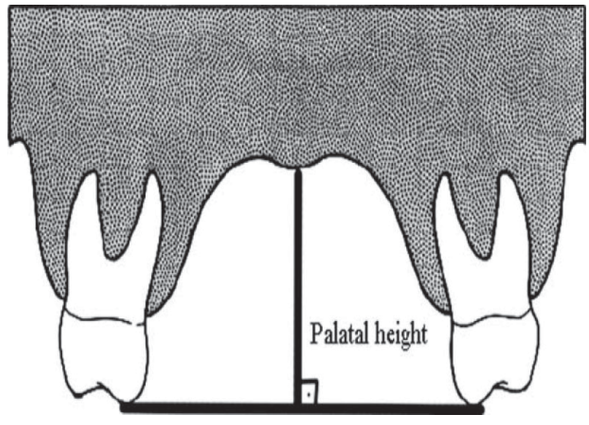


Figure 3: Measurement of palatal height/depth

SMM score was calculated by applying the clinical rule as follows:

$$P+(Mx-Mn)+3xOJ+3x(BMI-25.0)x(NC/BMI)$$

Where *P* is palatal height in millimeters, NC is neck circumference in centimetres, measured at the level of cricothyroid membrane, Mx is distance between the mesial surfaces of the crowns of the maxillary molars in millimeters, Mn is distance between the mesial surfaces of the crowns of the mandibular molars in millimeters, OJ is overjet, horizontal overlap of the crowns of the maxillary and mandibular central incisors in millimeters, BMI is body mass index (kg/m^2).

Data compilation and statistical analysis

The readings were tabulated separately for the OSA (test) group and control group. The measurement of 20 randomly selected casts was repeated on separate occasions with a 2-week interval, for evaluation of intra-operator error. The difference between the first and second measurements was not significant. All measurements obtained in the study were expressed as

mean ± standard deviation (SD). The data was analysed using MATLAB version 1.0 and Excel 2007. To determine the correlation between OSA severity as indicated by AHI and SMM, linear and multiple regression models were applied.

Results

SMM values were calculated for all the subjects. The comparison of MM values between OSA and non-OSA groups showed an extremely statistically significant difference (P<0.0001) with the OSA group having an average MM value of 67.30±11.95, while in the control group it was 55.43±7.80, as shown in Table 1. The results of the regression analysis showed that there was no significant correlation between the severity of OSA as indicated by AHI and SMM value in this sample of Indian OSA patients (Table 1). The line diagram for the distribution of patient's AHI versus the calculated SMM value is depicted graphically in Graph 1, while the scatter plot of AHI against predicted values of SMM is shown in Graph 2.

The average age was 53.6±9.42 years. While the two groups had no significant difference in terms of height, the OSA patients were found to be significantly heavier than control subjects with a resulting statistically significant increase in BMI (P<0.05), as shown in Table 2. The patients in the test group also had a statistically significant increase in NC (P<0.05), when compared to the controls. The NC in the test group ranged from 34 to 45 cm, with an average of 41.11±2.05 cm for men and 37.55±3.53 cm for women. Table 2 presents the mean of general physical examination measurements of the two groups. All patients in the test group had varying degree of OSA, as confirmed by overnight PSG and symptoms of snoring and excessive daytime sleepiness. OSA severity was defined by the AHI. The AHI ranged from 5.6/h to 86.4/h with an average of 42.04±26.14 events per hour. In the test group, the ESS recorded a statistically significant increase (P<0.05) and ranged from 9 to 20 with an average of 13±2.85 events per hour.

The comparison of mean intraoral values between OSA and controls is summarised in Table 3. Overjet was found to be larger in the controls when compared with the OSA sample, but analyses failed to detect statistically significant differences (P>0.05). Statistically significant differences were found between the groups for the measurements of palatal height/depth (P<0.05).

Table 1

Sl No	Parameter	Patients with OSA (Test Group; n=30)	Patients without OSA (Control Group; n=30)	P-value (<0.05)
1	Age, years	53.6±9.42	53.6±9.422	—
2	ESS score	13(±2.85)	3.26(±0.94)	<0.0001*
3	Weight, kg	80.10(±12.5)	67.13(±6.78)	<0.0001*
4	Height, m	1.64(±0.01)	1.64(±0.09)	1
5	Body mass index, kg/m^2	29.47(±4.57)	24.84(±1.87)	<0.0001*
6	Neck circumference, cm	39.80(±3.16)	36.10(±2.59)	<0.0001*
7	Maxillary intermolar distance, mm	53.05(±3.57)	51.58(±3.26)	<0.01*
8	Mandibular intermolar distance, mm	46.51(±3.93)	44.48(±2.87)	0.208
9	Palatal height, mm	24.1(±1.74)	20.75(±2.01)	<0.05*
10	Overjet, mm	1.97(±1.92)	2.80(±1.76)	0.086
11	AHI, eventsper hour	42.04(±26.14)		
12	Morphometric model value	67.30(±11.95)	55.43(±7.80)	<0.0001*
13	Corelation between AHI and SMM			0.209

AHI: apnoea/hypopnoea index, ESS: Epworth Sleepiness Scale, OSA: obstructive sleep apnoea, SMM: Stanford Morphometric Model.

