EVALUATION, COMPARISON AND VOLUMETRIC ANALYSIS OF PHARYNGEAL AIRWAY IN SKELETAL CLASS I AND II INDIVIDUALS WITH DIFFERENT VERTICAL GROWTH PATTERNS : *A MRI STUDY.*

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List of Abbreviations

Sr. No.	Abbreviations	Full Form
1.	NA	Nasopharyngeal airway
2.	OA	Oropharyngeal airway
3.	CBCT	Cone beam computed tomography
4.	CT	Computed tomography
5.	MRI	Magnetic resonance imaging
6.	OSA	Obstructive sleep apnea
7.	SAS	Sleep apneas syndrome
8.	SPS	Superior nasopharyngeal space
9.	VAL	Vertical airway length
10.	PAS	Pharyngeal airway space
11.	TV	Total volume
12.	So	Middle point of the sella-basion line
13.	ANOVA	Analysis of Variance
14.	P	Probability of occurring of an event
15.	HS*	Highly significant ($p < 0.0001$)

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INTRODUCTION

A patent airway is one of the important factors for the normal growth of the craniofacial structures[1]. Nasorespiratory function and its relation to craniofacial growth is ofgreat interest, not only for the orthodontist but for paediatricians, otorhinolaryngologists, speech pathologists and other members of health care community. The normal growth of the skull is closely associated with the growth and function of the nasal cavities, the nasopharynx and the oropharynx.

The effects of breathing and its participation in craniofacial growth and development have been the objective of orthodontic diagnoses and treatment plans. Alterations in upper airway breathing, may affect the development of structures and functions of the stomatognathic system during facial growth.

The size of the pharyngeal airway space is of importance in its relationship to the morphology of the face including mandible. Nasal breathing becomes difficult and mouth breathing becomes necessary because of the reduction of the nasopharyngeal airway space[1].

Harvold[2] reported that the lower border of the mandible becomes steeper and the gonial angle increases in mouth-breathing animals. The lowering of the mandible was followed by a downward displacement of the maxilla. Thus, a change in breathing pattern led to a variety of skeletal and dental deformities in subjects that do not ordinarily develop malocclusions.

The predisposing factors for obstruction of the pharyngeal airways are allergies, environmental irritants and infections, which are amenable to adequate treatment and also natural anatomical predisposition of narrower airway passages[3].

The pharynx is a tube shaped structure which is formed by muscles and membranes. It is located behind the nasal and oral cavities which extends from the cranial base to the level of the sixth cervical vertebra and the lower border of the cricoid cartilage. Its length is approximately 12 to 14 cm. It is divided into three parts: nasopharynx, oropharynx, and hypopharynx[4].

The nasopharyngeal airway (NA) is a cone-shaped tube that consists of muscles and mucosa. It also includes the adenoid, a complex network of lymphatic tissues located in the posterior area.In growing children, predisposing factors, repeated infection or inflammation usually lead to adenoid hypertrophy and constriction of the posterior airway.Children with narrowed nasopharyngeal airway tend to use mouth breathing because of partially impaired nasal respiration function[5].

The oropharyngeal airway (OA) lies between the soft palate and the hyoid bone. Many reports have demonstrated a relationship between various malocclusion patterns and variations in the size and form of the oropharyngeal airway caused by palate and/or tongue position[6]. The hypopharynx is the area of the pharynx caudal to the epiglottis.

The nasopharynx and the oropharynx have significant locations and functions because they form a part of the unit in which respiration and deglutition are carried out. The nasal portion of the nasopharynx has bony elements in its wall, thus rigid whereas pharyngeal part is contractile as a result of the muscular nature of its wall[4].

Nasal obstruction which is secondary to hypertrophied inferior turbinates, adenoidal pad hypertrophy and hypertrophy of the faucial tonsils can cause chronic mouth breathing , loud snoring, obstructive sleep apnea, excessive daytime sleepiness and even cor pulmonale. In this situation, a number of postural changes such as mandible posture, downward and forward positioning of the tongue and extension of the head can take place. If these postural changes continue for a long period, especially during the active growth stage, then different levels of severity in dentofacial disorders, inadequate lip structure, long face syndrome and adenoid facies can be seen [4].

Evaluation of the airway has become an important aspect in orthodontic treatment planning. An excellent way to identify the symptoms of airway disorders is by evaluating the initial orthodontic screening. Clinical detection of structural narrowing of the upper airway may facilitate early recognition of obstructive sleep apnea[7].

The methods to view the airway includes cephalometricradiographs, CBCT, and MRI. Lateral cephalometricradiographs were the only method used before CBCT and MRI. This method had the limitation of imaging a 3D structure in 2 dimensions. Volumeand cross-sectional areas could not be accuratelyassessed with lateral cephalometric radiographs[6].Some additional limitations with lateral cephalometricradiographs are image magnification or enlargement, distortion, structure overlap, limited identifiablelandmarks, and positioning problems[8].Recently, it has become possible for magnetic resonance imaging (MRI) to determine accurately the pharyngeal airway volume. The development and implementation of MRI for the assessment of OSAS has provided useful information on structural alterations in the pharyngeal airway, the location of abnormal sites, and the severity of apnea. As magnetic resonance imaging (MRI) provides excellent soft tissue resolution and three dimensional reconstruction, MRI is considered as a diagnostic modality for OSA[9].

Thus, evaluation of upper and lower airway space should be an integral part of diagnostic and treatment planning, so as to achieve functional balance and stability which is essential. Hence this study is aimed to measure the airway volume and dimensions in skeletal Class I and Class II vertical (“hypo-divergent” and “hyper-divergent) skeletal patterns.

AIM AND OBJECTIVES

AIM –

The present study aimed to evaluate the pharyngeal airway dimensions of individuals presenting with the different growth patterns in skeletal Class I and Class II malocclusions using MRI.

OBJECTIVE –

- To evaluate the pharyngeal airway dimensions in skeletal Class II individuals with Hypodivergent growth pattern.
- To evaluate the pharyngeal airway dimensions in skeletal Class II individuals with Hyperdivergent growth pattern.
- To evaluate the pharyngeal airway dimensions in skeletal Class I individuals
- To compare volume of the pharyngeal airway in skeletal Class I and Class II individuals with Hypodivergentgrowth pattern.

- To compare volume of the pharyngeal airway in skeletal ClassI and Class II individuals with Hyperdivergent growth pattern.
- To compare volume of the pharyngeal airway in skeletal Class II individuals with Hypodivergent and Hyperdivergent growth pattern.

REVIEW OF LITERATURE

The debate in orthodontics concerning the role of respiration in the etiology of malocclusion and facial deformity dates back over 100 years. Current trends in clinical practice are focused on attempting to modify growth in an endeavour to prevent the development of orthodontic problem or at least to minimize the effect of environmental factors that may alter growth unfavourably.

Even before 1900, there were reports in the literature on the possible relationship between certain orofacial morphologic types and the mode of respiration. There was a degree of uniformity in the description of facial type associated with mouth breathing.

Morrison (1931) [10] who promoted the idea that mouth breathing is a significant etiological factor in malocclusion. To his credit, Morrison at last, started that the issue was unresolved and that research effort had been little more than clinical speculation up to that point. He called for a more critical scientific approach to the problem.

Neivert(1939) [11] restated the theory of muscular imbalance and regarded the adenoids as occlusion in the airway sufficient to induce breathing through the mouth.

Hartsook (1946)[12], in a review of contemporary epidemiologic research, could not concluded that mouth breathing is an etiologic factor in the production of malocclusion.

A study where **James Bosma** (1963)[13] noted that the mechanism of pharyngeal airway maintenance is a principal determinant of the anteroposterior relationship between the tongue tip and incisors. At any given moment, mandibular position is relevant to both the head and neck posture and the pharyngeal airway.

The relationship between airway adequacy and type of malocclusion was studied by **Watson**[14] in 1968. No association was found between rhinometric measures of airway adequacy and type of malocclusion or craniofacial morphology. The incidence of clinically observable mouth breathing was found to be greater in subjects with greater nasal resistance.

Ricketts(1968)[15] attributed a variety of abnormalities to nasorespiratory impairment that he and several physicians determined subjectively. Later, he started, “The lack of function in the nose seems to hold the front of the palate upward or prevent its downward decent. A micro-rhinodysplasia case will develop on its own from lack of function of the nose.

The functional matrix theory in facial growth (**Moss** in 1969) [16] states that cell growth changes in the size, shape and spatial position and indeed the very maintenance in being of all skeletal units are always secondary to temporary primary changes in their functional matrices. Moss calls the pharynx as one of the primary functional spaces. Accordingly, to him, it is the volumetric growth of pharyngeal, oral or nasal spaces which is primary morphogenetic event in facial skull growth.

A study by **Aronson** in (1974)[17] was done to demonstrate the changes in craniofacial morphology due to obstruction of the upper airway because of enlarged adenoids. The changes observed were reduced facial prognathism, opening up of the mandibular plane angle and also a mouth breathing habit.

Some authors like **Savoie and Simard** (1976)[18] emphasized the importance of the pharyngeal airway. They described how the tongue would be held in an altered posture to maintain airway adequacy if there was even a slight amount of respiratory embrassment. This forward or downward posture of the tongue could lead to Class III malocclusion.

Profitt (1978) [19] wrote that if there is difficulty in breathing, the physiologic adaptations which facilitate mouth breathing include a forward position of the head on the neck and a lowered position of the mandible with a low and forward tongue posture.

A study of**Vig, Sarver** (1981) [20] examining the relationship between facial morphologyand respiration, concluded that the respiratory patterns between lip incompetent, long faced and normal person, when compared in groups are not significantly different[28].

A critical review of literature by **Ryan, Gallagher** in (1982)[21] concerning the effect of nasal airway functions upon dentofacial morphogenesis failed to support a consistent relationship between obstructed nasorespiratory function and the long face syndrome.

An experiment was designed to test whether there was a morphologic response to changes in neuromuscular patterns induced due to alterd mode of respiration in rhesus monkeys by **Vargervik** (1984)[22]. The neuromuscular changes were triggered by complete nasal obstruction. Alteration was triggered again by removal of obstruction and return of nasal breathing. There was considerable variation in morphologic response among the animals.

