

Comparative evaluation of craniofacial anthropometric measurements in Indian adult patients with and without obstructive sleep apnea: A pilot study

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Abstract

Aims: The study aimed to compare the craniofacial features of North Indian patients suffering from obstructive sleep apnea (OSA) to that of normal North Indian population.

Materials and Methods: Selected 25 North Indian subjects (age: 18–65 years) were divided into two groups (OSA group [$n = 14$] and non-OSA group [$n = 9$]) according to the results of full night polysomnographic sleep study. Body mass index (BMI), neck circumference (NC), and lateral cephalograms were recorded for each subject in both groups and total 22 parameters of craniofacial anthropometric features were measured on lateral cephalograms for each subject. The differences in BMI, NC, and craniofacial features between the OSA and non-OSA groups were compared statistically.

Results: Independent sample *t*-test was used to compare the differences between OSA group and non-OSA group. The results showed that the BMI, NC, bulk of tongue (tongue length, tongue height, and tongue area) and length of the soft palate (PNS-U) were significantly higher in OSA group. OSA group was also found to have inferior positioning of hyoid bone (MP-H, ANS-H, PNS-H, ANS-Eb), narrower superior and middle airway space (SPAS and MAS), antero-inferior positioning of mandible (Gn-C3, ANS-Me, SNB, N-Me) and lower cranial base flexure angle (N-S-Ba).

Conclusion: Craniofacial features, which play an important role in the pathophysiology of OSA, differ significantly between North Indian patients suffering from OSA and normal North Indian population.

Key Words: Body mass index, craniofacial features, lateral cephalogram, neck circumference, obstructive sleep apnea

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Received: 5th April, 2015, **Accepted:** 11th June, 2015

INTRODUCTION

Sleep-disordered breathing is a series of disorders ranging from primary snoring to severe obstructive sleep apnea-hypopnea

syndrome (OSAHS). The OSAHS is characterized by recurring episodes of upper airway obstruction during sleep, leading to markedly reduced (hypopnea) or absent (apnea) airflow at the nose/mouth leading to sleep fragmentation.^[1] It is thought to be due to varying combinations of anatomical and neuromuscular factors resulting in complete or partial obstruction of the airway.

Obstructive sleep apnea is a common disorder with variable prevalence rates among different ethnic populations. A community-based study of Chinese population showed an overall prevalence rate of 20.4%.^[2] A community-based

Access this article online	
Quick Response Code:	Website: www.j-ips.org
	DOI: 10.4103/0972-4052.161567

study of sleep apnea among middle-aged Chinese men in Hong Kong using full polysomnography demonstrated an estimated prevalence of OSA at 4.1%.^[3] Similar study in middle-aged Chinese women in Hong Kong demonstrated an estimated prevalence of OSA at 2.1%.^[4] A community-based study of OSA with fully supervised PSG showed overall prevalence rate of 13.74% (19.7% in men, 7.4% in women) in North-Indian population.^[5] However, a similar study in the same population showed overall prevalence rate of OSA 9.3% (13.5% in men, 5.6% in women).^[6] A hospital-based study of OSA with unsupervised PSG found the prevalence rate of 19.5% in middle-aged urban Indian men.^[7] Snoring is even more common affecting 40–60% of adults.^[8] OSA is characterized by increased effort of respiration, reduced blood oxygen saturation and frequent disturbances in normal sleep and arousals during sleep. Snoring, excessive daytime sleepiness, early morning headaches, impaired concentration, social impairments, systemic and pulmonary hypertension, traffic and work-related accidents, ischemic heart disease, and cerebrovascular disease, are often associated with this syndrome.^[9,10] Severity of OSA can be assessed by Apnea/Hypopnea Index (AHI). AHI is calculated by overnight polysomnography analysis. AHI <5 events/h, is considered to be normal. OSA can be classified as mild (AHI = 5–15 events/h), moderate (AHI = 15–30 events/h), and severe (AHI = more than 30 events/h).^[11] The pathogenesis of this syndrome is still not entirely clear. During sleep, tongue base contacts the posterior pharyngeal wall and occludes the upper airway partially or completely. Further, relaxation of the genioglossus and pharyngeal muscles leading to diminution of upper airway dilator muscle activity, which counteracts the negative intra-luminal pharyngeal pressure during sleep may result in pharyngeal collapse and obstruction in patients with OSA.^[11] However, this mechanism depends on the morphology of craniofacial skeleton and oro-facial musculature.

