THE RELIABILITY OF 3D CBCT IN ASSESSING THE AIRWAY VOLUME AMONG PATIENTS WITH CLASS III MALOCCLUSION

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KEYWORDS

CBCT, Class II malocclusion, Class III malocclusion, Nasopharyngeal airways, Oropharyngeal airways

ABSTRACT

Introduction: The pharyngeal airways play an important role in respiration, deglutition, phonation and important in the growth and development of craniofacial skeleton. Alteration in the craniofacial skeleton leads to obstruction of pharyngeal airway which leads to class II and class III malocclusion. Thus the aim of the present study was to evaluate the impact of 3D CBCT to assess class III malocclusion on oropahrygneal and nasopharyngeal airways.

Materials and methods: The cross sectional, prospective study was conducted on a total 60 patient was divided into 2 groups. Group A comprised of 30 patients with class I and group B 30 patients with class III malocclusion. The patients were in the age range of 20-35yrs with BMI 18.5-29.9. The images of pharyngeal airway spaces were recorded using CBCT and or Oropharyngeal airways (OPV), Nasopharyngeal airways (NPV), vertical height of oropharynx (HOP), Constricted minimum axial area (CMinAx), and Constricted posterior airway space (CPAS) were measured. The difference between the two groups was determined by using ANOVA test and the correlation of variables were assessed using Pearson's correlation.

Results: OPV in class I was 829±1786.59 and in class III was 10941.43±2863.22 with p value of <0.001. For NPV in class I, 9889.57±2274.40 and class III 8166.30±1673.94 with p value of 0.03 (significant). For HOP in class I, 41.08±4.50 and class III 44.43±4.10 with p value of 0.08 (non-significant). For CMinAx in class I, 152.15±71.74 and class III 249.91±170.98 with a p value of 0.008 (significant). For CPAS in class I 6.83±2.46 and class III 10.01±4.94 with p value of 0.02 (significant). The mean and standard deviation for BMI was 23.23±1.76 for class I and

23.46± 2.30 for class III with p value of 0.70. In class I there was a positive correlation with NPV and CMinAx), whereas in Class III there was a positive correlation with NPV, CMinAx and CPAS.
Conclusion: The constricted minimum axial area was the predictor variable that best explained the Oropharyngeal airway volume. 3D CBCT provides a low-radiation rapid scan capability to assess patients airway using highly correlative linear, cross-sectional area, and volumetric measurements that include assessing the morphometry of the airway in three dimensional view helps in their accurate assessment.

INTRODUCTION

The human upper airway or pharyngeal airways is made up of 3 parts nasopharynx, oropharynx and laryngopharynx. The physiological function of the upper airways is respiration, deglutition and phonation.[1]The retropalatal region of maxilla demarcates nasopharyngeal and oropharyngeal airways and the tip of epiglottis demarcate oropharyngeal and laryngopharyngeal airways. Muscles of tongue attach the airway between tongue and soft palate and tongue affects the size and position of the oropharyngeal airway.[2]These airway spaces assist in the normal growth and development of craniofacial skeleton and they are influenced by the different skeletal patterns.[3]The size and shape of the facial skeleton, dental skeleton and the airways in mostly determined by genetics as well as environmental factors.[4] The reasons for pharyngeal airway obstruction are allergies, environmental irritants, infections, sleep disorders like obstructive sleep apnea, vertical growth patterns of facial skeleton with mouth breathing. Surgical procedures of mandible which reduce the jaw dimension can restrict the space for tongue thus endangering airway space. It has also been noted that disparities in different skeletal patterns predisposes to upper airway obstruction. Changes in the pharyngeal airway spaces can be introduced while craniofacial surgeries and reconstructions and pharyngeal airways are directly proportional craniofacial growth pattern which results in malocclusion. [5]

Malocclusion classification was given in 1899 By Edward Hartley Angle and is the 3rd most prevalent oral health problem as described by WHO. Malocclusion is classified into 3 types class I, class II and class III. [6]Of these Class III is the least prevalent form of malocclusion and it results due to mandibular prognathism in relation to the maxilla or cranial base. It leads to complications like dentoalveolar problems with functional shift of the mandible in anterior direction leading to critical inter arch discrepancy.[7,8]

The pharyngeal airways are ideally measured using a lateral cephalogram which provides 2D view of the pharyngeal airway spaces andprovides limited data like linear and angular measurement but cannot provide details of volume of airways. 3D CBCT provides more sophisticated analysis of airways in 3D.[9]

Thus the aim of the present study was to evaluate the impactof 3D CBCT to assess class III malocclusion on oropharyngeal and nasophryngeal airways.