Solow B, **Siersbaek-Nielsen S**, **Greve E** (1984)[23] demonstrated the associations between craniocervical angulations and craniofacial morphology, airway obstruction by adenoids and craniofacial morphology, airway obstruction and craniocervical angulations. Cephalometric radiographs were takenand correlations were calculated between twenty-seven morphologic, eight postural and two airway variables. A large craniocervical angle was on the average seen with small mandibular dimensions, mandibular retrognathism and a large mandibular inclination. Obstructed nasopharyngeal airways were seen with a large craniocervical angle and with small mandibular dimensions, mandibular retrognathism, a large mandibular inclination, and retroclination of the upper incisors.

A study by **McNamara** in (1984)[24] suggested that lower pharyngeal width measured from the intersection of the posterior border of the tongue and inferior border of the mandible to closest point on the posterior pharyngeal wall. It was felt that a width of the lower pharynx greater than 15mm suggested anterior positioning of the tongue.

Another study by **Lowe** in (1985)[25] documented the relationship between tongue muscle parameters at rest and craniofacial morphology in adult human subjects with normal and anterior open bite malocclusions. They found that in patients with open bites, the tongue tip was ahead of the incisal edges of the lower central incisor and above the lower occlusal plane. Also, there was a mandibular rotation and forward tongue posture to maintain the airway.

Alan A. Lowe, John D. Santamaria, John A. Fleetham and Colin Vancouver (1986)[26] took subjects with moderate to severe obstructive sleep apnea. The interaction among craniofacial, airway, tongue, and hyoid variables was quantified by means of a canonical correlation analysis. One lateral cephalometric radiograph with the teeth in occlusion was obtained for each subject together with overnight polysomnographic measurements before the initiation of therapy. Sleep apnea subjects showed a posteriorly positioned maxilla and mandible, a steep occlusal plane, overerupted maxillary and mandibular teeth, proclined incisors, a steep mandibular plane, a large gonial angle, high upper and lower facial heights, and an anterior open bite in association with a long tongue and a posteriorly placed pharyngeal wall. Subjects with sleep apnea demonstrated several alterations in craniofacial form that may reduce the upper airway dimensions and subsequently impair upper airway stability.

William H.Bacon, Jean Christophe Turlot, Jean Krieger and Louis Stierle (1990) [27] determined the morphological characteristics specific to patients with sleep apneas syndrome(SAS)in a cephalometric evaluation with a homologous control group. In SAS patients, the soft palate was enlongated, the sagittal dimensions of upper face and anterior cranial base were reduced and correlated with reduced bony pharynx opening and increased lower face height was associated with a retruded position of the chin and tongue, thus contributing to lower pharynx crowding.

G.E Shen, N. Samman, W. L. Qiu, Y. S. Tang, J. Xia, Y. L(1994)[28]conducted a detailed cephalometric analysis of the soft and hard tissues of the upper airway with lateral cephalographs from 116 normal Chinese, aged between 18 and 25 years. Normal values and deviation range were preliminarily established for the size of the tongue, soft palate, nasopharynx, oropharynx, and hypopharynx, and for the relative position of the hyoid bone and valleculain both sexes. Significant relationships were observed 1) betweenthe hypopharyngeal depth and the position of the hyoid bone and the vallecula,in which the horizontal position of vallecula appears to be the best predictor ofthe hypopharyngeal depth, as confirmed by the multiple regression equation;2) between the upper airway depths at four different levels; and 3) between thenaso-oropharyngeal area and tongue, soft palate, and oral area.

Ismail Ceylan and HfisamettinOktay (1995) [4] investigated pharyngeal size on the lateral cephalometric films of 90 subjects having different ANB angles. It has been observed that two measurements, hy-apw4 and oropharynx area measurements were affected by the change of ANB angle, and two other measurements, t-ppw and hy-apw2 measurements, by the sex; and that hy-apw4 measurement and oropharynx area became smaller with the increase of ANB angle.

Beni Solow, SerenSkov, Jan Ovesen, Pia W. Norup and Gordon Wildschi¢dtz (1996)[29] described the antero-posterior diameters of the pharyngeal airway in a sample of obstructive sleep apnoea patients and a reference sample and examined the relationship between these diameters and the posture of the head and the cervical column. Pharyngeal airway diameters were measured at seven levels ranging from the maxillary tuberosity to the vallecula of the epiglottis. The largest difference was observed at the level behind the soft palate where the diameter was 50 per cent narrower in the GSA sample than in the reference sample. Extension of the cranio-cervical angle and forward inclination of the cervical column were correlated with an increase in the three most caudal airway diameters in the GSA sample: at the uvula, the root of the tongue, and the epiglottis, but only to increase in the lowest diameter in the reference sample. The findings were considered to reflect a compensatory physiological postural mechanism that serves to maintain airway adequacy in GSA patients in the awake erect posture, most efficiently so at the lowest levels of the oropharyngeal airway.

Joseph AA, Elbaum J, Cisneros GJ, Eisig SB (1998) [30]compared the dimensions of the nasopharynx, oropharnynx, and hypopharynx of persons with hyperdivergent and normodivergent facial types, and to determine whether any variations exist. The narrower anteroposterior dimension of the airway in hyperdivergent patients may be attributable to skeletal features like retrusion of the maxilla and the mandible and vertical maxillary excess. Even obtuse soft palate and low-set hyoid may be a contributory factors. The relatively thin posterior pharyngeal wall observed in hyperdivergent patients might be a compensatory mechanism.

Schwab RJ, Goldberg AN (1998)[31]studied the mechanisms underlying the pathogenesis and biomechanics of sleep apnea and the mechanisms underlying the efficacy of therapeutic interventions in patients with sleep disordered breathing. The primary upper airway imaging modalities include nasopharyngoscopy, cephalometrics, CT scanning, and MR imaging. Imaging studies using these modalities have provided important insights into the static and dynamic structure and function of the upper airway and surrounding soft-tissue structures during wakefulness and sleep. Such imaging studies have highlighted the importance of the lateral pharyngeal walls in mediating upper airway caliber. These imaging modalities have also been used to study the effect of respiration, weight loss, mandibular repositioning devices, and upper airway surgery on the upper airway. Three-dimensional reconstruction of the airway and surrounding soft-tissue structures can be performed with MR imaging and CT scanning. Clinical indications for upper airway imaging are evolving such that imaging studies should be considered in patients with sleep apnea who are being treated with dental appliances or upper airway surgery.

Michael J. Trenouth. Donald J. Timms (1999) [32]investigated the association between the functional oropharyngeal airway and craniofacial morphology using 16 craniofacial variables taken from lateral cephalometric radiographs. There was no difference in ages between males and females and no correlation with age except upper face height found. Oropharyngeal airway was positively correlated with the length of the mandible, the distance between the third cervical vertebrate and the hyoid bone and cranial base angle. Although short mandible length is a characteristic finding in patients with obstructive sleep apnea, none of the subjects in this study had this diagnosis.

RaananArens, Joseph M. Mcdonough et al (2001)[33] compared the upper airway structure in 18 young children with OSAS and an apnea index of 4.3±3.9, with 18 matched control subjects . All subjects underwent magnetic resonance imaging and were obtained and analyzed with image-processing software to obtain linear, area, and volumetric measurements of the upper airway and the tissues comprising the airway. The volume of the upper airway was smaller in subjects with OSAS in comparison with control subjects and the adenoid and tonsils were larger. Volumes of the mandible and tongue were similar in both groups; however, the soft palate was larger in subjects with OSAS. They concludedthat in children with moderate OSAS, the upper airway is restricted both by the adenoid and tonsils; however, the soft palate is also larger in this group, adding further restriction.

M.OkanAkcam, T. UfukToygar, Takeshi Wada (2002) [34] investigated the relationship between the soft palate and the nasopharyngeal airway in different mandibular growth rotation models. A total of 72 lateral cephalograms were obtained three years longitudinally which showed a normal, posterior and anterior mandibular rotation pattern. Linear and angular measurement of the soft palate and nasopharyngeal airway were recorded by using PORDIOS computer program. A linear increase in the soft palate length (SPL) was observed in all groups, with the posterior mandibular rotation group showing the largest increase within the observation period. According to the paired *t*-test, palatal plane (ANS–PNS)/soft palate tip (SPT) angle showed a statistically significantdecrease in the posterior rotation group. The ratio between SPL and superior nasopharyngeal space (SPS) did not show a statistically significant difference among the groups. Although various amounts of soft palate and nasopharyngeal airway growth occurred in the different mandibular rotation types, the ratio between SPL and SPS (SPL/SPS), which plays an indispensable role in velopharyngeal functions, did not show a statistically significant difference in the groups. This assured velopharyngeal closure throughout the active growth period.

Kevin C. Welch, Gary D. Foster et al (2002)[35] studied the upper airway and surrounding soft-tissue structures using novel three-dimensional volumetric analysis techniques with magnetic resonance imaging (MRI). Studied in 12 obese, nonapneic women during wakefulness before and after weight loss. With reduction in weight, upper airway volume increased in both the retropalatal and retroglossal regions were found. This increase in upper airway volume was mediated by significant reductions in the volume of the lateral pharyngeal walland parapharyngeal fat pads. However, the volume of the tongue and soft palate were not reduced significantly with weight loss. These data indicated that volumetric MRI is a powerful tool to study anatomic changes in the upper airway and surrounding soft-tissue structures and is sensitive enough to detect changes in these structures.

Aboudara CA, Hatcher D, Nielsen IL, Miller A (2003)[36]investigated lateral cephalometric headfilms depicting three-dimensional upper airway structure. Airway information over the same anatomic area in the nasopharynx is compared between lateral cephalometricheadfilms and threedimensional cone beam computed tomography (CT) scans. They concluded thatCT airway volume shows more variability than corresponding headfilm airway area.

C. Brian Preston, Judith D. Lampasso, and Phillip V. Tobias (2004)[37] stated that the growth and function of the nasal cavities, the nasopharynx, and theoropharynx are closely associated with the normal growth of the skull.Mouth breathing which has been associated with specific facial growth patterns, may resultfrom obstruction or restriction of any part of the upper airway. The use oflateral cephalometric radiographs to evaluate the upper airway is somewhatlimited as they provide 2-dimensional images of the nasopharynx, whichconsists of complex 3-dimensional anatomical structures. Volumetric radiographic techniques elucidate aspects of the normal and the abnormal, functions of theupper airway.