Many other studies have also found that the interrelationship of craniofacial morphology and muscle function of the upper airway is important in the understanding pathogenesis behind OSA.^[12] Different ethnic groups have significant differences in craniofacial as well as general body skeletal and soft tissue features. These ethnic differences in craniofacial morphology greatly affect airway dimensions and consequently AHI. Brachycephaly is associated with an increased AHI in Caucasians, but not in Afro-Americans.^[13] Asian males are less obese despite the presence of severe OSA as compared to Caucasian males.^[14] Craniofacial morphology differences have also been noted among OSA-subjects of three major ethnic populations in Asia.^[15]

Since craniofacial features differ among ethnic populations, specific characteristics for each population might suggest the

risk for OSA in concerned ethnic population and requires further diagnostic interventions for definitive diagnosis of OSA. Thus, craniofacial features being important risk factor for OSA should be investigated intra-ethnically as well. Hence, the aim of this study was to compare the difference in the craniofacial features of North Indian patients with OSA and non-OSA subjects.

MATERIALS AND METHODS

Totally 25 North Indian subjects in the age group of 18–65 years were included in this cross-sectional study through simple random sampling representing general population of the above-mentioned age group as OSA is prevalent in middle-aged population.

Exclusion criteria

- Subjects with psychiatric illness and taking central nervous system (CNS) depressants
- Subjects who consumed alcohol (not avoided it for at least 1 week prior to the overnight sleep study)
- Subjects who had uncontrolled systemic disease
- Subjects with craniofacial anomalies associated with syndromes, such as Crouzon syndrome, Apert Syndrome, Treacher–Collins Syndrome
- Subjects who were snorers only or who had mixed sleep apnea (which includes CNS component in the pathophysiology of sleep apnea).

Informed consent was obtained from the patients and ethical approval was obtained from Institutional Ethical Committee. Poststratification of the sample population was done using polysomnographic analysis to divide the population in OSA group and non-OSA group.

Polysomnographic analysis

All subjects underwent full night polysomnography sleep study (S-7000, Cogent technologies, EMBLA System Inc., UK), which includes electroencephalograms, (C3-A2, C4-A1, O2-A1, O3-A2), Bilateral Electro-oculogram (ROC, LOC), Chin and Leg Electromyogram, Nasal airflow, thoracic and abdominal movements, electrocardiogram, O₂ saturation measured by finger pulse oximeter and body position recorders. AHI was calculated with the help of Somnologica Studio Software (EMBLA System Inc., UK). The apnea episodes were defined as complete cessation of airflow for ≥ 10 s, and hypopnea was defined as a $\geq 50\%$ reduction in oro-nasal airflow accompanied by a reduction of at least 4% oxygen saturation calculated by pulse oximetry. Apnea events were classified as obstructive, mixed, or central, according to the presence or absence of breathing efforts with thoraco-abdominal movements. AHI was determined by the frequency of these

events per hour during sleep time based on the results of the overnight polysomnography. Recorded polysomnographic data were cross-checked manually for scoring of sleep stages, apnea and hypopnea events regarding each subject. Two subjects with mixed sleep apnea were excluded from this study.

Based on AHI calculated from polysomnography, subjects were divided in two groups: OSA group – AHI >5 (14 subjects) and non-OSA group – AHI <5 (9 subjects). The body mass index (BMI) was calculated in kg/m², and neck circumference (NC) was measured at the level of the thyroid cartilage.

Cephalometric analysis

The polysomnography was followed by taking lateral cephalograms (Gendex Digital System, Hamburg, Germany) utilizing standardization parameters. Each lateral cephalogram was taken with the Frankfort Horizontal Plane oriented parallel to the floor and teeth in maximum intercuspation. To standardize the position of the hyoid bone, the patient was requested to inhale slowly and then exhale just before exposing the film. All the cephalograms were analyzed by a single observer in the morning (between 9 am and 11 am). Due care was taken to conceal participant identity to prevent future observer bias. Landmarks and reference lines were then drawn on acetate tracing sheets for taking linear, angular and areal measurements. Cephalometric analysis was performed by plotting soft tissue and hard tissue landmarks [Table 1, Figures 1 and 2].

