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Cone beam evaluation of pharyngeal airway space in adult skeletal class II div I and class II div II patients with different growth patterns

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Abstract
Objective: To determine and compare the relationship between pharyngeal volume in subjects with class II div I and div II malocclusions. And To determine the relationship between different growth patterns and pharyngeal volume.
Materials and Method: This study was conducted among 60 patients in the age group of 18 to 45 years of North Indian origin with class II malocclusions requiring CBCT, reporting to the department of Orthodontics and Dentofacial Orthopaedics at RUHS College of Dental Sciences, Jaipur out of which 30 were class II div I (15 vertical and 15 horizontal growth pattern) and 30 were class II div II (15 vertical and 15 horizontal growth pattern Cone beam computed tomography scans were taken using Carestream CS9300 imaging system (CS 3D Imaging v3.5.7; Carestream Health Inc New York, USA) using FOV of 17x11 cm. Two characteristics in each CBCT were measured using the dr Able (3d doctor) software : pharyngeal volume in (cm) cube in relation to type of class II malocclusion and pharyngeal volume in (cm) cube in relation to type of growth pattern in class II malocclusion.
Results: No significant difference in pharyngeal volume found between skeletal class II div I and div II group Significantly Reduced pharyngeal volume found in vertical growth pattern group.
Conclusion: Pharyngeal volume in class II div II group was less as compared to class II div I group but difference was statistically insignificant Vertical growth pattern patients have lower pharyngeal volume as compared to horizontal growth pattern in both sub divisions of class II malocclusion confirming an association between pharyngeal airway space and a vertical skeletal pattern.

Keywords: Pharyngeal volume, nasopharynx oropharynx, 3D dr Able, CBCT

Introduction
The growth of each compartment of the craniofacial skeleton is integrated with the other and coordinated growth is required for normal development to occur. Similarly Growth and function of the nasal cavities, the nasopharynx and the oropharynx are closely associated with the normal growth of the skull.

Obstructions of the nasal passage cause a functional imbalance that would result in an oral breathing pattern. Consecutively, there will be changes in the tongue and lip positions, downward and backward rotation of the mandible, long face, constricted maxillary arch, incompetent lip seal, flat nose and narrow nasal base.

The vertical relationship is of particular importance whether an individual is long faced or short-faced and it can either be skeletal or dental. The vertical dysplasia is difficult to treat and even more difficult to retain than the antero-posterior dysplasia. A lot of studies in the past have compared the pharyngeal airway with the facial morphology.

Linder-Aronson *et al.* [1] found a definite correlation between the mode of breathing and growth pattern of the maxilla-mandibular complex. McNamara at al [2] stated that individuals who had upper airway obstruction had a steep mandibular plane. Zettergren-Wijk [3] *et al.* have shown that the growth tends to be normalized after adenoidectomy was done in obstructive sleep apnea patients. Guray and Karaman [4] on the other hand found that adenoidectomy results in a change in breathing pattern without having a significant effect on malocclusion and facial type. With advances in medical care, the pharyngeal airway space of orthodontic patients is beginning to attract attention. The pharyngeal airway can be divided into three sections, namely the nasopharyngeal, oropharyngeal and laryngopharyngeal airways. The nasopharyngeal and the oropharyngeal airways are demarcated by the retropalatal region of maxilla, whereas the oropharyngeal and the laryngopharyngeal airways are demarcated by the tip of the epiglottis. Among these three sections of the pharyngeal airway, the oropharyngeal airway is the airway section that is most likely to be affected by the size and position (i.e., forward or backward) of the tongue. The base of the tongue is linked with the hyoid bone and muscles link the airway between the soft palate and the tongue. If the structure of a patient's pharyngeal airway is not completely understood before the administration of orthodontic treatment, the airway space changes that occur during orthodontic treatment process may easily be overlooked. Thus, the retraction of dentition due to orthodontic treatment may result in the compression of the tongue space and thereby jeopardizing the pharyngeal airway space.