Elham Saleh Abu Allhaija; Susan Nadeem Al-Khateeb (2005)[38] investigated the uvulo-glosso-pharyngeal dimensions insubjects with different anteroposterior jaw relationship. Cephalometric radiograph of 90 subjectswere divided into three groups according to theANB angle, ie, group 1, skeletal Class I (ANB angle 1–5); group 2, skeletal Class II (ANB angle>5); and group 3, skeletal Class III (ANB angle <1). On average, the vertical airway length (VAL) was reduced in Class II male subjects. In Class II subjects, the hyoid bone was closer to the mandible vertically and to C3 horizontally compared with Class I and Class III male subjects. Anteroposterior skeletal pattern showed a weak, but significant correlation with inferior pharyngeal airway space , vertical position of hyoid bone in relation to mandibular plane and anteroposterior position of hyoid bone in relation to C3. In conclusion, uvulo-glossopharyngeal dimensions are affected by anteroposterior skeletal pattern.

Marcos Roberto de Freitas, Nadyr Maria PenteadoVirmondAlcazar et al (2006)[3] compared upper and lower pharyngeal widths in patients with untreated Class I and Class II malocclusions and normal and vertical growth patterns. The upper and lower pharyngeal airways were assessed according to McNamara'sairways analysis. 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. However, malocclusion type does not influence upper pharyngeal airway width, and malocclusion type and growth pattern do not influence lower pharyngeal airway width.

Muto T, Yamazaki A, Takeda S (2008) [39] assessed the antero-posterior diameter of the pharyngeal airway space (PAS) at the level of the soft palate and base of the tongue in age-matched females with a normal mandible, mandibular retrognathism or mandibular prognathism . All subjects were examined by lateral cephalometry. Pharyngeal airway diameter was largest in the group with mandibular prognathism, followed by the normal mandible and mandibular retrognathism groups. These results indicate that the antero-posterior dimension of the PAS is affected by different skeletal patterns of the mandible.

Cameron Aboudara, Nielsen,John C. Huang,Koutaro Maki et al (2009)[40] compared imaging information about nasopharyngeal airway size between a lateral cephalometric headfilm and a 3-dimensional cone-beam computed tomography scan in adolescent subjects. A moderately high correlation was found between airway area and volume; the larger the area, the larger the volume. However, nine of the 35 patients had over 25% of the potential nasopharyngeal airway volume occupied by inferior turbinate protuberances, leading to significant airway restriction in some patients. They concluded that the cone-beam 3-dimensional scan is a simple and effective method to accurately analyze the airway.

Hung Hsiag Tso, Janice S. Lee, John C. Huang et al (2009)[41]defined and measured human airway space with radiographic volumetric 3-dimensional imaging and digital reconstruction of the pharynx using cone-beam computerized tomography. The maximum constriction of the airway in 10 subjects quietly breathing for 10 seconds indicated variation in the level of the pharynx and the extent of the rostrocaudal zone of restriction.

Dan Grauer, Lucia S. H. Cevidanes, Martin A.Styner (2009)[42]assessed the differences in airway shape and volume among subjects with various facial patterns. Cone-beam computed tomography records of 62 nongrowing patients were used to evaluate the pharyngeal airway volume (superior and inferior compartments) and shape. There was a statistically significant relationship between the volume of the inferior component of the airway and the anteroposterior jaw relationship and between airway volume and both size of the face and sex. No differences in airway volumes related to vertical facial proportions were found. Skeletal Class II patients often had forward inclination of the airwaywhereas skeletal Class III patients had a more vertically oriented airway.Airway volume and shape vary among patients with different anteroposterior jaw relationships; airway shape but not volume differs with various vertical jaw relationships. The methods developed in this study make it possible to determine the relationship of 3-dimensional pharyngeal airway surface models to facial morphology, while controlling for variability in facial size.

Zachary Abramson,Srinivas Susarla, Meredith August et al (2010)[43] identified abnormalities in airway size and shape that correlate with the presence and severity of obstructive sleep apnea (OSA).Digital 3D-CT reconstructions were made and 12 parameters of airway size and 4 of shape were analyzed. The posterior airway space, middle airway space, and hyoid to mandibular plane distance were measured on the lateral cephalograms of the patients with OSA. Of the 44 patients with OSA, 15 had pre- and postoperative CT scans available. In addition, 17 patients were used as controls. The airway length was significantly increased in the patients with OSA.The results of this study was that the presence of OSA is associated with an increase in airway length. Airways that were more elliptical in shape and mediolaterally oriented (greater lateral/retroglossal anteroposterior dimension ratio) had a decreased tendency toward obstruction.

Yoon-Ji Kim,Ji-Suk Hong,Yong-In Hwang and Yang-Ho Park (2010) [44]compared the 3-dimensional pharyngeal airway volumes in healthy children with a retrognathic mandible and those with normal craniofacial growth and investigated possible significant relationships and correlations among the studied cephalometric variables and the airway morphology in these children. Three-dimensional airway volume and crosssectional areas of 27 healthy children were measured by using cone-beam computed tomography volume scans and 2-dimensional lateral cephalograms were created and analyzed. The subjects were divided into 2 groups based on their ANB angles and cephalometric variables, airway volumes, and cross-sectional measurements were compared. The mean total airway volume, extending from the anterior nasal cavity and the nasopharynx to the epiglottis, in retrognathic patients was significantly smaller than that of patients with a normal anteroposterior skeletal relationship. On the other hand, differences in volume measurements of the 4 subregions of the airway were not statistically significant between the 2 groups.

Lenza MG, Lenza de O MM, Dalstra M, Melsen B et al (2010) [45]correlated linear measurements (sagittal and transversal), cross sectional areas, and volumes of the upper airway determined on Cone Beam CT (CBCT) data sets. CBCT-scans of 34 patients were used to perform a 3D evaluation of the upper airway. Linear sagittal measurements reproducing those usually performed on lateral cephalograms, linear transversal measurements, crosssectional areas, partial and total volumes (TV) were computed.The analysis showed a weak correlation between most of the linear measurements. The correlations between sagittal, transversal, and crosssectional area with partial volumes were weak, except for the lower part of the nasopharynx which was highly correlated with sagittal measurement and with area. The upper part of the velopharynx presented a good correlation between area and volume. Good correlation between most transversal measurements and the corresponding areas was found. Minimal sagittal, minimal transversal, and minimal area were weakly correlated with TV.Upper airway cannot be accurately expressed by single linear measurements as performed on cephalograms. The TV alone does not depict the morphology of the airway. A CBCT-based 3D analysis gives a better picture of the anatomical characteristics of the upper airways and therefore can lead to an improvement of the diagnosis.

Ucar FI, Uysal T (2011)[46] tested the null hypotheses that there were no significant differences in craniofacial structures and orofacial airway dimensions in subjects with Class I malocclusion and different growth patterns. Groups were constituted according to the SN-MP angle. High angle subjects had a larger tongue gap than those with normal and low angles. Additionally, nasopharyngeal airway space and upper PAS measurements were larger and palatal tongue space was narrower in low angle than in high angle subjects. The null hypotheses were rejected. Significant differences in craniofacial morphology and orofacial airway dimensions of Class I subjects with different growth patterns were identified.

Kyung-Min Oha; Ji-Suk Honga; Yoon-Ji Kima et al (2011) [47] tested the null hypothesis that the form and size of the pharyngeal airways in preadolescents do not differ among various skeletal patterns. Using cone-beam computed tomography, the inclination and the volume of the pharyngeal airway were measured and compared with craniocervical angles and cephalometric variables. Children with Class II malocclusion have more backward orientation and smaller volume of the pharyngeal airway than do children with Class I and III malocclusion. Inclination of the oropharyngeal airway might be a key factor in determining the form of the entire pharyngeal airway and is related to head posture.

Ahmed Ghoneima and Katherine Kula (2011) [48] evaluated the accuracy and reliability of airway volume digital measurements of cone- beam computed tomography (CBCT) compared with the manual measurements of an airway model. An acrylic airway model was constructed and attached to a human dry skull in the natural position of the airway passage. The total and internal airway volumeswere measured manually on the model and on the CBCTs taken after the model was attached to the skull. The CBCT images were analysed using the Dolphin 3D software. No significant statistical difference was found between the total, the internal airway volume and the most constricted airway area measured on CBCTs compared with the manual measurement. These results suggested that the three -dimensional CBCT digital measurements of the airway volume and the most constricted area of the airway are reliable and accurate. The use of CBCT imaging for the assessment of the airway can provide clinically useful information in orthodontics.

Nicola A. Miller, Jennifer S. Gregory, Scott I. K. Semple, Richard M. Aspden et al (2012)[49] investigated vocal structures within this wider context and assess the airway. and breathing quietly. With reference points based on cephalometry, 17 craniocervical, craniocaudal, and anteroposterior variables were chosen to describe craniofacial morphology, craniocervical posture, and airway dimensions. Increasing airway size (hyocervical distance) was associated with greater distances from the cranial base of the hyoid, larynx, epiglottis tip and uvula tip, and of C3 from the menton. A wider velopharyngeal opening was associated with a shorter and higher soft palate, and a greater (lower) craniocervical angle was associated with a wider laryngeal tube opening, narrower airway at the uvula tip and shorter distances of the hyoid and uvula tip from the cranial base.

Memon S, Fida M, Shaikh A (2012) [50] compared different craniofacial patterns with pharyngeal widths. Data were collected using pre-treatment records and divided into 2 groups: skeletal Class I and skeletal Class II and subdivided according to the vertical pattern into normodivergent, hyperdivergent and hypodivergent facial patterns. Upper and lower pharyngeal airways were measure using McNamara's airway analysis. Hyperdivergent facial pattern subjects belonging either to skeletal Class I or Class II malocclusion showed a statistically significant narrow upper pharyngeal airway width as compared to normodivergent and hypodivergent facial patterns. However, no statistically significant difference was found in lower pharyngeal airway widths in sagittal and various vertical facial patterns.

Claudino LV, Mattos CT, Ruellas AC, Sant' Anna EF (2013)[51] characterized the volume and the morphology of the pharyngeal airway in adolescent subjects, relating them to their facial skeletal pattern. Fifty-four subjects who had cone-beam computed tomography were divided into 3 groups-skeletal Class I, Class II, and Class III-according to their ANB angles. The volumes of the upper pharyngeal portion and nasopharynx, and the volume and morphology of the lower pharyngeal portion and its subdivisions (velopharynx, oropharynx, and hypopharynx) were assessed with software.The Class II subjects had smaller minimum and mean areas (lower pharyngeal portion, velopharynx, and oropharynx) than did the Class III group and significantly less uniform velopharynx morphology than did the Class I and Class III groups. A negative correlation was observed between the ANB value and airway volume in the lower pharyngeal portion and the velopharynx (both sexes) and in the oropharynx (just in male subjects).