Statistical analysis

Statistical analysis was performed using the Statistical Package for Social Services version 12.0 software (SPSS Inc., Chicago, Illinois, USA). Independent sample *t*-test was used to compare craniofacial differences between the OSA and non-OSA groups. The level of significance was set at 0.05.

RESULTS

Body mass index and NC are the parameters of outmost importance when considered as screening parameters for diagnosis of OSA. BMI and NC were found to be significantly higher in OSA group when compared to non-OSA group ($P < 0.001$) [Table 2].

Higher tongue volume being a cause of obstruction for airway is significant risk factor for OSA. Thickness (tongue height) and length (tongue length) of tongue were found to be significantly higher in OSA group ($P = 0.006$, <0.001 , respectively). Furthermore, total tongue area (TA) was also found to be higher in OSA group ($P = 0.001$) [Table 3].

OSA group also have significantly less antero-posterior dimension of superior airway space (SPAS), and middle airway

Table 1: Cephalometric landmarks

Landmark	Interpretation
A	A point on the concavity between ANS and the lowest point in the alveolar bone overlying maxillary incisors
B	A point on the anterior concavity of mandibular symphysis
Ba	The median point on the anterior margin of foramen magnum, located by following the image of slope of inferior border of basilar part of occipital bone
N	The innermost point on the concavity between frontal and nasal bones
ANS	The most anterior point of the ANS
PNS	Located at intersection of continuation of the pterygopalatine fossa and the floor of the nose. It marks the posterior limit of maxilla
S	The center of pituitary fossa of sphenoid bone
H	The most superior point on anterior surface of H bone
Gn	The most antero-inferior point on the contour of symphysis
Go	A constructed point at intersection of ramus and MP
Ar	The point of intersection of the images at the posterior border of condylar process of mandible and inferior border of the basilar part of occipital bone
Me	The lowest point on symphysis of mandible
MP	Line joining points Go and Gn
Eb	Most antero-inferior point of the epiglottic fold
U	Tip of the U
T	Tip of the tongue
H	The most antero-superior point of the H bone
C3	The most antero-inferior point of the third vertebral corpus
SNA	Angle between lines joining S to N and N to point A
SNB	Angle between lines joining S to N and N to point B
ANB	Angle between lines joining point A to N and N to point B
PNS-ANS (mm)	Linear distance between ANS and PNS
Go-Me (mm)	Linear distance between Go and Me
Ar-Go (mm)	Linear distance between Ar and Go
MP-H (mm)	Linear distance between MP and H
ANS-H (mm)	Linear distance between ANS and H
ANS-Eb (mm)	Linear distance between ANS and Eb
Gn-C3 (mm)	Linear distance between Gn and C3
PNS-H	Linear distance between PNS and H
N-Me	Linear distance between N and Me
ANS-Me	Linear distance between ANS and Me
N-S-Ba (°)	Angle of line joining N and S and S to Ba
PNS-U	Linear distance between PNS and Tip of U
TGL (mm)	Linear distance between T and Eb
TGH (mm)	Maximum height along perpendicular line of T-Eb
TA (mm ²)	Triangle area constructed TGL as the base and TGH as the height
SPAS (mm)	Width of the airway behind the soft palate along parallel line to Go-B line
MAS (mm)	Width of the airway along parallel line to Go-B line through the soft palate tip
IAS-1 (mm)	Width of the airway along Go-B line
IAS-2 (mm)	Width of the airway along parallel line to Go-B line through C3

Ba: Basion, N: Nasion, ANS: Anterior nasal spine, PNS: Posterior nasal spine, S: Sella, H: Hyoid, Gn: Gnathion, Go: Gonion, Ar: Articulare, Me: Menton, MP: Mandibular plane, U: Uvula, TGL: Tongue length, TGH: Tongue height, SPAS: Superior airway space, MAS: Middle airway space, IAS: Inferior airway spaces, TA: Tongue area, Eb: Vallecula

space (MAS) when compared to non-OSA group ($P < 0.001$), but the difference between inferior airway spaces (IAS-1 and IAS-2) was found to be insignificant [Table 3].