Materials and Methods

The present study was a cross sectional, prospective study conducted on a total of 60 patients who were divided into 2 groups Group A 30 patients with class I and Group B comprised of 30 patients with class III skeletal malocclusion. The patients were selected based on their facial profile and molar relationship.Patients with class I and class III malocclusion, in the age range of 20-35years with BMI 18.5-29.9 were included in the present study. Whereas, patients with transverse deficiencies, congenital craniofacial deformities, severe hypodivergent growth pattern FMA $<19^0$, severe hyperdivergent growth pattern FMA $>31^0$, obese subjects whose BMI ≥30, pharyngeal pathologies, nasal obstruction, past history of adenoidectomy and scans showing incomplete imaging of airways were excluded from the present study. Written informed consent was obtained from selected patients of both groups prior to the study. Patient details likeheight, weight and BMI were recorded and all patients were advised full skull CBCT imaging of nasopharyngel airway and oropharyngeal airway. In the present study CBCT images were captured using CBCT machine Carestream 9300 (Kodak India Private Limited) in natural head posture. Each patient image consisted of 455 slices, each thickness measuring 0.377mm, a resolution of 1280x1024 pixels and 16 bits per pixel (4096 grey scale). The findings of the images were obtained by viewing in DICOM viewer which allows total analysis of CBCT scan including measuring airway volume and segmenting. The images of airways were delineated and surrounding structure was removed to get a clearer image of airway which thenwas easier to analyse.

Oropharyngeal (OP) volume was measured as the volume of the pharynx between palatal planes (ANS-PNS) extending from posterior wall of pharynx and the plane parallel to the palatal plane that passes from the most antero-inferior point of second cervical vertebrae (2cv). The inferior limit(pp) of the Nasopharyngeal airway was the superior limit (PNP) of the Oropharyngeal airway and the superior limit was the last slice before the nasal septum fused with the posterior wall of the pharynx(PNP). To better view this fusion, the superior border of the NP was defined on the axial slice first and then reflected to the sagittal plane.

The CBCT images were opened in DICOM software the intensity of the images wereadjusted so that airway could be seen clearly with its borders. The upper limit (pp) and lower limit 2cv of oropharynx were contoured using livewire method in axial, sagittal and coronal section. The software was allowed to make 3D segmentation and then displayed the volume of the segmented part in mm^3which was entered and recorded as oropharyngeal volume in excel sheets.TurtleSeg software 1.3.0.1777 was used to segment nasopharynx with lower limit as pp and upper limit as PNP. Nasopharynx was similarly segmented like oropharynx mentioned above. And the volume displayed was recorded and entered as Nasopharyngeal volume. The error during segmentation was displayed as “spotlight” by software thus aiding in better segmentation.

Medical Imaging Interaction Toolkit (MITK) workbench 2015-02 software (the latest at the time of study) was used to measure the vertical length of the oropharynx (OPvert) and the constricted posterior airway space (CPAS) (the most constricted space behind the base of the tongue and limited by soft tissues) in mid sagittal slices.

The sagittal line corresponding to the CPAS region was opened on the axial slice, and the area of the most constricted region at the base of the tongue (minAx) was calculated. The DICOM file was opened in MITK Workbench. Using the linear measurement scale provided in the software the OPvert was measured from pp to 2cv in sagittal section. The CPAS was measured in mid-sagittal section using linear measurement scale. The images in axials sections were zoomed so as to see the borders clearly and the boundaries of minAx was marked using polygonal tool. Once the boundaries are marked the area of minAxwasdisplayed in mm^2 and circumference was shown in mm and the values obtained were entered into excel sheet.

All the values obtained were entered into an excel sheet and stored for statistical analysis using SPSS software (version 17.0, SPSS, Chicago III). The mean and standard deviation was calculated forindependentvariables like age, skeletal variables, height, weight, BMI, and dependable variables like volumetric area and linear measurements like Oropharyngeal airway volume (OPV), Nasopharyngeal airway volume (NPV), Vertical height of Oro pharynx (HOP), Constricted minimum axial area (CMinAx), Constricted posterior airway space (CPAS).