Despite the vast amount of research concerning airway and its influence on craniofacial growth and development, most studies have been two-dimensional (2D). A number of authors have evaluated the airway using lateral cephalograms.

Lateral cephalometric films have severe limitations, such as distortion, difficulties in landmark identification, differences in magnification and the superimposition of bilateral craniofacial structures. Computed tomography (CT) has the advantage of providing a better accuracy in identifying the boundaries of soft tissues and empty spaces and, therefore, helps in better airway visualization. three-dimensional (3D) technology in the form of computed tomography (CT) has made possible to accurately measure and visualize the pharyngeal airway. Most 3D studies in the literature have used multislice CT to evaluate the airway, but because of the high radiation dose, it is restricted to patients with severe craniofacial deformities.

Recently, cone beam CT (CBCT) systems have been developed specifically for the maxillofacial region in which the radiation is less and can be used in a wide range of patients. Previous studies have confirmed that volumetric measurements of airways with CBCT are accurate and with minimal error. CBCT allows to easily differentiate between the hard and soft tissues as it has different gray level intensities. It allows the segmentation and visualization of hollow structures such as the airway in 3D. Thus, with the 3D imaging, we are moving from lengths and angles toward volume and surface areas. The purpose of this study was to determine the pharyngeal airway in all 3D in individuals with varying vertical proportions using CBCT Volumetric studies provide a new perspective on the airway and constrictions of the airway might be a precipitating factor for different Dentofacial skeletal patterns. By considering the existence of discrepancies in relation to pharyngeal airway and malocclusion form, it was decided to do a retrospective study to compare and evaluate the pharyngeal airway of patients in Class II div I and Class II div II malocclusion with different type of growth pattern in these cases.

Materials and Methods

Sample: This study was conducted among 60 patients in the age group of 18 to 45 years of North Indian origin with class II malocclusions requiring CBCT, reporting to the department of Orthodontics and Dentofacial Orthopaedics at RUHS College of Dental Sciences, Jaipur Sample size was calculated using G Power Software (version 3.0.10). Based on the calculated effect size of 5, 5% level of precision, 95% confidence level and 80% power of the study, minimum sample size was calculated as 60. So total 60 patients were taken as sample which were divided into two group – Group A – 30 class II div I (15 vertical and 15 horizontal growth pattern. Group B – 30 class II div II (15 vertical and 15 horizontal growth pattern The patients were randomly selected from the records of department of orthodontics, who required orthodontic treatment having class II malocclusions who had CBCT done previously

Inclusion Criteria

1. Patient having class II malocclusions
2. Age group of 18-45 years
3. Exclusion Criteria:
4. Patients who had undergone any orthodontic treatment previously
5. Patients with craniofacial anomaly like cleft lip or palate
6. Patients below 18 yrs of age
7. Previous history of adenoidectomy or tonsillectomy patients

Radiographic Examination: Cone beam computed tomography scans were taken with standard protocol using Carestream CS9300 imaging system (CS 3D Imaging v3.5.7; Carestream Health Inc New York, USA) using FOV of 17x11 cm. Image Volume was reconstructed with isotropic isometric 300x300x300 um voxels. The tube voltage ranged from 68-90 KVp, tube current was 4 mA and an exposure time of 11.30 seconds was used. This resulted in exposure which ranged from 697-1585 mGy.cm2. Patient was positioned in a standing posture, the head upright and teeth closed together with lips relaxed, in the natural head position, standing in front and looking at the eyes of self-mirror image. Patient is positioned so that the intersection lines were straight horizontal and vertical through the centre of the region of interest to construct a three-dimensional (3D) computer model.