Karen Regina Siqueira de Souza, Paula Vanessa PedronOltramari, NavarroRicardo de Lima Navarro et al (2013) [52] assessed the reliability of a method to measure the following upper airway dimensions: total volume (TV),the nasopharyngeal narrowest areas (NNA), and the oropharyngeal narrowest areas (ONA). The sample consisted of 60 cone-beam computed tomography (CBCT) scans, evaluated by two observers twice, using the Dolphin 3D software which afforded image reconstruction, and measurement of the aforementioned dimensions. The data demonstrated an agreement between the two assessments of each observer and between the first evaluations of both observers, thus confirming the reliability of this methodology.The results suggested that this methodology can be used in further studies to investigate upper airway dimensions (TV, NNA, and ONA), thereby contributing to the diagnosis of upper airway obstructions.

Kula, Katherine, Ahn, EunJeong, Halum, Stacey et al (2013)[53] determineddifferences in the volume of various upper airway segments and the most constricted area (MCA) of children with different dental and skeletal patterns. The initial CBCTs of 83 orthodontic patients (Angle's Class I [n = 30]; Class II [n = 26]; and Class III [n = 27]) were collected from a private orthodontic office. Following reliability studies, various parameters of the craniofacial complex, airway volume, and MCA were measured utilizing Dolphin three-dimensional (3D) software. Maxillary right sinus volume was the only airway segment showing significant difference among different dental classes. Maxillary sinus volume also correlated moderately with anterior facial height and mandibular length. No significant differences were found between the MCA and different dentoskeletal classifications.

L. Eslamian, MR. Badiee, S. Yousefinia, MJ. Kharazifard (2014)[54] measured and compared nasopharyngeal, oropharyngeal and hypopharyngeal airway volumes in Iranian subjects with sagittal(Class I, II and III) and vertical (normodivergent, hyperdivergent and hypodivergent) jaw discrepancies using standard cephalometric radiographs. Subjects were divided into two large groups of normal sagittal and normal vertical patterns. Linear variables i.e. the size of nasopharyngeal space (PNS-UPW), oropharyngeal space (U-MPW) and hypopharyngeal space (V-LPW) were measured by cephalometric tracing. In patients with normal sagittal pattern, by an increase in vertical dimension, size of nasopharynx (PNS-UPW), oropharynx (U-MPW) and hypopharynx (V-LPW) decreased and the mentioned volumes were significantly smaller in subjects with hyperdivergent facial patterns compared to hypodivergents. In subjects with normal vertical pattern, by an increase in ANB angle, size of oropharynx (U-MPW) and hypopharynx (V-LPW) decreased and the mentioned volumes in CL II patients were significantly smaller than in CL III subjects; whereas, the largest nasopharynx (PNS-UPW) was observed in CL I subjects.Sagittal and vertical discrepancies affect upper and lower airway dimensions and by an increase in facial height, the mentioned volumes decrease. Smaller ANB angle results in larger airway dimensions.

Saba Yousuf Shaikh, Arshad Mahmood Malik, Owais Khalid et al (2014)[55] evaluated the widths of the upper pharyngeal airways in patients with skeletal Class II and Class III malocclusions. The sample comprised of sixty subjects divided into 2 groups (30 Class II and Class III respectively). The upper pharyngeal airway was assessed according to McNamara’s airways analysis. Results showed a statistically significant difference in upper airway space between two groups showing Class II cases to have narrower upper airway space as compared to Class III cases. Subjects with Class II skeletal malocclusions have significantly narrower upper pharyngeal airways than those with Class III malocclusions.

GianguidoCossellu, Roberto Biagi, Michele Sarcina et al(2015)[56] tookten Italian patients with moderate or severe OSA who cannot tolerate continuous positive air pressure therapy and rejected a surgical approach, were treated with non-adjustable customized OAs and evaluated with CBCT and polysomnography. Upper airway form was examined in the presence and absence of OA and the volume was measured and compared in 2 different areas. Specific planes have been considered to match the data and calculate the benefit obtained with therapy. Nine out of ten patients showed an improvement of total upper airway volume and an improvement in apnea-hypopnea index. Volume increased both in the posterior soft palate region and in the posterior tongue region. In the inferior area, we observed greater differences. 3D image reconstruction accurately confirmed morphological changes in the upper airway during OA therapy. The use of this 3D evaluation is expected to improve the results of OA therapy in the future.

Nayanna Nadja e Silva, Rosa Helena WanderleyLacerda, Alexandre Wellos Cunha Silva et al (2015)[57]assessed the upper airways measurements of patients with skeletal Class II malocclusion in order to investigate the association between measurements and the position and length of the mandible as well as mandibular growth trend, comparing the Class II group with a Class I .Individuals withmandibular Class II malocclusion were shown to have upper airways measurements diminished. There was a correlation between mandibular length and position and the size of oropharynx and nasopharynx.

Eva Dalmau, Natalia Zamora, Beatriz Tarazona, Jose L. Gandia, Vanessa Paredes(2015)[58] determined any existing association between airway dimensions, measured with cone beam computed tomography (CBCT), and the different patient craniofacial morphologies. Measurements at three different levels of the airway (upper, medium, lower) were taken, in both the anteroposterior and transversal directions of the airway space. The area (mm^2) of the airway space at the three levels was also measured.In the anteroposterior airway measurements, there were differences between the measurements by level and depended on the skeletal pattern of the individual. In the transversal airway measurements and in the area airway measurements, there were no differences according to the skeletal pattern. However, in the transversal direction, measurements in the lower level were significantly higher than in the superior level in all cases. When measuring the area, significantly higher measurements in the upper level were recorded. The homogeneity between medium and lower levels decreased gradually from class I to class III subjects. No statistically significant results were observed that related the anteroposterior and vertical skeletal craniofacial morphology with airway dimensions.

Jaipal Singh Tarkar, Sandeep Parashar, Garima Gupta et al (2016)[59] evaluated the upper and lower pharyngeal airway dimensions, posture of tongue and hyoid bone position in young adults with different growth patterns. Lateral cephalogram were analysed for evaluation of upper and lower pharyngeal airway, tongue posture and hyoid bone position. The results showed that upper oropharyngeal widths were significantly different in different facial skeletal patterns. Subjects with vertical skeletal pattern have significantly narrower upper airways than those with horizontal skeletal pattern. The upper oropharyngeal width was found to be narrower in subjects with vertical growth pattern. Variations are seen in upper and lower oropharyngeal widths, posture of the tongue and hyoid bone position in all the growth patterns.

Yasas Shri NalakaJayaratne, Roger Arthur Zwahlen (2016)[60] determined the accuracy and reliability of an automated anthropometric measurement software for the oropharyngeal airway and compared the anthropometric dimensions of the oropharyngeal airway in skeletal class II and III deformity patients. Cone-beam CT

(CBCT) scans of 62 patients with skeletal class II or III deformities were used for this study. The total oropharyngeal volume was significantly greater in the skeletal class III deformity group compared with class II subjects.The average surface area of both the RG and RP compartments were significantly larger in the class III deformity group. The most constricted area in the RG and RP airway was significantly larger in individuals with skeletal class III deformity. The anterior-posterior (AP) length of this constriction was significantly greater in skeletal class III individuals in both compartments, whereas the width of the constriction was not significantly different between the two groups in both compartments. The RP compartment was larger but less uniform than the RG compartment in both skeletal deformities. Significant differences were observed in morphological characteristics of the oropharyngeal airway in individuals with skeletal class II and III deformities.

Romeo Patini, MariantoniettaArrica, Enrico Di Stasio et al (2016)[61] assessed the effectiveness of MRI in evaluating upper airway structures in children affected by obstructive sleep apnoea syndrome (OSAS). UsedMRI with traditional polysomnography (PSG) among children up to 15 years of age affected by OSAS. The primary outcome to be evaluated was the efficacy of MRI in analyzing the upper airway total volume among healthy children compared with children affected by OSAS. Secondary outcomes were to compare the efficacy of MRI in analyzing the upper airway cross-sectional area in the areas adjacent to the adenoids and tonsils, adenoid and tonsil volume, and soft-tissue and maxillofacial bone parameters in the same sample. The meta-analysis found evidence of MRI effectiveness in evaluating differences in the upper airway total volume between paediatric patients affected by OSAS and paediatric patients not affected by OSAS. Although MRI could be considered effective in evaluating upper airway structures in children affected by OSAS, based on the present evidence, PSG is still the golden standard and further studies are required to verify MRI reliability.

MojtabaMohamadiArdehali, VarastehVakiliZarch, Mohammad-esmaeilJoibari et al (2016)[62] investigated craniofacial growth deformities in children with upper airway obstruction. Cephalometry is used as a screening test for anatomic abnormalities in patients with obstructive sleep apnea syndrome to investigate the effect of upper airway obstruction on craniofacial morphology. Patients with upper airway compromise had mandibular hypoplasia, mandibular retrognathism, and higher hard palates in comparison with controls with no history of airway obstruction. The difference was higher in the older age group. Airway obstruction has significant correlation craniofacial morphology.

Jose E. Barrera, Candace Y. Pau, Veronique-Isabelle Forest et al (2017)[63]determined if anatomic dimensions of airway structures are associated with airway obstruction in obstructive sleep apnea (OSA) patients. Skeletal and soft tissue dimensionswere measured from radiocephalometry and magnetic resonance imaging. The soft palatethickness, mandibular plane-hyoid (MP-H) distance, posterior airway space (PAS) diametersand area, and tongue volume were calculated.Compared to controls, the OSA group demonstrated a significantly longer MP-H distanceand shorter nasal PAS diameter.The PAS area was smallerand tongue volume larger in the OSA group. The MP-H distance,PAS measurements, and tongue volume are of clinical relevance in OSA patients.A long MP-H distance, and small PAS diameters and area are significant anatomicmeasures in OSA; however, the most substantial parameter found was a large tongue volume.