The Shapiro-Wilk test was used to check the normality of the OP and NP volumes. Because of the non-normality of the distribution of the OP volume data, non-parametric tests were used.Differences between the two groups were determined by using the ANOVA test. To check the correlations between the variables, the Pearson's correlation was performed.

Results

The present study was a cross sectional prospective study conducted on 60 patients grouped as Group A(controls) 30 patients with class I skeletal malocclusion and Group B (study group) 30 patients with Class III skeletal malocclusion. The participants of the study were in the age range of 20-35yrs. In Group A there were 12 males and 18 females whereas in group B there were 18 females and 12 males. [Chart1]

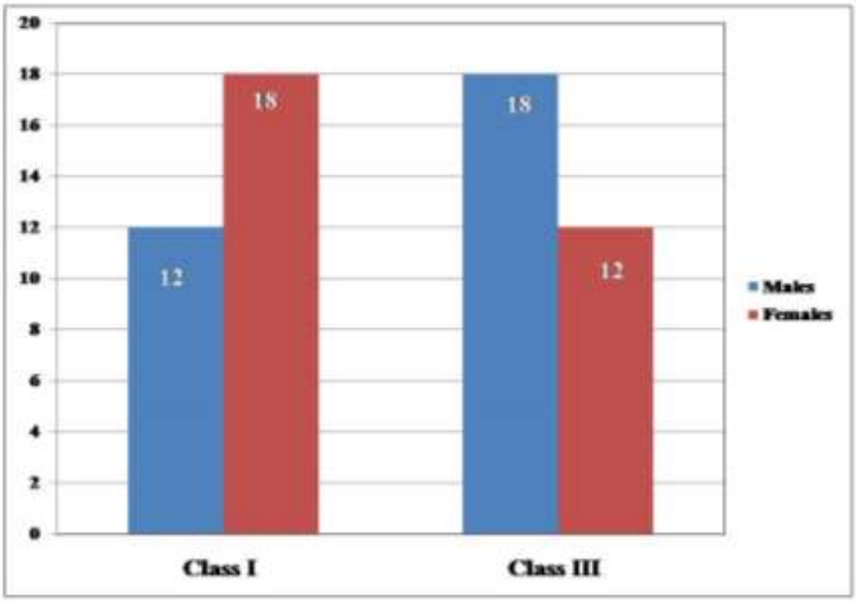

Chart 1 Bar graph showing distribution of males and females in Group A and Group B

Among a total of 60 participants the BMI was in the range of ≥18.5-≤24.9 in 52 participants whereas BMI range of ≤24.9 ≥ 29.9 was seen in only 8 participants. [Chart 2]

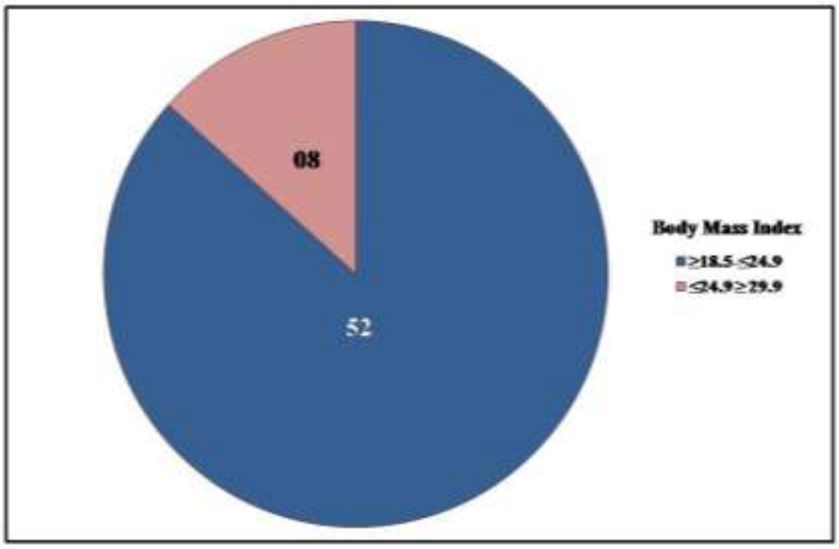

Chart 2 pie chart showing distribution of participants based on BMI in the present study