Fig 1: Patient positioning during CBCT

The 3D Assessment: The data from CBCT scans was saved in format of digital imaging and communications in medicine (DICOM) files. The DICOM files of the patients were imported into Dr Able 3D Doctor software files were open in sagittal section and area and region of interest was marked superior limit of the OP airway was taken as the palatal plane (ANS-PNS) fig 1, extending to the posterior wall of the pharynx and the inferior limit was line parallel to the palatal plane, touching the most anteroinferior point of the second cervical vertebrae. And the anterior limit of the NP airway was selected as a line perpendicular to palatal plane drawn from posterior nasal spine in axial view. The inferior limit was the palatal plane. And volume rendering tool was used to measure volume in cm cube. fig 2, 3 and 4

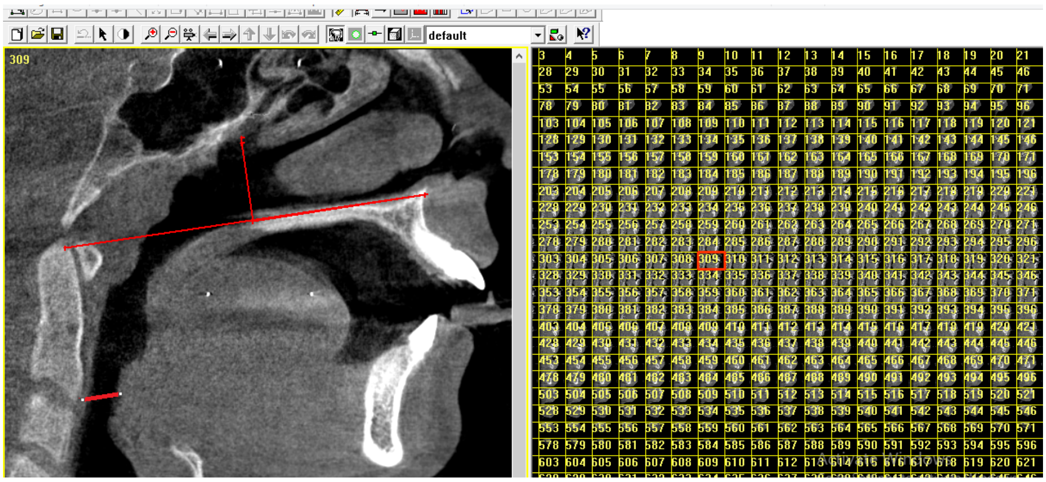


Fig 2: CBCT image showing reference markings for pharyngeal volume measurement

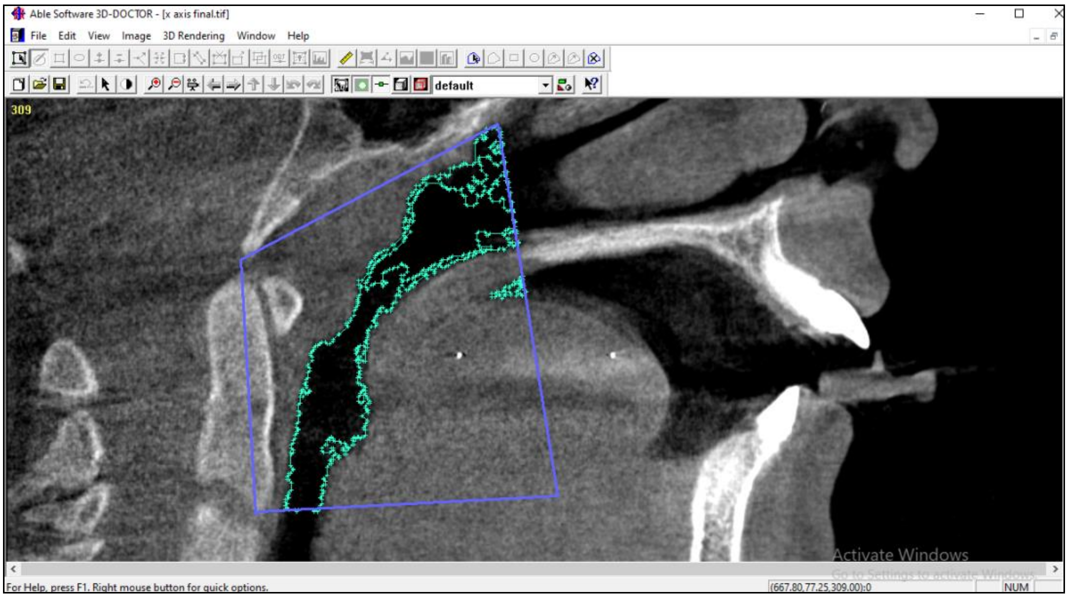


Fig 3: CBCT image showing region of interest demarcation

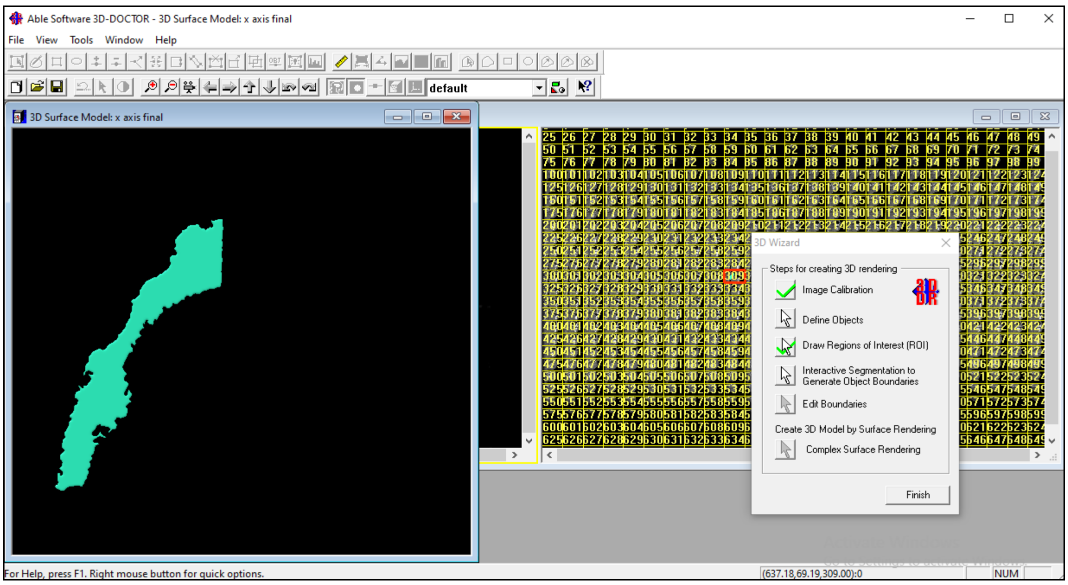


Fig 4: CBCT image showing selected region for volume rendering

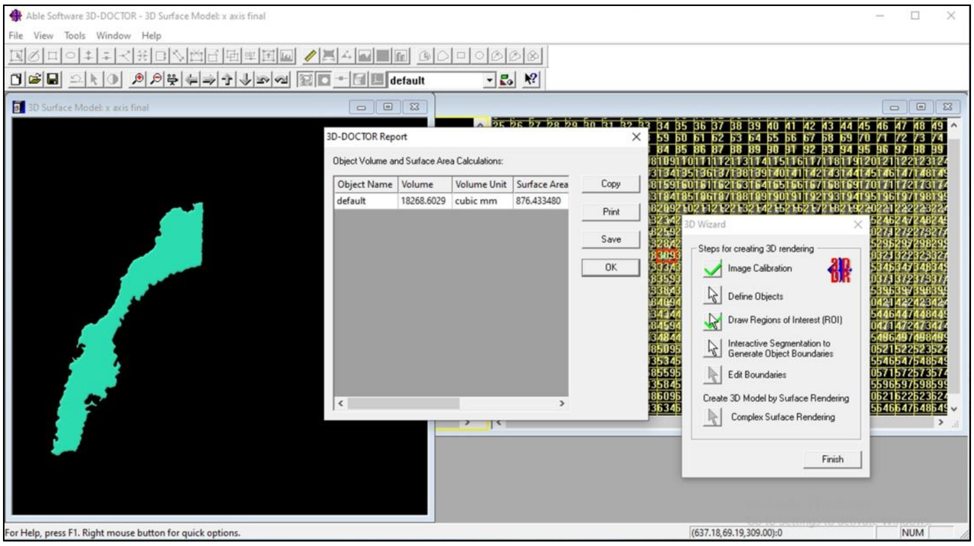


Fig 5: CBCT image showing selected region with volume rendering

Statistical Analysis

The data was tabulated in Microsoft excel software and analyzed with SPSS V.24 software. Unpaired t test or independent t test were used for the comparisons. The p value≤0.05 was considered as statistically significant