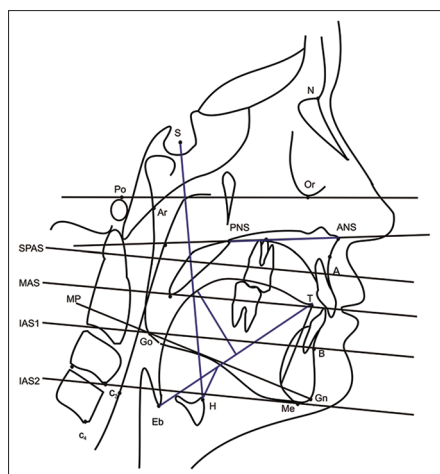


Figure 1: Cephalometric landmarks – soft tissue

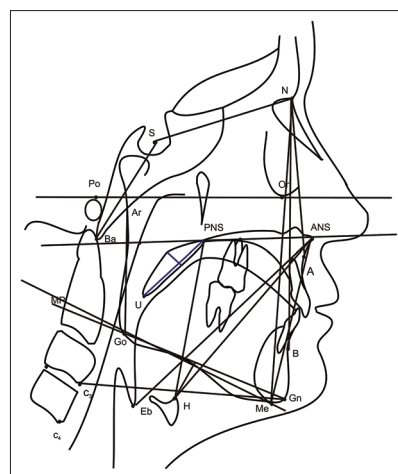


Figure 2: Cephalometric landmarks – hard tissue

Table 2: Comparison of BMI and NC measurements between groups

Parameter	Group	n	Mean	SD	SEM	Mean difference	P
BMI (kg/m ²)	OSA	14	30.61	3.74	1.00	6.47	<0.001
	Non-OSA	9	24.13	1.78	0.59		
NC (inch)	OSA	14	16.28	1.26	0.34	2.71	<0.001
	Non-OSA	9	13.57	0.78	0.26		

BMI: Body mass index, SD: Standard deviation, SEM: Standard error of mean, NC: Neck circumference, OSA: Obstructive sleep apnea

Table 3: Comparison of soft tissue variables between groups

Parameter	Group	n	Mean	SD	SEM	Mean difference	P
TGL	OSA	14	84.93	9.13	2.44	9.71	0.006
	Non-OSA	9	75.22	2.82	0.94		
TGH	OSA	14	37.00	6.27	1.67	9.00	<0.001
	Non-OSA	9	28.00	3.16	1.05		
TA (mm ²)	OSA	14	1590.96	419.70	112.17	539.29	0.001
	Non-OSA	9	1051.67	109.86	36.62		
SPAS	OSA	14	4.07	1.49	0.40	-8.26	<0.001
	Non-OSA	9	12.33	1.94	0.65		
MAS	OSA	14	4.86	1.56	0.42	-4.25	<0.001
	Non-OSA	9	9.11	2.32	0.77		
IAS-1	OSA	14	7.29	1.27	0.34	-1.60	0.077
	Non-OSA	9	8.89	2.85	0.95		
IAS-2	OSA	14	9.21	1.37	0.37	-2.90	0.099
	Non-OSA	9	12.11	6.11	2.04		

All the dimensions are in mm unless specified. SD: Standard deviation, SEM: Standard error of mean, OSA: Obstructive sleep apnea, TGL: Tongue length, TGH: Tongue height, SPAS: Superior airway space, MAS: Middle airway space, IAS: Inferior airway spaces, TA: Tongue area

Position of the hyoid bone was also found to be significantly lower in OSA group (MP-H, ANS-H, PNS-H, ANS-Eb) ($P < 0.001$). OSA group patient also showed infero-posterior position of mandible when compared to non-OSA group (Gn-C3, ANS-Me [$P < 0.001$] and SNB, N-Me [$P = 0.043$ and $P = 0.005$, respectively]) [Table 4].

When compared to OSA group, length of soft palate (PNS-U) was found to be shorter in non-OSA group ($P < 0.001$). The cranial base flexure angle (N-S-Ba) was significantly lower in

OSA group when compared to non-OSA group ($P < 0.001$). Patients in OSA group had significant posterior positioning of maxilla and mandible with reference to cranium ($P = 0.031$ and $P = 0.043$, respectively). In contrast, antero-posterior position of mandible with reference to maxilla did not differ significantly ($P = 0.0332$) [Table 4].