Shapiro-Wilk test was performed to check for the normality in the distribution of data in the 2 study groups. In class I the p value for OPV, NPV, HOP, CMinAx, CPAS was 0.05, 0.75, 0.94, 0.23, 0.29 respectively and were all found to be non-significant. Similarly in Class III the p value for OPV, NPV, HOP, CPAS was 0.17,0.74, 0.56, 0.14 respectively and were non-significant. Whereas the p value of CMinAx in Group 2 was 0.02 and was statistically significant. The p value for BMI in Group A was 0.10 and in Group B was 0.16 both of which were non-significant (Table 1)

	Class	Min	Max	Shapiro-Wilk		
				Statistic	df	p-value
OPV (mm3)	**Class I**	4460.91	10472	0.88	15	0.05(NS)
	Class III	6233	14758.5	0.91	15	0.17(NS)
NPV (mm3)	**Class I**	6602.48	14263.26	0.96	15	0.75(NS)
	Class III	5501	11420.56	0.96	15	0.74(NS)
HOP (mm)	**Class I**	33.14	49.01	0.97	15	0.94(NS)
	Class III	38.69	54.21	0.95	15	0.56(NS)
CMinAx (mm2)	**Class I**	63.08	282.5	0.92	15	0.23(NS)
	Class III	60.85	589.82	0.85	15	**0.02***
CPAS (mm)	**Class I**	3.84	11.9	0.93	15	0.29(NS)
	Class III	3.16	19.11	0.91	15	0.14(NS)
BMI	**Class I**	21.11	27.69	0.90	15	0.10(NS)
	Class III	20.86	28.52	0.91	15	0.16(NS)
***P>0.05 statistically significant NSP>0.05 non-significant**						

Table 1 showing values of Shapiro- Wilk test for normality in the present study

One way ANOVA test was used to analyse the difference between the means of 2 study groups so as to find any existing correlation between variables. In the present study the mean and standard deviation for OPV for Class I was 829±1786.59 and class III was 10941.43±2863.22 and the p value was <0.001 (significant). For NPV in class I, 9889.57±2274.40 and class III 8166.30±1673.94 with p value of 0.03 (significant). For HOP in class I, 41.08±4.50 and class III 44.43±4.10 with p value of 0.08 (non-significant).For CMinAx in class I, 152.15±71.74 and class III 249.91±170.98 with a p value of 0.008 (significant). For CPAS in class I 6.83±2.46 and class III 10.01±4.94 with p value of 0.02 (significant). The mean and standard deviation for BMI was 23.23±1.76 for class I and 23.46± 2.30 for class III with p value of 0.70. (Table 2)

		N	Mean	Std. Deviation	ANOVA	
					F value	**p-value**
OPV (mm3)	**1**	15	8294.73	1786.59	11.06	**<0.001***
	3	15	10941.43	2863.22		
NPV (mm3)	**1**	15	9889.57	2274.40	3.90	**0.03***
	3	15	8166.30	1673.94		
HOP (mm)	**1**	15	41.08	4.50	2.67	0.08(NS)
	3	15	44.43	4.10		
CMinAx (mm2)	**1**	15	152.15	71.74	5.38	**0.008***
	3	15	249.91	170.98		
CPAS (mm)	**1**	15	6.83	2.46	4.22	**0.02***
	3	15	10.01	4.94		
BMI	**1**	15	23.23	1.76	0.35	0.70(NS)
	3	15	23.46	2.30		
***P>0.05 statistically significant NSP>0.05 non-significant**						

Table 2 showing values of one way ANOVA test correlating the variables of the present study

Pearson's correlation test was used to determine the intra group linear correlation in Group A. It showed a positive significant correlation with NPV and CMinAx with a p value of 0.02 and 0.03 respectively. It was further noted that in Group ACMinAx showed a positive significant correlation with CPAS with a p value of 0.005. While other variables in Group A showed a negative correlation with each other with a p value of > 0.05 and were not significant. Even the BMI showed a negative correlation with OPV, NPV, HOP, CMinAx, CPAS and was not significant with a pa vlue of >0.05. (Table 3) Similarly Pearson's correlation test was used to determine the intra group correlation in Group B which showed that OPV showed a positive significant correlation with NPV, CMinAx and CPAS with a p value of 0.01. A significant positive correlation between CminAx and CPAS was noted with a p value of <0.01. A negative correlation was noted among other intra group variables in class III showing p value of >0.05. BMI showed a positive significant correlation with only HOP with a p value of 0.02 whereas BMI with other variables showed a negative correlation. (Table 3)