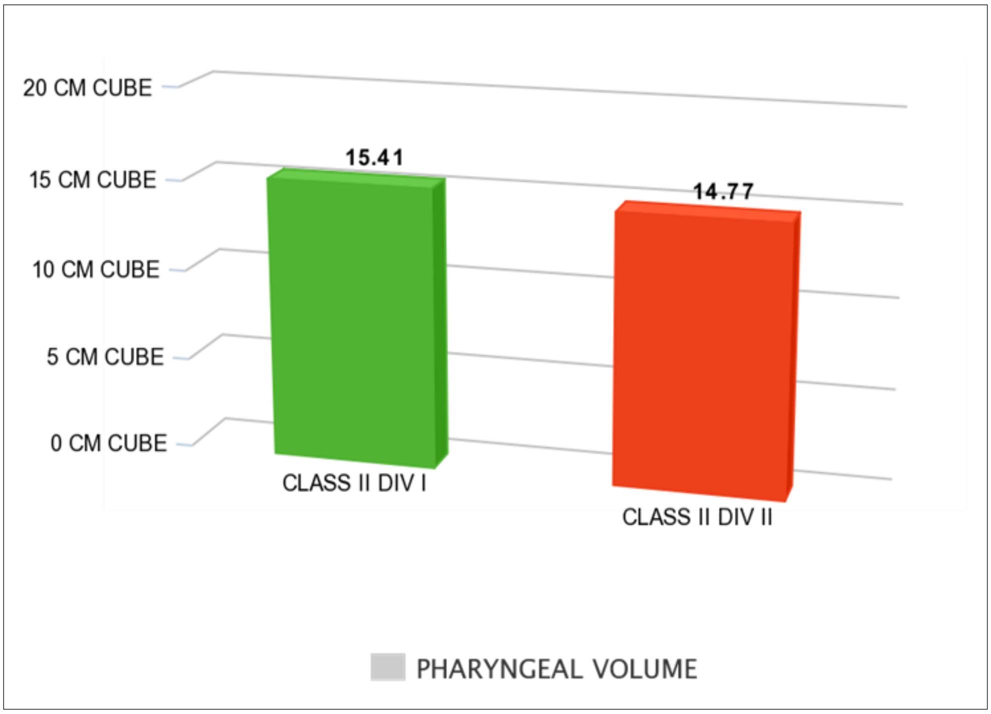
Results

1. Comparison of pharyngeal volume in class II div I and div II group.

Pharyngeal volume in class II div I group showed mean volume of 15.41 +/- 2.29 cm^3 and in class II div II group mean volume was 14.77 +/-2.37 cm^3 with a mean difference in pharyngeal volume of 0.64 cm^3.difference between the pharyngeal volumes of two groups was statistically insignificant ($p>0.05$)

Table 1: Comparison of pharyngeal volume in class II div I patients and class II div II patients

Class II	Mean	SD	Mean difference	T value	P value
Div I	15.41cm^3	2.29	0.64	1.0298	0.3074
Div II	14.77 cm^3	2.37			