**P≤0.05=statistically significant.*

Table 2: Comparison of mean of general physical characterstics between test and control groups

S no	Parameter	Test group (n=30)		Control group (n=30)		df (n-1)	P-value (<0.05)
		Mean	SD	Mean	SD		
1	Ht in m	1.64	0.01	1.642	0.09	29	1
2	Wt in kg	80.1	12.5	67.13	6.78	29	<0.0001*
3	BMI (kg/m^2)	29.47	4.57	24.84	1.87	29	<0.0001*
4	NC in cm	39.8	3.16	36.1	2.59	29	<0.0001*
5	ESS	13	2.85	3.26	0.94	29	<0.0001*
6	AHI	42.04	26.14			29	

AHI: apnoea/hypopnoea index; BMI: body mass index;
ESS: Epworth sleepiness scale; Ht: height; NC: neck circumference; Wt: weight .
**P≤0.05=statistically significant.*

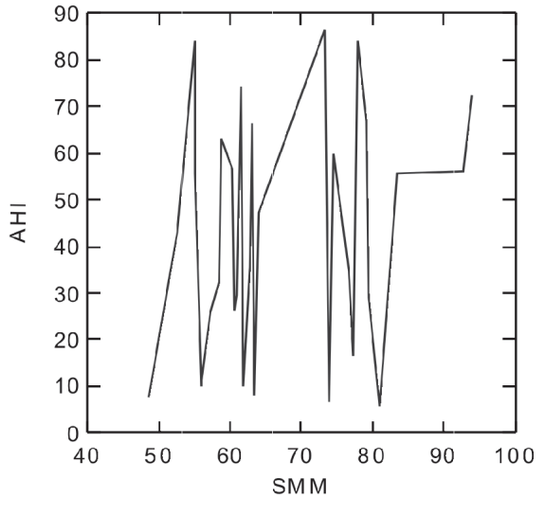
Table 3: Comparison of mean of intraoral measurements between test and control groups

S no	Parameter	Test group (n=30)		Control group (n=30)		df (n-1)	Regression coefficient	P-value (<0.05)	R-value (<0.01)
		MEAN	SD	MEAN	SD				
	Column1	Column2	Column3	Column4	Column5	Column6	Column7	Column8	Column9
1	Mx	53.05	3.57	51.58	3.26	29	0.061	<0.05*	<0.01**
2	Mn	46.51	3.93	44.48	2.87	29	-1.875	0.208	≥0.01
3	OJ	1.97	1.92	2.8	1.76	29	0.06	0.086	≥0.01
4	P	24.1	1.74	20.75	2.01	29	0.043	<0.05*	<0.01**

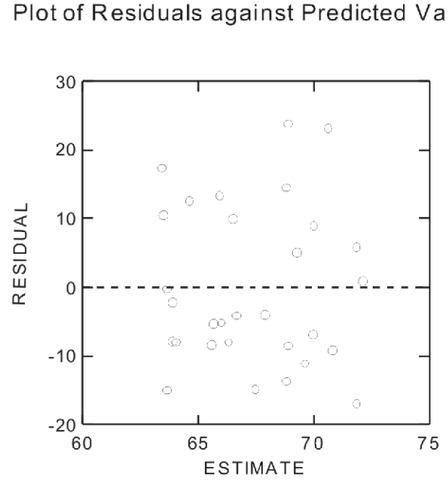
Mn: mandibular intermolar width; Mx: maxillary intermolar width; OJ: overjet;
P: depth of palate
**P ≤ 0.05=statistically significant.*
***R < 0.01=statistically significant.*

Discussion

Sleep problems are common among primary care patients. The ability to identify patients at risk for OSA in a busy primary care setting is difficult. A study conducted in an Indian population estimated the prevalence of sleep-disordered breathing (SDB) among middle-aged urban Indian men to be at 19.5% and that of obstructive sleep apnoea–hypopnea syndrome (SDB with excessive daytime sleepiness), to be 7.5%[6].



Graph 1: Line diagram for the distribution of patient's AHI versus calculated Stanford Morphometric Model values



Graph 2: Scatter plot of AHI against predicted values of Stanford Morphometric Model

On comparing the SMM values in this pilot study, we have been able to demonstrate statistically significant differences between the two groups. The comparison of MM values between OSA and non-OSA groups showed a highly statistically significant difference, with the OSA group having an average SMM value of 67.30, while in the control group it was 55.43. Kushida *et al*. have stated in their paper that, similar to other predictive models, the SMM is useful to screen and identify the more severe cases; these patients may then be prioritised for treatment. Furthermore, the authors also maintained the importance of PSG as an adequate tool for diagnosis. The average MM value in this sample of Indian OSA patients is only slightly lesser than that observed by Kushida *et al*. who found that patients with values equal to or more than 70, typically had OSA[2]. The fact that the populations under our study group and in the study by Kushida *et al*., belong to different origins (Indian and North-Americans) and that there was no standardisation to account for ethnicity may explain the differences between both studies.