Alok Kumar, Mrinal Kr Nandi (2017)[64] evaluated the effect of craniofacial morphology on pharyngeal airway space (PAS) in individuals with normal sagittal skeletal pattern. A total of 30 adult female patients with skeletal Class I jaw relationship were included in the study. Lateral cephalograms were obtained and various soft and hard tissue points were identified and linear and angular measurements carried out to evaluate the pharyngeal airway space. The study concluded that craniofacial morphology does not have any significant bearing on the pharyngeal airway space. At best its role in pharyngeal airway discrepancies can be defined as secondary and contributory.

SuatAvci, HaticeLakadamyali&HuseyinLakadamyali et al (2018)[65] classifiedRP airway patterns using quantitative magnetic resonance imaging (MRI). They recruited 117 males; 20 simple snorers and 97 patients with OSA. Lateral/anteroposterior ratios were calculated inthree parallel planes and RP patterns were classified accordingly. Lateral wall soft tissue structures, skeletal dimensionsrepresenting those planes, pharyngeal lengths, and skeletal and vertical axis ratios were also measured. They found that the cross-sectional area at the hard palate level and the RP lateral dimension were associated with OSA. OSApatients had longer pharynges than controls. The oblique pattern was associated with narrow lateral dimensions. The verticalpattern was associated with a narrow nasopharynx but a longer pharynx. The airway ratio at the hard palate level and the skeletalratios of all three planes were negatively correlated with the vertical axis ratio and together explained 40.8%of the variance in thevertical axis ratio.

Sona Molaei(2018)[66] comparedairway volume and length in patients with obstructive sleep apnea (OSA) with healthy people using cone-beam computed tomography (CBCT) images. This descriptive cross-sectional study was carried out on CBCT scans of 50 patients in which the mean area, mean volume, and total length of the upper airway were measured. The findings of this study revealed that the area and length of the upper airway were higher in patients with OSA than in healthy people, but the volume of airway in healthy subjects was higher than those with OSA. As well as, the vertical and horizontal length of soft palate was higher in people with OSA than in healthy people. The anteroposterior distance in patients with OSA was lower than normal subjects. The final results of this study indicated that the area and length of the upper airway were higher in people with OSA than in healthy people, meaning that people with a longer upper airway have a higher risk of developing OSA.

Juhi Ansar, Raj Kumar Singh, Preeti Bhattacharya et al (2018)[67] compared the pharyngeal airway dimensions by cephalometric examination ofindividuals with different morphological patterns. The sample were divided into three distinct groups, according to their morphological patterns, that is, hypodivergent, normodivergent and hyperdivergent. The upper and lower pharyngeal airways were assessed according to McNamara's airways analysis. The results showed that the upper and lower pharyngeal width in hyperdivergent growth patterns subjects was statistically significantly narrower than in the normodivergent and hypodivergent growth pattern groups. Subjects with vertical growth patterns have significantly narrower upper and lower pharyngeal airways than those with Class II malocclusions and horizontal and normal growth patterns. These patients may be more prone to mouth breathing as a result of their relatively diminished pharyngeal dimensions.

MATERIALS AND METHODS

The present study was carried out to evaluate and compare the upper and lower pharyngeal airway volume, width and area in skeletal Class I and Class II hypo-divergent and hyper-divergent skeletal pattern. A total of 60 patients between the age group of 16 to 30 years which were grouped into skeletal Class I (n=20), Class II hypo-divergent (n=20) and hyper-divergent skeletal pattern(n=20) were selected from the Department of Orthodontics and Dentofacial Orthopaedics of our institute. The study was initiated after the clearance from the Institutional Ethics Committee.

INCLUSION CRITERIA:

- Patients aged 16 -30 years.
- Patients desiring orthodontic treatment.
- Patients with skeletal Class I and II hypodivergent and hyperdivergent facial form.

EXCLUSION CRITERIA:

- Patients with history of orthodontic treatment.
- Patients with congenital anomalies.
- Patients with history of adenoidectomy or tonsillectomy.
- Patients with nasal obstruction or any other symptoms of respiratory pathology.
- Patients with history of surgery in the head and neck region.
- Patients with neuromuscular disorder.
- Patients with history of trauma.

METHODS:

Samples were classified according to the following parameters:

Establishment of study groups:

Antero-posterior and vertical skeletal type was established from the pre-treatment lateral cephalogram.

1. Antero-posterior skeletal type: The study sample was categorized in Class I and II skeletal patterns with ANB angular measurements. This refers to the skeletal Class or the relationship between the maxilla and the mandible with respect to the cranial base. For that, the Steiner'sANB angle was used (Class I = 2º ± 2 º, Class II >4º) [68].
2. Vertical skeletal pattern. This refers to the vertical craniofacial growth of themandible with respect to the cranial base. Sella-Nasion to Gonion-Gnathion angle (SN.GoGn) that is the angle between SN and Steiner's mandibular planes was used to divide the sample into hypodivergent,

normodivergent,hyperdivergent growth patterns with values of <32°, 32° and >32° respectively.

Lateral cephalometric radiographs were taken in a cephalostat (Kodak 8000c G-XR-29461 machine). All subjects were positioned in the cephalostat with the sagittal plane at a right angle to the path of the x-rays and the Frankfort plane was parallel to the horizontal plane and the teeth were in centric occlusion. All radiographs were manually traced and whole angular and linear measurements were recorded by a single investigator and were reviewed twice by other investigators for accurate landmark identification.

Acquiring image data:

Studies were performed using a 1.5 Tesla magnetic resonance imaging scanner (GE health care)(fig.1). Since head and neck position may alter upper-airway soft-tissue configuration and upper-airway geometry[69,70], subjects were aligned in the Frankfort plane (a plane bisecting the soft tissue of the orbit and the tragus of the ear, perpendicular to the scanner table) prior to the scanning. Foam pads were placed between the patient's head and volume neck coil was received each side to ensure that head movement did not occur during the MRI scanning. Throughout the scan, patients remained in the supine position and were instructed to breathe normally through their nose and were encouraged to refrain from swallowing. All images were taken during wakefulness which was ensured with frequent communication with the subjects. Each study was initiated with a 3.5-minute sagittal localizing spin echo scan [TR (repetition time)=400.0 ms, TE (echo time)=16.0 ms, 256x128 matrix, 1 NEX, flip angle=90°, FOV(field of view)=24.0 cm, slice thickness of 3.0 mm, and 1.5 mm, skip to establish the rostral and caudal margins of the upper airway (roof of the nasopharynx and the base of larynx). Subsequently, a 4.0-minute contiguous axial T1-weighted spin echo data set(TR=400.0 ms, TE=16.0 ms, 0.5 NEX, flip angle=90°, FOV=24.0 cm, slice thickness of 5.0 mm and 0.0 mm skip) was acquired from the roof of the nasopharynx to the vocal cords.

Anatomic Definitions and Measurements:

To build 3D models of the airways for the 60 subjects, the MRI data were loaded into Insight SNAP software (version 1.4.0, Cognitica, Philadelphia, Pa). There are 2 interactive steps to the segmentation: selection of an initial threshold and placement of initial seed regions[71]. The segmentation process is then defined as the construction of 3D virtual surface models (called segmentations) by regional growth of the initial seed regions to match best the volumetric data. This segmentation method has been described, validated, and tested for accuracy which is superior to the conventional slice-by-slice, manual tracing method. The limits for segmentation and an example of a virtual surface model of the pharyngeal airway are shown in the following figure.

Once segmented, the pharyngeal airways were refined to obtain the true shape of the airway by eliminating projections that did not belong to the airway and then were subdivided into superior and inferior compartments by a plane perpendicular to the sagittal plane that included the posterior nasal spine and the lower medial border of the fourth cervical vertebra.

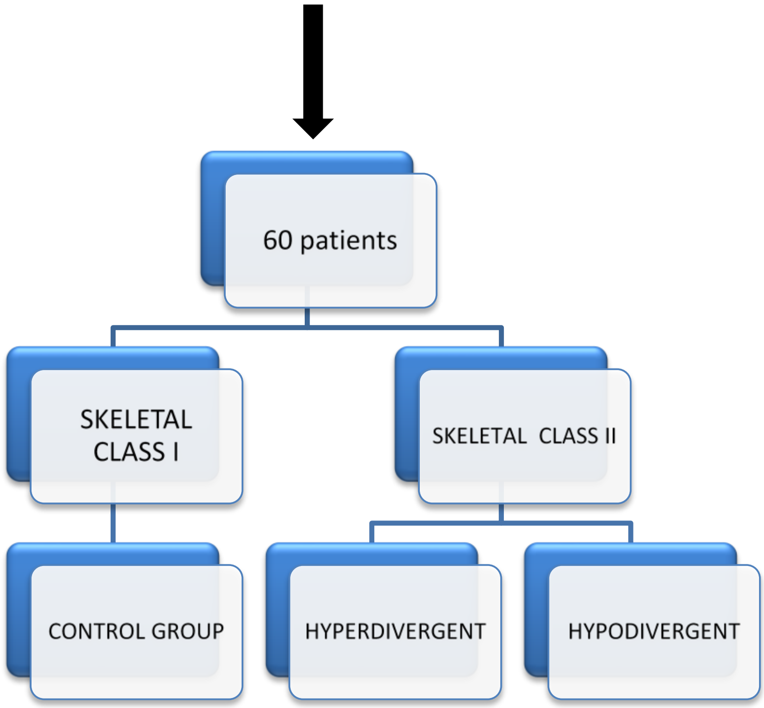
Airway volumes were measured in cubic milli-meters with the Insight SNAP measuring tool. The limits adopted for the upper pharyngeal portion were those proposed by El and Palomo[72](fig2). The upper limit of upper pharyngeal portion was defined in the sagittal view as the line uniting the posterior nasal spine and the So (middle point of the sella-basion line) points[45]and its posterior limit was defined in the sagittal view as a line approximately perpendicular to the palatal plane that intersects the So point and the lower limit of the nasopharynx segment was the palatal plane(fig3). The lower pharyngeal portion's upper limit was the palatal plane extended to the posterior pharyngeal wall, and the lower limit was the plane parallel to the palatal plane that intersected the lower and most anterior point in the fourth cervical vertebra and epiglottis(fig4).

The airway transverse width (fig6)and area (fig5) were determined at the same levels, that is at the hard palate (upper) and lower and most anterior point in the fourth cervical vertebra (lower) were measured.