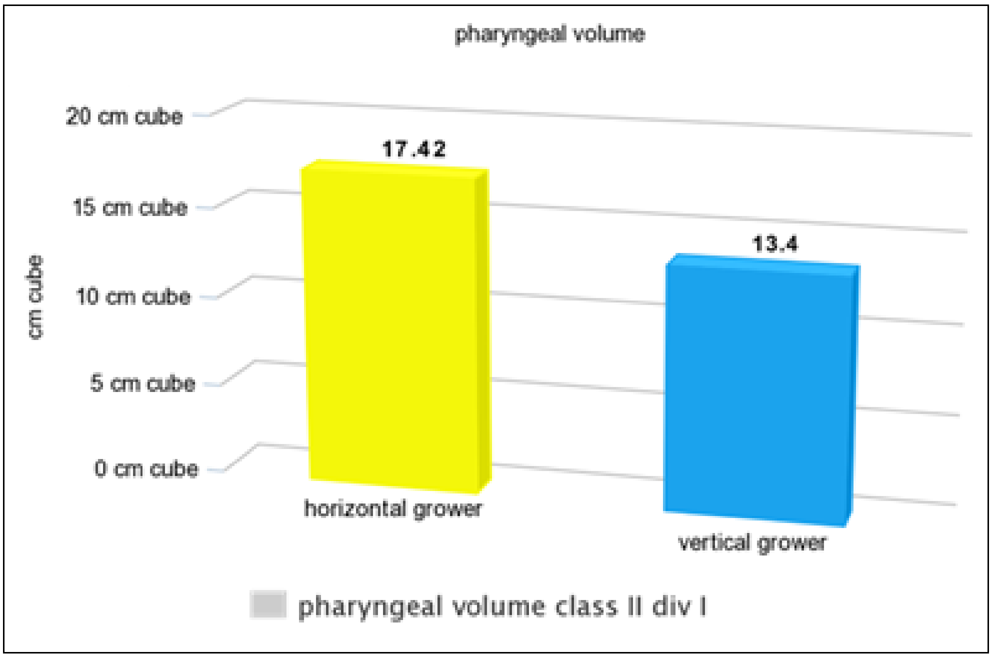
Graph 1: Comparison of pharyngeal volume in class II div I patients and class II div II patients

2. Comparison of pharyngeal volume in horizontal and vertical subgroup of class II div I group

Pharyngeal volume in class II div I horizontal growth pattern group showed mean volume of 17.42 +/- 1.17 cm^3 and in class II div I vertical growth group mean volume was 13.40 +/ 0.96 cm^3 with a mean difference in pharyngeal volume of 4.02 cm^3.difference between the pharyngeal volumes of two groups was statistically significant ($p≤0.05$).

Table 2: Comparison of Pharyngeal volume in class II div I patients with vertical and horizontal growth pattern

Class II div I	Mean	SD	Mean difference	T value	P value
Horizontal	17.42 cm^3	1.17	4.02	10.185	0.0001
Vertical	13.40 cm^3	0.96			



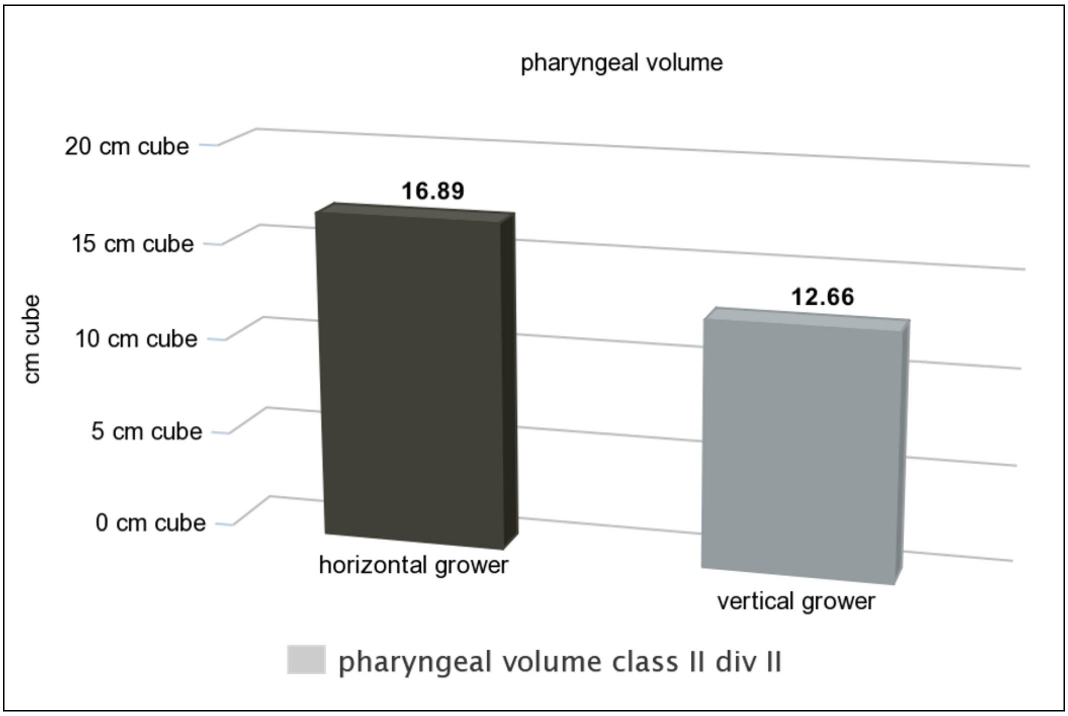
Graph 2: Comparison of pharyngeal volume in class II div I patients with vertical and horizontal growth Pattern