DISCUSSION

Due to increase in number of patients suffering from OSA and lack of awareness about the disease, the screening of such patients in day to day medical as well as dental practice is very essential to tackle this life-threatening disease. There are certain craniofacial features, which are different in individuals suffering from OSA when compared to normal population. Identifying such patients through the knowledge of these features can help a practitioner identify them and treat them in an appropriate way. However, these craniofacial features vary from one ethnicity to another. So, these features should be studied by comparing individuals suffering from OSA to the normal individuals. Indian population differs significantly from other ethnic populations in craniofacial features.^[15]

Body mass index and NC are the basic parameter of obesity, which is most commonly related to OSA.^[16,17] Obesity is a common factor associated with OSA and it is more prevalent in Caucasian population. Although higher BMI is related to apnea severity in Asian population also, correlation between BMI and apnea severity is weaker in the Asian population.^[3] The results of this study demonstrate that BMI and NC were significantly higher in this Indian OSA group than in the non-OSA group. In the supine position, the tongue fall back posteriorly and obstruct the hypopharyngeal space.^[11,18] Furthermore, relaxation of tongue musculature during sleep significantly increases this back-fall of tongue. Severity of obstruction of airway depends on bulk of tongue and amount of relaxation

Table 4: Comparison of hard tissue variables between groups

Parameter	Group	n	Mean	SD	SEM	Mean difference	P
ANS-PNS	OSA	14	53.50	3.84	1.03	-0.83	0.571
	Non-OSA	9	54.33	2.50	0.83		
Go-Me	OSA	14	75.29	3.89	1.04	2.06	0.254
	Non-OSA	9	73.22	4.47	1.49		
Ar-Go	OSA	14	56.29	6.11	1.63	1.40	0.715
	Non-OSA	9	54.89	11.99	4.00		
MP-H	OSA	14	27.29	6.65	1.78	16.40	<0.001
	Non-OSA	9	10.89	2.47	0.82		
ANS-H	OSA	14	99.43	8.62	2.30	15.87	<0.001
	Non-OSA	9	83.56	2.70	0.90		
ANS-Eb	OSA	14	110.79	10.57	2.82	17.56	<0.001
	Non-OSA	9	93.22	3.03	1.01		
Gn-C3	OSA	14	98.43	7.13	1.91	23.43	<0.001
	Non-OSA	9	75.00	8.94	2.98		
SNA	OSA	14	82.14	1.96	0.52	-2.08	0.031
	Non-OSA	9	84.22	2.33	0.78		
SNB	OSA	14	79.36	1.45	0.39	-1.64	0.043
	Non-OSA	9	81.00	2.24	0.75		
ANB	OSA	14	2.79	1.31	0.35	-0.66	0.332
	Non-OSA	9	3.44	1.88	0.63		
PNS-H	OSA	14	75.00	7.32	1.96	17.56	<0.001
	Non-OSA	9	57.44	4.64	1.55		
N-Me	OSA	14	119.43	7.49	2.00	8.65	0.005
	Non-OSA	9	110.78	4.47	1.49		
ANS-Me	OSA	14	74.00	6.46	1.73	13.89	<0.001
	Non-OSA	9	60.11	3.48	1.16		
N-S-Ba (°)	OSA	14	117.57	7.86	2.10	-11.10	0.001
	Non-OSA	9	128.67	5.36	1.79		
PNS-U	OSA	14	46.29	6.01	1.61	10.06	<0.001
	Non-OSA	9	36.22	3.77	1.26		

All the dimensions are in mm unless specified. SD: Standard deviation, SEM: Standard error of mean, OSA: Obstructive sleep apnea, ANS: Anterior nasal spine, PNS: Posterior nasal spine, Gn: Gnathion, Go: Gonion, Ar: Articulare, Me: Menton, MP: Mandibular plane, H: Hyoid, Eb: Vallecula, U: Uvula, S: Sella, Ba: Basion, N: Nasion

of tongue musculature. Bulk of tongue being a cause of obstruction for airway has a significant effect on apnea severity. The study showed significantly longer length and thickness of tongue in OSA group patients resulting in narrow airway space. These features of tongue are closely related to increase in BMI and NC.^[19]