Parameter		**OPV (mm3)**	**NPV (mm3)**	**HOP (mm)**	**CMinAx (mm2)**	**CPAS (mm)**
Class I (Group A)						
OPV (mm3)	**r**					
	p-value	1				
NPV (mm3)	**r**	0.56	1			
	p-value	**0.02***				
HOP (mm)	**r**	0.47	-0.10	1		
	p-value	0.07(NS)	0.72 (NS)			
CMinAx (mm2)	**r**	0.54	0.22	0.24	1	
	p-value	0.03*	0.42 (NS)	0.37 (NS)		
CPAS (mm)	**r**	0.22	-0.02	0.01	0.68	1
	p-value	0.42(NS)	0.93 (NS)	0.9 (NS)	0.005*	
BMI	**r**	0.16	-0.008	-0.001	0.35	0.12
	p-value	0.55(NS)	0.97 (NS)	0.99 (NS)	0.19 (NS)	0.64 (NS)
Class III (Group B)						
OPV (mm^3)	**r**	1				
	p-value					
NPV (mm3)	**r**	0.61	1			
	p-value	0.01*				
HOP (mm)	**r**	-0.15	-0.21	1		
	p-value	0.57(NS)	0.45 (NS)			
CMinAx (mm2)	**r**	0.63	0.48	-0.35	1	
	p-value	0.01*	0.06 (NS)	0.19 (NS)		
CPAS (mm)	**r**	0.60	0.42	-0.46	0.94	1
	p-value	0.01*	0.11 (NS)	0.07 (NS)	<0.001*	
BMI	**r**	-0.21	-0.09	0.57	-0.14	-0.23
	p-value	0.44(NS)	0.75 (NS)	0.02*	0.60(NS)	0.39 (NS)

Table 3 showing intra group correlation Pearson’s correlation test for class I and class III

Discussion

According to the functional theory of Moss the contiguous structures influence the skeletal system.[10]Based on this theory, a skilled craniofacial surgeon can manipulate the craniofacial skeletal and guide it in reconstruction. The goal of providing ideal dental treatment is fulfilled when airway spaces are maintained without compromise. There is an established close relationship between position of cervical vertebrae, pharyngeal airways and mandible which impact head posture, pharyngeal airway space and skeletal malocclusion. The Upper pharyngeal airways are closely associated with different cranial morphologies and they normally measure 15-20mm.[4]Hence assessment of pharyngeal airways is included in orthodontic diagnosis and treatment planning.[11]The size and location of tongue greatly influences the oropharyngeal airway and the anteroposterior constriction of oropharyngeal airways is associated with location of maxilla and mandible. Such obstruction of the pharyngeal airways alters the morphology of craniofacial skeleton leading to malocclusion. Malocclusion is the result of an altered dental development and dental defects which can occur at any stage of normal development. These deviations lead to change in the proportions of shape and locations of jaws which have a direct impact on the facial profiles.[10]Malocclusions manifest due to genetic constitution as well as environmental factors.[12]

Malocclusion is successfully managed by predicting and correcting the skeletal growth patterns. Malocclusion is classified based on cranio maxillofacial patterns as Class I, Class II and Class III. Among these, class III malocclusion starts manifesting at an early age hence needs to be managed at an early age. Malocclusions with mouth breathing habit and restricted pharyngeal space can lead to obstructive sleep apnea syndrome, dental deformities, crowding, bruxism, trismus, masticatory problems and digestive disturbances. Treatment modalities aimed at increasing the airway spaces eases the respiration.[13]

Traditionally the pharyngeal airway spaces are studied using lateral cephalograms producing 2D images which might not estimate the airway volume accurately. CBCT imaging was opted as they provide 3D images, gives precise measurements, economical and safe as they have low radiation.[14,15]Thus the present study was aimed at estimating the impact of class III malocclusion on oropharyngeal and nasopharyngeal airways using 3D CBCT.

With 3D CBCT imaging 455 slices were obtained and segmented and the OPV and NPV were obtained using tools from software used in the present study. DICOM software allows visualizing hollow structure like airways in 3D. HOP, CMinAx, CPAS were measured using MITK software tools.