These measurements were made on an axial section and the average distances were registered.

ASSAY PROCEDURE SUMMARY –

Patients were selected from the Department of Orthodontics and Dentofacial Orthopaedics of our institute.



Patients undergone MRI scanning

MRI data was loaded into Insight SNAP software

3D models of the airway for the 60 subjects were builded

The pharyngeal airways were than subdivided into upper and lower compartments

Airway volumes, area and width were measured with the Insight SNAP measuring tool

Figure 1 – MRI machine

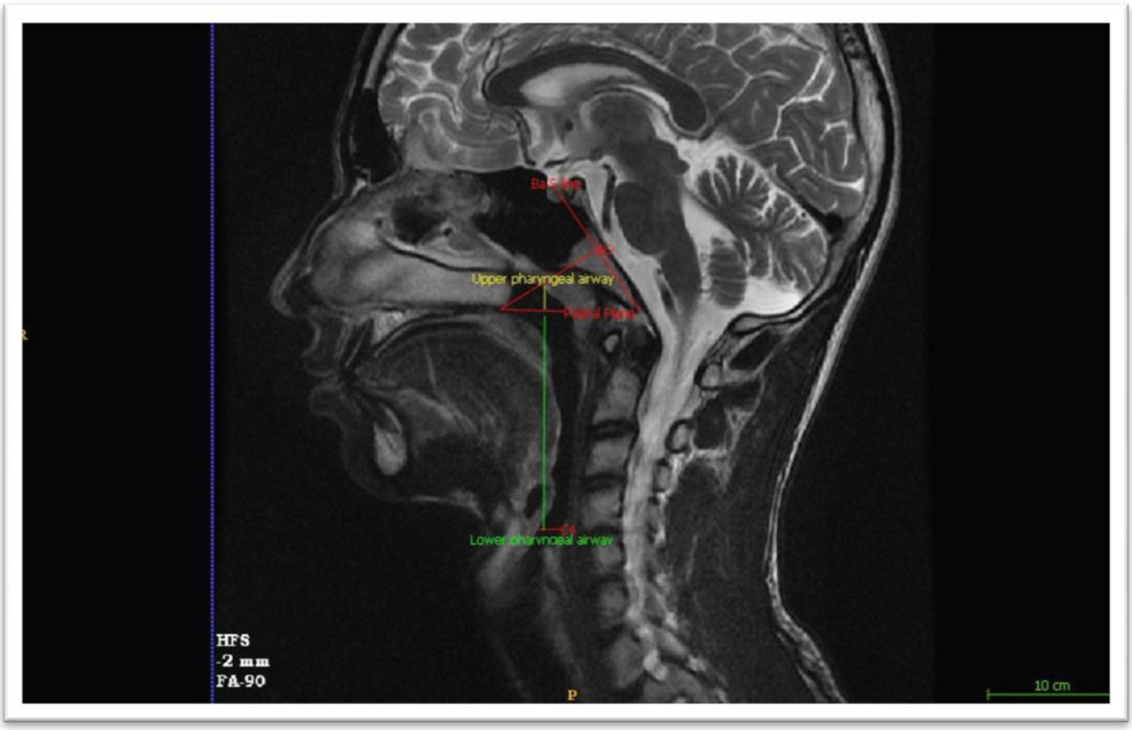


Figure 2 – Landmarks of MRI

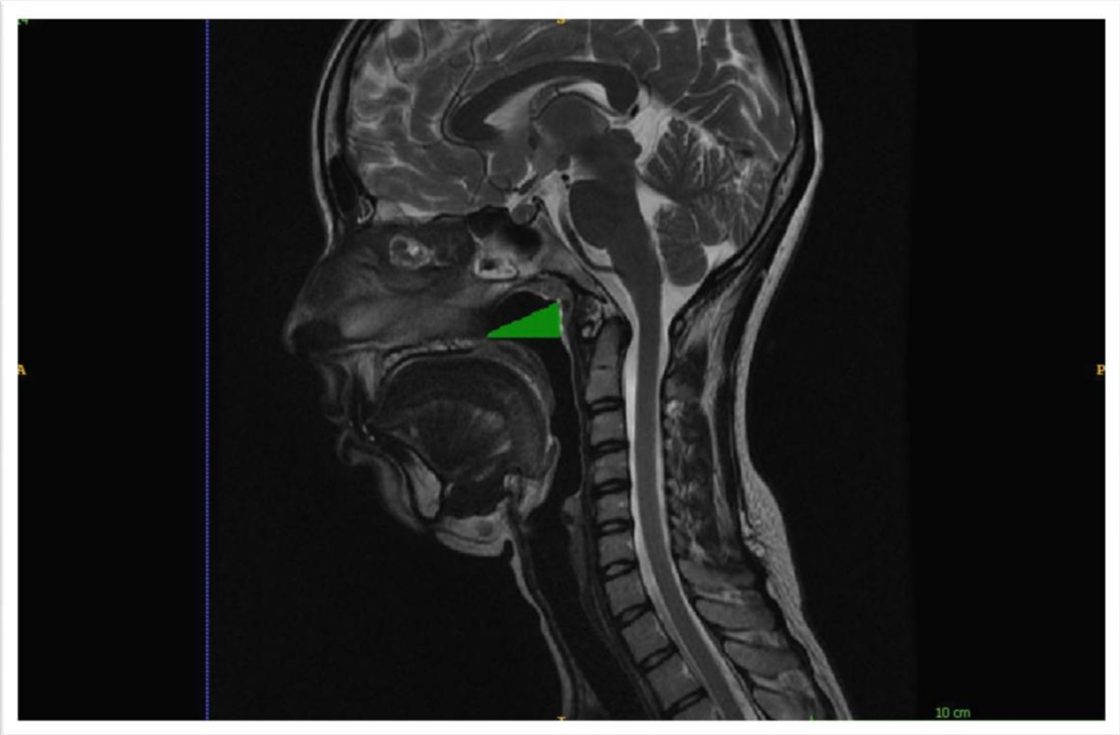


Figure 3 –Measuringof upper pharyngeal airway (Saggital view)

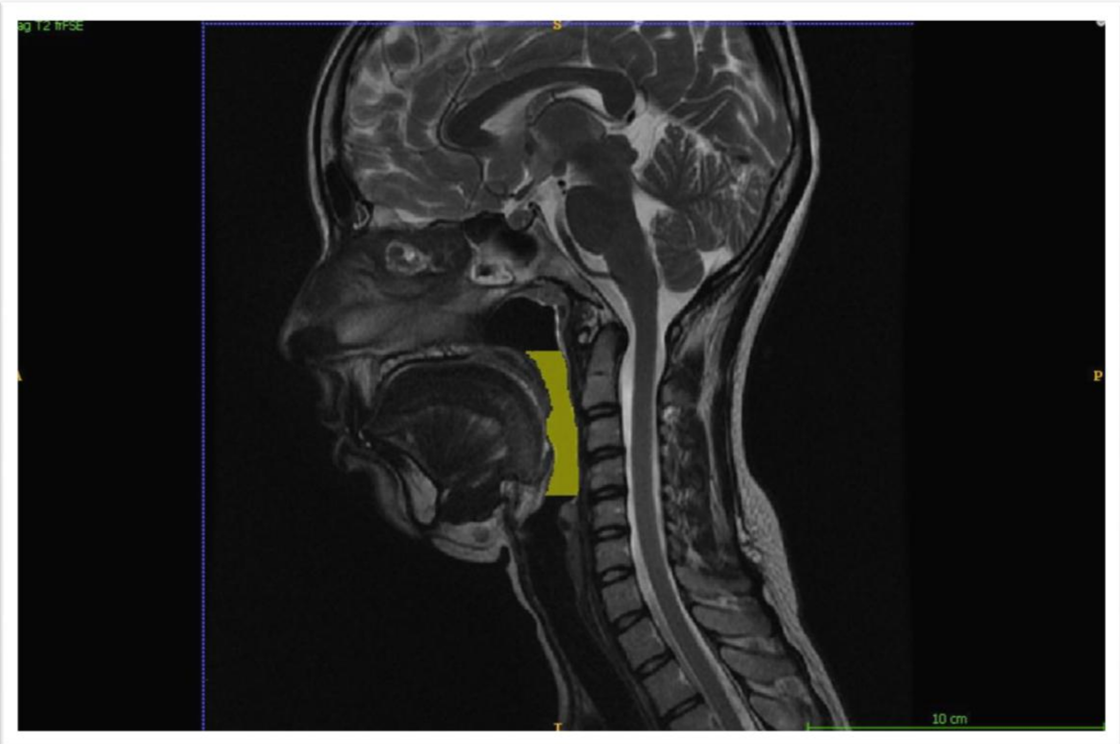


Figure 4 –Measuring of lower pharyngeal airway (Saggital view)

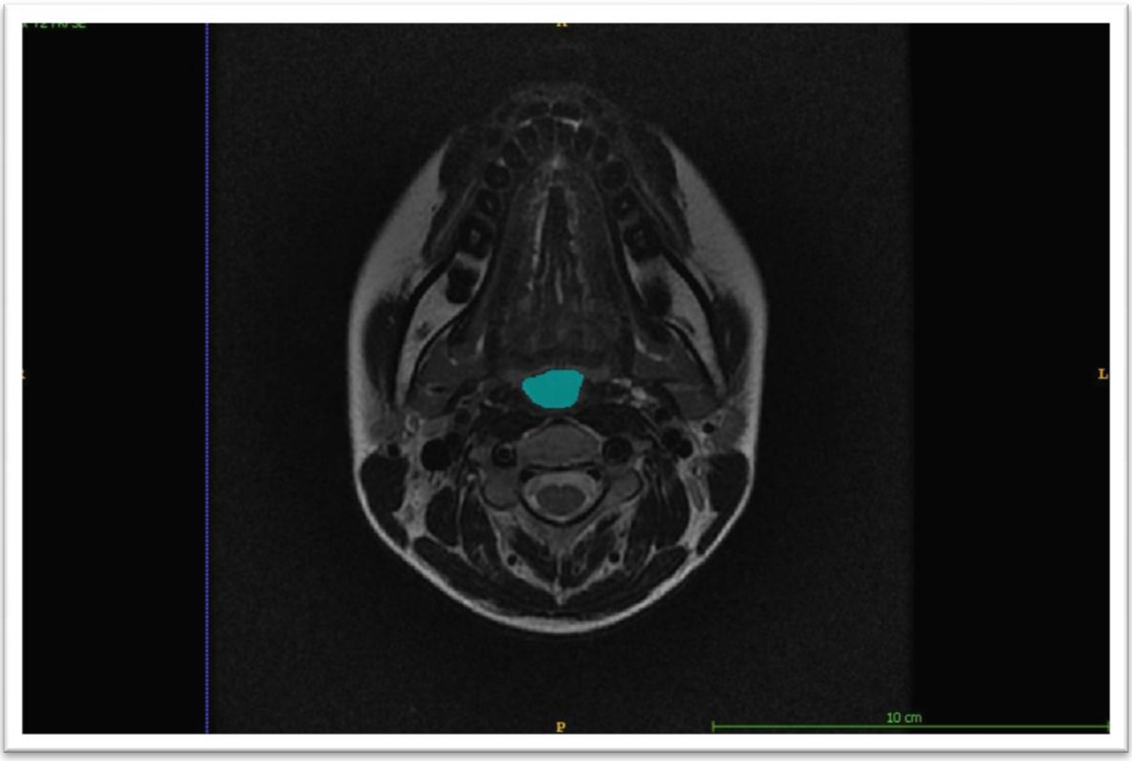


Figure 5 – Measuring of pharyngeal airway (Axial view)