3. Comparison of pharyngeal volume in horizontal and vertical subgroup of class II div II group

Pharyngeal volume in class II div II horizontal growth pattern group showed mean volume of 16.89 +/- 1.17 cm^3 and in class II div II vertical growth group mean volume was 12.66 +/ 0.87cm^3 with a mean difference in pharyngeal volume of 4.23 cm^3. difference between the pharyngeal volumes of two groups was statistically significant ($p \leq 0.05$)

Table 3: Comparison of pharyngeal volume in class II div II patients with vertical and horizontal growth

Class II div II	Mean	SD	Mean difference	T value	P value
Horizontal	16.89 cm^3	1.17	4.23	11.18	0.0001
Vertical	12.66 cm^3	0.87			



Graph 3: Comparison of pharyngeal volume in class II div II patients with vertical and horizontal growth Pattern

Discussion

Growth and function of the nasal cavities, the nasopharynx and the oropharynx are closely associated with the normal growth of the skull. and coordinated growth is required for normal development of the craniofacial skeleton Obstructions of the nasal passage cause a functional imbalance that would result in an oral breathing pattern. Consecutively, there will be changes in the tongue and lip positions, downward and backward rotation of the mandible, long face, constricted maxillary arch, incompetent lip seal, flat nose and narrow nasal base.

Linder-Aronson *et al.* found a definite correlation between the mode of breathing and growth pattern of the maxilla-mandibular complex. McNamara [2] stated that individuals who had upper airway obstruction had a steep mandibular plane.

A lot of studies in the past have compared the pharyngeal airway with the facial morphology. Despite the vast amount of research concerning airway and its influence on craniofacial growth and development, most studies have been two-dimensional (2D) and used lateral cephalogram

A number of authors have evaluated the airway using lateral cephalograms.

Lateral cephalometric films have severe limitations, such as distortion, difficulties in landmark identification, differences in magnification and the superimposition of bilateral craniofacial structures.

In the present study, the pharyngeal airway was measured three dimensionally as a volume and not in terms of linear and angular measurements for the Indian population.

3d doctor (Dr able) software was used for evaluating pharyngeal airway from CBCT and conventional lateral cephalogram was used to evaluate Frankfort horizontal plane and mandibular plane Tracing was done to confirm that they meet the inclusion criteria and further division of the sample can be done on the basis of Frankfurt mandibular plane angle

The nasopharyngeal and the oropharyngeal airways are demarcated by the retro palatal Region of maxilla, whereas the oropharyngeal and the laryngopharyngeal airways are demarcated by the tip of the epiglottis. Among these three sections of the pharyngeal Airway, the oropharyngeal airway is the airway section that is most likely to be affected by the size and position (i.e., forward or backward) of the tongue.

The base of the tongue is linked with the hyoid bone and muscles link the airway between the soft palate and the tongue. If the structure of a patient's pharyngeal airway is not completely understood before the administration of orthodontic treatment, the airway space changes that occur during orthodontic treatment process may easily be overlooked. Thus, the retraction of dentition due to orthodontic treatment may result in the compression of the tongue space and thereby jeopardizing the pharyngeal airway space.