The study population in our present study belonged to the age group of 20-35 years as we were aware that the most accurate values are obtained in these age groups. The soft palate becomes longer and thicker and pharyngeal region becomes narrower as age increases which is a predisposing factor to obstructive sleep apnea.[16]In the present study it was noted that the pharyngeal dimensions were not affected by gender in any group. This finding of the study is in contrast with Oscar Martin et al 2011 who found that upper airway length was more in males than in females. Pharyngeal airway volume is known to decrease with increase in age in both men and women.[11]It is well-established fact that sleep apnea is commonly seen in obese individuals. Due to this reason, obese participants were excluded from the study. Extrinsic and intrinsic fat accumulation in the neck area can collapse the pharyngeal airways exacerbating the obstructive sleep apnea.Hence in the present study height and weight of the participants of the study was recorded and BMI was calculated. In the present study it was found that there was a non-significant association of BMI in class I and class III malocclusion. This might be due to the reason that the mean BMI was 23.2 kg/m^{2}which is considered as normal weight. This finding is like minded with studies of Yu Chuang et al 2019.[2] An indirect correlation between pharyngeal volumes and BMI was noted in studies by Francesco 2016.[17]The only significant correlation of BMI noted in then present study was with HOP in class III. It was noted that class III showed an increased oropharyngeal volume when compared with class I and was found to be statistically significant which is similar to the findings of Shokri A 2018.[18]

Abu Allhaija suggested that in class III there is forward positing of the hyoid bone which increases the airway spaces.[19]Class III was found to have a greater NPV when compared with class I and was statistically significant in the present study. A constricted nasopharyngeal airway is associated with detrudedmandible and maxilla.Alves et al concluded that patients with mandibular growth deficiencyhad less airway volume than the patients with good growth anteroposterior relationshipbetween maxilla and mandible.[20]

In the present study there was positive correlation between the OPV and NPV. The positive correlationmight be the result of using healthy subjects with no airway pathology because situations suchas nasal congestion, craniofacial anomalies, hypertrophic adenoids, and nasopharyngealdiminished airway space are known to cause structural narrowing of the pharynx.[16]Kim 2010also found a significant positive correlation between the nasal airway and the superiorpharyngeal airway.[21]

The most constricted region at the base of the tongue CMinAx was measured using software tools and it was noted that the class III showed increased cross sectional areas of the lower part of the pharyngeal airway in axial plane. CMinAx was more in class III thanin class I andtheir comparison were found to be statistically significant. This is similar to the findings of Walsh 2008 and Hakan 2013.[16, 22] The constricted minimum axial area CMinAx was the predictor variable that best explained theOropharyngeal airway volume.Hakan 2011 suggested that CMinAx was more likely to explain OPV than NPV.[23]

Tsoet al also mentioned a high correlation between the most constricted cross-sectional area of theairway and the total airway volume.[24]Height of oropharynx HOP measured using MITK software showed that there was no significant difference in their measurement in class I and class III. This is similar to the findings of Kerr 1985. [25]Pae1997 reported that length is more in class III due to the position of hyoid bone. The pharyngeal length becomes longer when hyoid bone is positioned inferiorly. [26]

The constricted posterior airway space CPAS in class III was the larger than Class I and was found to be statistically significant. Abu Allhaija 2005 suggested that the hyoid bone is located further front in class III skeleton where the upper airway is more open.[19]It is well known that posterior airway space and skeletal patterninteract with each other as they have a close relationship and pharyngeal airway width shows lowest values in high angle group. The present study showed a positive correlation between OPV and NPV and was similar to findings of Kim 2010.[21]This might be the result of including healthy subjects with no airway pathologies. Airway space is diminished in conditions like nasal congestion, craniofacial anomalies, hypertropic adenoids which show narrowing of the pharynx. Although CPAS was also significantly correlated with the OPV in our study and this correlation was lower compared with that obtained with CMinAx.Volumetric studies provide anew perspective on the airway, and possible constrictions might be a precipitating factor fordifferent dentofacial skeletal patterns. Volumetric analysis by far is best carried out with the use of 3D CBCT.

Conclusion

Variation in dentoskeletalgrowth leads to an obstruction of the upper airwayand development of deleterious habits like mouthbreathing, which eventually leads to an altered patternof craniofacial growth and dental malocclusion and leads to either class II or class III malocclusion. Narrow posterior airway space, elongated tongue, enlarged soft palate, and an inferiorly locatedhyoid may be variables that can be significant determinants of apnea severity. 3D CBCT provides a low-radiation rapid scancapability to assess patients airway using highly correlative linear, cross-sectional area, andvolumetric measurements that include assessing the morphometry of the airway in threedimensional view helps in their accurate assessment.Theresults of this research can be used as a guideline for subsequent works related to the airwaystudy and presurgicalassessment for orthognathic surgeries.

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