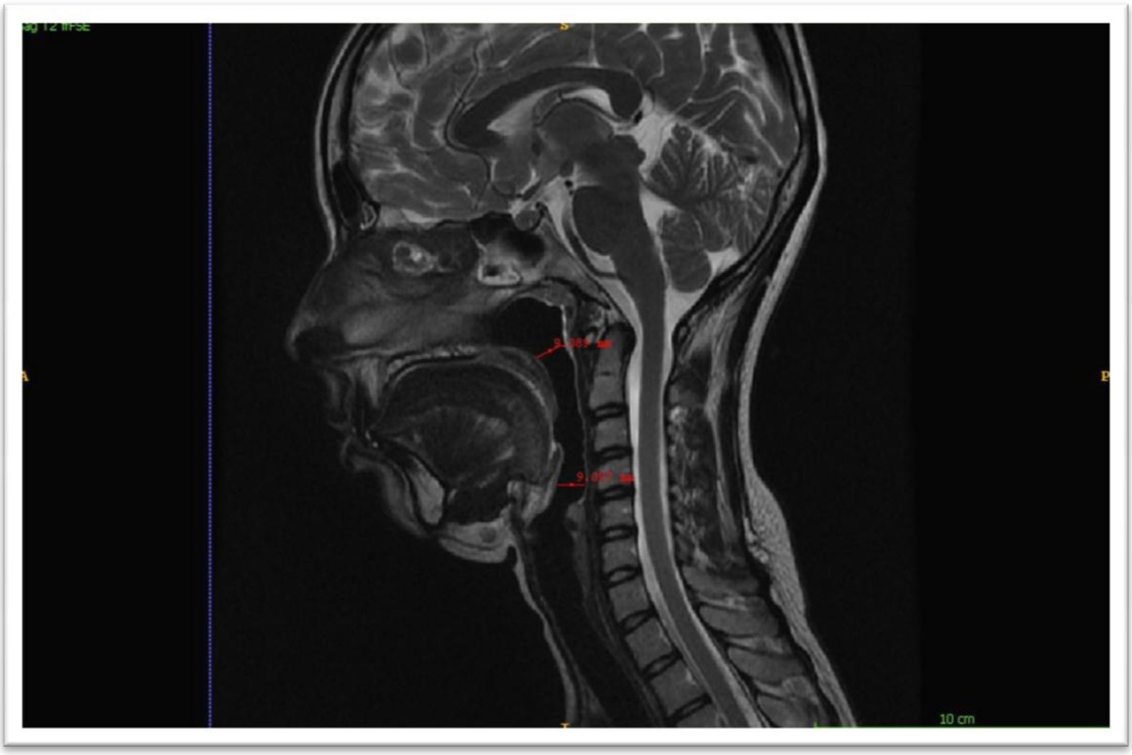


Figure 6 -Upper and lower pharyngeal airways width

STATISTICAL METHODS

SPSS for Windows, Version 16.0. Chicago, SPSS Inc software was used to analyse the data to evaluate and compare the upper and lower pharyngeal airway volume, width and area in skeletal Class I and Class II hypo-divergent and hyper-divergent skeletal pattern.

Statistical analysis was done by using tools of descriptive statistics such as Mean, and SD for representing quantitative data (e.g. volume, area, width of pharyngeal airway)

One-way ANOVA test was applied to compare measurements of means of three differentmalocclusion groups. Probability p< 0.05, considered as significant as alpha error set at 5% with confidence interval of 95% set in the study. Power of the study was set at 80% with beta error set at 20%.

Post hoc data analysis which follows One way ANOVA was done by using Tukeys multiple comparison test was also used. Post hoc test analyses multiple pair – wise individualcomparison at two different time interval each.

RESULTS

The aim of the present study was to assess a relationship between airway dimension in its volume, area and width according to the different craniofacial skeletal pattern morphologies of patients, both anteroposterior that is skeletal class I and II and vertical growth pattern.

The results showed that there is a significant relationship between airway volume, anteroposteriorand vertical facial dimensions. In this study, the comparison of volumetric analysis of upper and lower pharyngeal airway in skeletal Class I (control group) and skeletal Class II hypodivergent and hyperdivergent growth patterns was evaluated using Anova F test and found that there exist highly significant statistical difference ($p < 0.001$) between groups.

Table 1(a): Comparisonof volumetric analysis ofupper pharyngeal airway in skeletal Class I (control) and ClassII with differentgrowth patterns

GROUPS	MEAN	Standard Deviation (S.D)	ANOVA F TEST	P value, Significance
CLASS I (CONTROL)	8682.9	40.0	F = 13620.0	p < 0.001, highly significant
CLASS II (HYPODIVERGENT)	7575.3	29.24		
CLASS II (HYPERDIVERGENT)	7109.4	20.58		

p >0.05 – not significant p <0.05 – significant p <0.001 – highly significant

On comparison of volumetric analysis of upper pharyngeal airway in skeletal class I with different vertical growth patterns using Anova F test, it was found that there exist highly significant statistical difference (p < 0.001) between group**.**

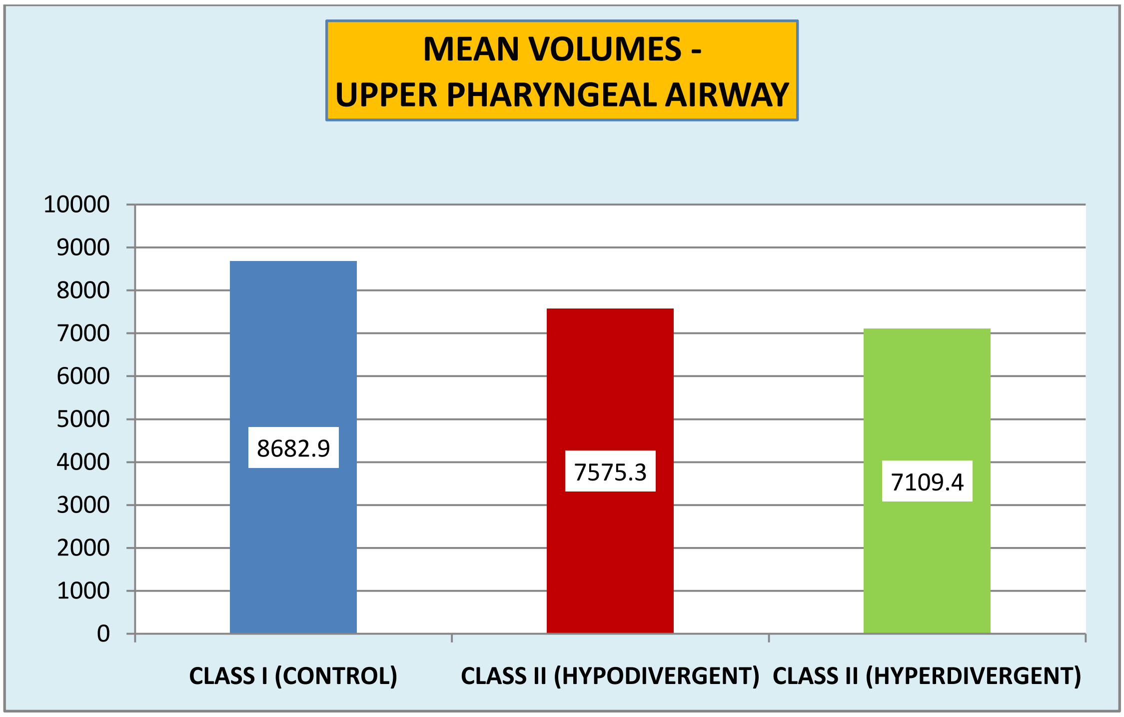
Table 1(b): Individual pair wise comparison of volumetric analysis of upper pharyngeal airway

Tukey'spost hoc test to find individual pair wise comparison			
GROUP	**COMPARISON GROUP**	**MEAN DIFFERENCE**	**p value, Significance**
CLASS I (CONTROL)	CLASS II (HYPODIVERGENT)	1107.6	p < 0.001**
	CLASS II (HYPERDIVERGENT)	1573.5	p < 0.001**
CLASS II (HYPODIVERGENT)	CLASS II (HYPERDIVERGENT)	465.92	p < 0.001**

p >0.05 – not significant p <0.05 – significant p <0.001 – highly significant

On individualpair wise comparison of volumetric analysis of upper pharyngeal airway in skeletal class I with different vertical growth patterns using Tukey's post hoc test , it was found that there exist highly significant statistical difference ($p < 0.001$) between any twotypes of group.

Table 1 provided the value for volume of upper pharyngeal airwayforskeletal Class I (control group) was 8682.9, forskeletal Class II hypodivergent it was 7575.3 with a standard deviation of 29.24 and for skeletal Class II hyperdivergent it was 7109.4 with a standard deviation of 20.58. This concluded that skeletal Class II hyperdivergent group has the lowest mean volume when compared with the skeletal Class II hypodivergent and the skeletal Class I.



GRAPH 1: Comparisonof volumetric analysis ofupper pharyngeal airway in skeletal Class I (control) and Class II with differentgrowth patterns.