The OSA patients in this study showed significantly longer soft palate, which occupied more space in the oropharyngeal area. Studies had indicated that continuous vibration of the soft palate during snoring leads to continuous trauma and causes mucosal edema, further reducing upper airway patency.^[20] The increased muscular stiffness of the soft palate suggests that its tissues undergo morphological and functional changes, supported by the histological findings of the uvular and soft palate muscles in snoring and apneic patients obtained at biopsy following uvulopalatopharyngoplasty.^[20] Antero-posterior as well as lateral dimensions of airway are one of the most important predictors of apnea severity. It also helps to identify the subjects with increased OSA risk as well as to select the most appropriate modality of treatment, especially for surgical procedures.^[21] Within limitations of the study, OSA group

also have a significantly less antero-posterior dimension of SPAS and MAS when compared to non-OSA group. Lateral dimensions of the airway space can be further evaluated in three-dimensional (3D) imaging techniques like computed tomography (CT), cone beam computed tomography (CBCT), magnetic resonance imaging (MRI), etc.

The hyoid bone in OSA patients was more inferiorly and posteriorly positioned as compared to non-OSA group thus encroaching onto airway space significantly. As the hyoid bone serves for anchorage of tongue muscles, infero-posterior displacement of hyoid pulls the muscles of the tongue into a downward and backward position resulting in a greater tongue mass in OSA patients.^[13-15] Wong *et al.* found that the hyoid bone was located more posteriorly in Chinese OSA subjects when compared with Malays and Indians.^[15]

An acute cranial base angle decreases the antero-posterior length of pharynx and will cause anterior displacement of posterior pharyngeal wall leading to obstruction of airway.^[22] This study also showed a more acute cranial base flexure angle (N-S-Ba) as well as narrower upper and MASs in OSA subjects than the non-OSA group. Because the upper airway is a soft tube without bony support, any changes in the cross-sectional area and radius of curvature can affect the dimensions of the upper airway.^[23] The result of the present study showed that the angle between the anterior and posterior segments of the cranial base was diminished resulting in the cervical spine at C3 level and posterior pharyngeal wall being further forward, thus reducing the space available for the airway.

Significant posterior positioning of mandible, as well as maxilla, was observed in OSA group suggesting posterior positioning of tongue hyoid complex.^[24] Maeda *et al.* found the same while comparing obese and nonobese Japanese OSA patients.^[25] They also noted a decreased bony pharynx width, which might reflect a posterior positioning of the maxilla and mandible. Lower facial height may also increase with increased facial convexity suggesting inferior and posterior placement of hyoid bone and base of tongue in OSA patients. This leads to narrowed bony inlet of the pharyngeal airway representing an inherent risk factor for the development of airway obstruction.^[26] Sforza *et al.* found no significant differences in lower and total facial heights between obese and nonobese OSA patients of the same height.^[27] This may provide a mean to reposition the maxilla and mandible with help of orthodontics and orthopedics and resolve the problem of airway narrowing to a great degree.

The study has limited sample size and has utilized lateral cephalogram as tool for evaluation of craniofacial dimensions. Lateral cephalometry provides only two-dimensional views. Further studies with large sample size using CT, CBCT, and

MRI are required for 3D information of the craniofacial features.

Moreover, until date there are no established guidelines for appliance selection for an individual OSA patient. Further studies comparing efficacy of different oral appliances for management of OSA for patients with different craniofacial features may enlighten the criteria for appliance selection for patient with particular craniofacial feature and help dental sleep medicine specialist to establish an individualized approach in management of OSA.

CONCLUSION

Within limitations of the study, Indian OSA subjects had significant hard and soft tissue differences when compared with non-OSA subjects. Thus, craniofacial abnormalities play a significant role in the pathogenesis of OSA. A thorough knowledge of these features can play an important role in understanding the complex pathophysiology of OSA and can help in appliance selection for a particular patient.

- North Indian OSA patients have higher BMI, NC and TA than normal individuals have
- North Indian OSA patients have inferiorly positioned hyoid bone, longer soft palate and acute cranial base flexure angle when compared to normal individuals
- North Indian OSA patients have constricted upper and MAS
- North Indian OSA patients have posteriorly positioned maxilla and mandible than normal North Indian population.

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How to cite this article: Dubey A, Upadhyay S, Mathur S, Kant S, Singh BP, Makwana R. Comparative evaluation of craniofacial anthropometric measurements in Indian adult patients with and without obstructive sleep apnea: A pilot study. *J Indian Prosthodont Soc* 2015;15:331-6.

Source of Support: Nil, **Conflict of Interest:** None declared.