The results of the linear and multiple regression analysis indicate that there is no significant correlation between OSA severity as indicated by AHI and the values of SMM in this sample of Indian OSA patients. Although there was a significant difference between the groups, we were unable to establish a cutoff point according to disease severity, as the values were very similar and did not increase linearly from the non-apnoeic to the mild, moderate and severe OSA groups. However, 13 (43%) of the 30 test subjects showed an increase in AHI value with increase in their predictive MM value.

Many studies have been done assessing craniofacial characteristics in OSA patients using cephalometrics, computed tomography, magnetic resonance imaging and acoustic reflection. Although there is controversy in the results, craniofacial alterations most closely related to the occurrence and severity of OSA are: retroposition of the maxilla, shortening of the mandibular body, inferiorly displaced hyoid bone, retrognathism, dental occlusion class II and narrow, arched hard palate[7,8].

Different clinical prediction rules have been described in the literature. Scientists have used various factors to predict a person's risk of having OSA, based on their demographics, symptoms and BMI. Using these factors, scientists have been able to correctly identify 76% to 96% of patients who have OSA and 13% to 54% of patients who do not have OSA[9]. A comprehensive comparative effectiveness review carried out by the US Department of Health and Human Services has concluded that of the available models, the MM by Kushida *et al*. gave near perfect discrimination between OSA and non-OSA subjects[10].

No data are available on the applicability of the predictive SMM in patients with OSA from the Indian subcontinent and a Medline search confirms that this is the first study evaluating the correlation between SMM values and the severity of OSA, from this country. There has been only one previous Indian study in which a

diagnostic model was derived and validated for the prediction of OSA in subjects presenting with non-sleep-related complaints[11]. In the previous study carried out at a tertiary care centre, gender, relative-reported snoring index and choking index were found to be significant, independent predictors of OSA. The results of the present study indicate that the relatively easier morphometric measurements afforded by the SMM, enable faster screening for OSA in a primary health care setting. Other studies worldwide have also validated the applicability of SMM in identifying OSA in clinical practice, with the separation value between subjects with or without OSA being 70[12,13].

A level I overnight PSG is considered the gold standard in the diagnosis of sleep apnoea. The PSG device used in this study meets the requirements of the consensus statement of the American Thoracic Society (1996). Plaster study models were used for the intraoral measurements in this study, since they are a standard component of orthodontic records and they are fundamental to diagnosis and treatment planning, case presentations, evaluation of treatment progress and results, besides record keeping[14]. The dental arch dimensions were measured on study models made of dental stone, by means of digital vernier callipers. Compared to dividers, studies have shown that by using sliding manual/digital vernier callipers, accurate measurements could be made from the study models in all three dimensions[15]. Although some new methods like geometric morphometrics provide excellent possibilities for morphological analysis, distance measurements on dental casts were calculated because most clinicians are familiar with the method used in this study.

In the present study, statistically significant differences were found between the two groups for the measurements of palatal height/depth ($P<0.05$) with the mean palatal depth in patients being greater than the mean palatal depth of the controls. The method used by Kushida *et al*. and in subsequent studies for measurement of palatal depth was found to be subjective and difficult to standardise for a large group. A new method for measurement of palatal depth was resorted to, because it is difficult to measure palatal depth with 20° mouth opening and from the dome of the tongue in all cases. In order to standardise the measurement of palatal depth in this study, the study models were trimmed until the distal contact point of the upper first molars showed up on the edge. Distance from the mid-deepest part of the palate to the line connecting the left and right distolingual cusp tips of the upper first molars was taken as palatal depth.

The minimum age of the subjects in this study was chosen on the basis of previous studies, which have reported that molar and canine arch widths do not change after 13 years of age in females and 16 years of age in males[16]. Therefore, it was assumed that the arch widths of the subjects studied were fully developed. The strength of the present study is the inclusion of a relatively large group of Indian patients with OSA, who underwent a limited hospital-based sleep study, matched with control subjects for age and gender. This study highlights the importance of matching subjects for age to prevent any age-related morphological changes from confounding the results.

Study limitations

This is a cross-sectional study based on enrolment of patients attending one hospital clinic. As expected, the patients in this study only represent at best the patients attending this clinic. Further research is necessary to generalise the results to the general population and other ethnicities. Another limitation of this study was that PSG was not carried out for the controls, due to ethical considerations and the prohibitive expense of the procedure. This is usually the case with studies incorporating normal controls who do not exhibit any symptoms of OSA.

Conclusion

1. There is no significant correlation between OSA severity as indicated by AHI and the SMM values in this sample of Indian OSA patients.
2. The SMM proposed by Kushida *et al*. is applicable to the selected sample in clinical practice.
3. The average predictive MM value for OSA in this sample of Indian patients is only slightly lesser than that observed by Kushida *et al*.

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