Therefore, prediction of the three-dimensional airway space of patients in different skeletal patterns is important before the orthodontic treatment. This study investigated differences between different skeletal patterns of class II patients in terms of the pharyngeal volume of airway by using cone-beam computed tomography

The volume of pharyngeal airway was found to be significantly different when compared between the horizontal growers and the vertical growers. The findings were in agreement with the findings of Vig [23] *et al.* who divided subjects into individuals with normal facial proportions with competent lips, normal facial proportions with incompetent lips and long vertical face height. Various respiration parameters Were measured for all the groups and it was found that the long faced subjects as a group had a higher mean value of nasal resistance, but the three groups did not differ significantly in terms of the respiratory patterns.

Grauer [10] *et al.* in contrast to our study found that there were no significant differences in the superior and total airway volumes among the long, normal and short groups where the division of vertical groups was done on the basis of bony facial index.

Ucar and Uysal [25] found that the nasopharyngeal airway was found to be statistically different when compared between the low angle and high angle cases but it was not found to be significant when the low angle group was compared with the normal and the when the high angle group was compared with the normal.

In agreement to our study, de Freitas [26] *et al.* found that subjects with Class I and Class II malocclusions and vertical growth patterns have significantly narrower upper pharyngeal airways than those with Class I and Class II malocclusions and normal growth patterns.

Joseph *et al.* [27] reported that the nasopharyngeal airway in the hyper divergent individuals was significantly narrower than the normo divergent individual However, this difference could be because of the retrusive maxilla and mandible exhibited by the hyper divergent group in their study. Which is also in agreement to our study

According to Joseph *et al.* [27] a normal sized yet retro positioned maxilla can lead to a narrowing of the nasopharynx and oropharynx. The difference could be because in the study, the position of the maxilla (SNA) was not found to be statistically different between the vertical growers and controls. Another reason could be that the nasopharyngeal airway was calculated as a linear measurement in the study by Joseph *et al.* whereas in our study, volumetric measurements were done using CBCT.

According to Opdebeeck28, patients with a longer face shape have a smaller airway space than those with a shorter face shape. El and Palomo [11] revealed that the position of mandible relative to the skull base also affects the oropharyngeal space. Studies examining the relationship between airway space and face shape have indicated that the patients in skeletal class II have a significantly smaller airway space than those in skeletal classes I and III; however, no significant differences in airway volume have been found between patients in skeletal classes I and III. These results are similar to those of the present study.

Patients in skeletal class III exhibited more protruding mandible and more forward tongue position, thus widening the distance between the dorsum of the tongue and the posterior pharyngeal wall. This condition implies a larger airway volume for patients in skeletal class III than for those in skeletal classes I and II.

Previous literature studies of Ackerman [29], Dunn [30] Linder Aronson 1, Proffit infer that upper airway width is influenced by the craniofacial growth pattern which is in favour of our study showing narrower pharyngeal volume in vertical growth pattern

Ricketts [31], Dunn *et al.* [30] and Linder-Aronson1 found that nasal obstruction leading to mouth breathing was related to the width of the nasopharynx; the narrower the nasopharynx, the less adenoidal enlargement was needed to obstruct the nasopharyngeal airway. This helps to explain the prevalence of mouth breathing in subjects with vertical growth patterns.

Kerr, Handelman32 found weak relationship between growth pattern, facial morphology and nasopharyngeal airway and this was in discord to our study

Conclusion

Pharyngeal volume in class II div II group was less as compared to class II div I group but difference was statistically insignificant

Vertical growth pattern patients have lower pharyngeal volume as compared to horizontal growth pattern in both sub divisions of class II malocclusion confirming an association between pharyngeal airway space and a vertical skeletal pattern. Moreover, the present study partially demonstrated that vertical growth patterns might predispose a person to pharyngeal narrowing, which in turn might predispose the person to upper airway obstruction

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