Table 2(a): Comparison of volumetric analysis of lower pharyngeal airway in skeletal Class I (control) and ClassII with different growth patterns

GROUPS	MEAN	Standard Deviation (S.D)	ANOVA F TEST	P value, Significance
CLASS I (CONTROL)	11694.4	15.10	F = 52770.0	p < 0.001, highly significant
CLASS II (HYPODIVERGENT)	9771.9	24.23		
CLASS II (HYPERDIVERGENT)	9617.4	26.58		

p >0.05 – not significant p <0.05 – significant p <0.001 – highly significant

On comparison of volumetric analysis oflower pharyngeal airway in skeletal class I with different vertical growth patterns using Anova F test, it was found that there exist highly significant statistical difference (p < 0.001) between group.

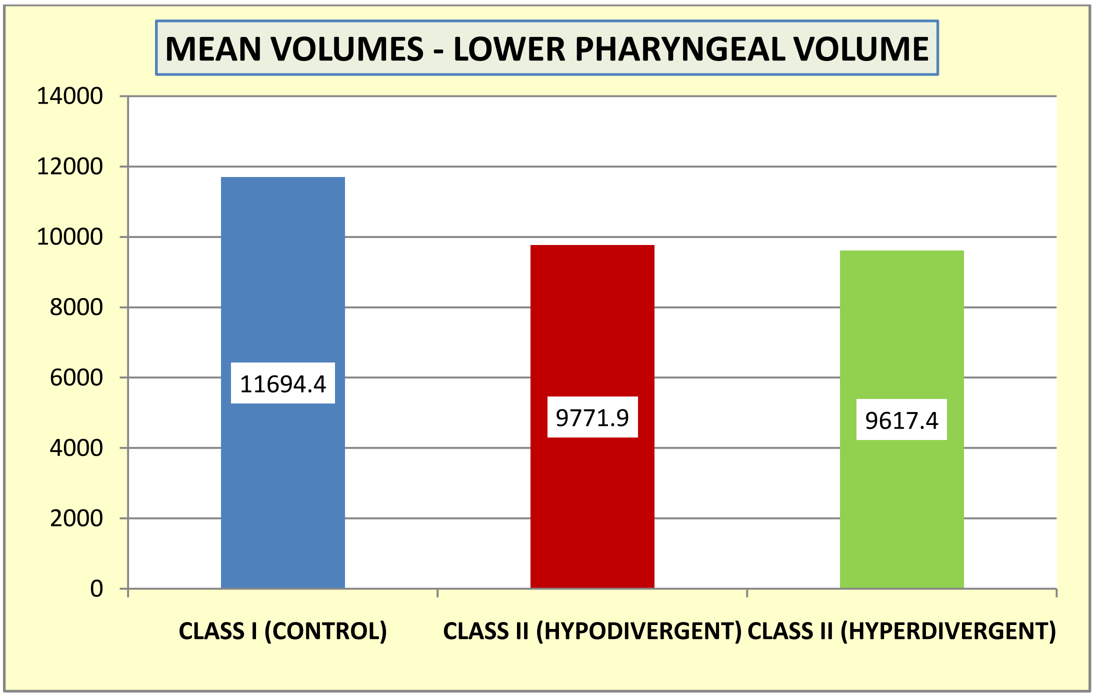
Table 2(b): Individual pair wise comparison of volumetric analysis of lower pharyngeal airway.

Tukey'spost hoc test to find individual pair wise comparison			
GROUP	**COMPARISON GROUP**	**MEAN DIFFERENCE**	**p value, Significance**
CLASS I (CONTROL)	CLASS II (HYPODIVERGENT)	1922.20	p < 0.001**
	CLASS II (HYPERDIVERGENT)	2076.67	p < 0.001**
CLASS II (HYPODIVERGENT)	CLASS II (HYPERDIVERGENT)	154.47	p < 0.001**

p >0.05 – not significant p <0.05 – significant p <0.001 – highly significant

On individualpair wise comparison of volumetric analysis oflowerpharyngeal airway in skeletal class I with different vertical growth patterns using Tukey's post hoc test , it was found that there exist highly significant statistical difference (p <0.001) between any twotypes of group.

Table 2 provided the value formean volume of lower pharyngeal airway for class I (Control group) was found to be 11694.4 with standard deviation of 15.10. For class II hypodivergent it was 9771.9 with a standard deviation of 24.23 & for Class II hyperdivergent it was 9617.4 with a standard deviation of 26.58. The analysis resulted into a p value < 0.001, indicating statistically significant differences between the groups. It showed lowest mean volume in skeletal Class II hyperdivergent group when compared with the skeletal Class II hypodivergent and the skeletal Class I.



Graph 2:Comparisonof volumetric analysis oflower pharyngeal airway in skeletal Class I (control) and Class II with differentgrowth patterns.

Table 3(a): Comparative analysis of area of pharyngeal airway in skeletal Class I (control) and ClassII with different growth patterns.

GROUPS	MEAN	Standard Deviation (S.D)	ANOVA F TEST	P value, Significance
CLASS I (CONTROL)	151.69	3.09	F = 1590.0	p < 0.001, highly significant
CLASS II (HYPODIVERGENT)	110.05	4.90		
CLASS II (HYPERDIVERGENT)	79.82	3.94		

p >0.05 – not significant p <0.05 – significant p <0.001 – highly significant

On comparison of volumetric analysisrelated to area of pharyngeal airwayin skeletal class I with different vertical growth patterns using Anova F test, it was found that there exist highly significant statistical difference (p < 0.001) between group.

Table 3(b): Individual pair wise comparison related to area of pharyngeal airway

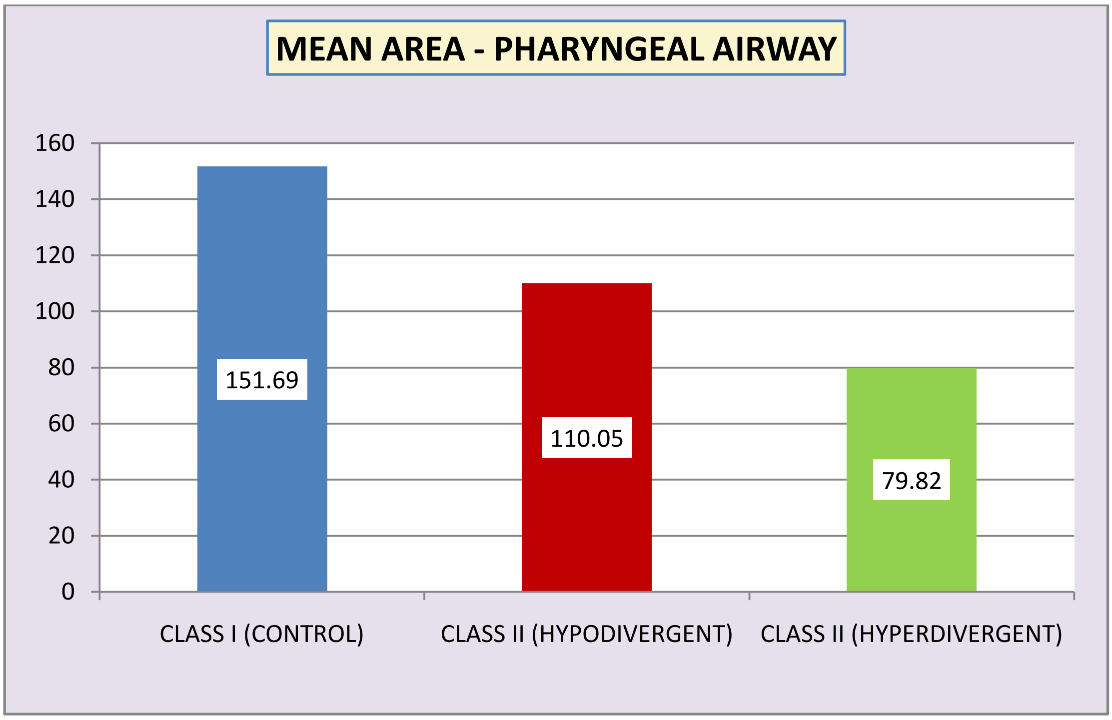
Tukey'spost hoc test to find individual pair wise comparison			
GROUP	**COMPARISON GROUP**	**MEAN DIFFERENCE**	**p value, Significance**
CLASS I (CONTROL)	CLASS II (HYPODIVERGENT)	41.64	p < 0.001**
	CLASS II (HYPERDIVERGENT)	71.87	p < 0.001**
CLASS II (HYPODIVERGENT)	CLASS II (HYPERDIVERGENT)	30.23	p < 0.001**

p >0.05 – not significant p <0.05 – significant p <0.001 – highly significant

On individualpair wise comparison of volumetric analysis related to area of pharyngeal airwayin skeletal class I with different vertical growth patterns using

Tukey's post hoc test , it was found that there exist highly significant statistical difference (p <0.001) between any twotypes of group.

Table 3 provided the value for mean area of pharyngeal airway for Class I (Control group) was found to be 151.69 with standard deviation of 3.09. For Class II hypodivergent it was 110.05 with a standard deviation of 4.90 & for Class II hyperdivergent it was 79.82 with a standard deviation of 3.94. The analysis resulted into a p value < 0.001, indicating statistically significant differences between the groups. It showed lowest mean area in skeletal Class II hyperdivergent group when compared with the skeletal Class II hypodivergent and the skeletal Class I.



Graph 3: Comparison of mean area of pharyngeal airway in skeletal Class I(control) and Class II with different growth patterns.

Table 4(a): Comparative analysis of width of upper pharyngeal airway in skeletal Class I (control) and ClassII with different growth patterns

GROUPS	MEAN	Standard Deviation (S.D)	ANOVA F TEST	P value, Significance
CLASS I (CONTROL)	15.80	0.82	F = 227.84	p < 0.001, highly significant
CLASS II (HYPODIVERGENT)	13.66	0.49		
CLASS II (HYPERDIVERGENT)	11.33	0.62		

p >0.05 – not significant p <0.05 – significant p <0.001 – highly significant

On comparison of volumetric analysis of width ofupper pharyngeal airway in skeletal class I with different vertical growth patterns using Anova F test, it was found that there exist highly significant statistical difference (p < 0.001) between group.

Table 4(b):Individual pair wise comparison related to width of upper pharyngeal airway

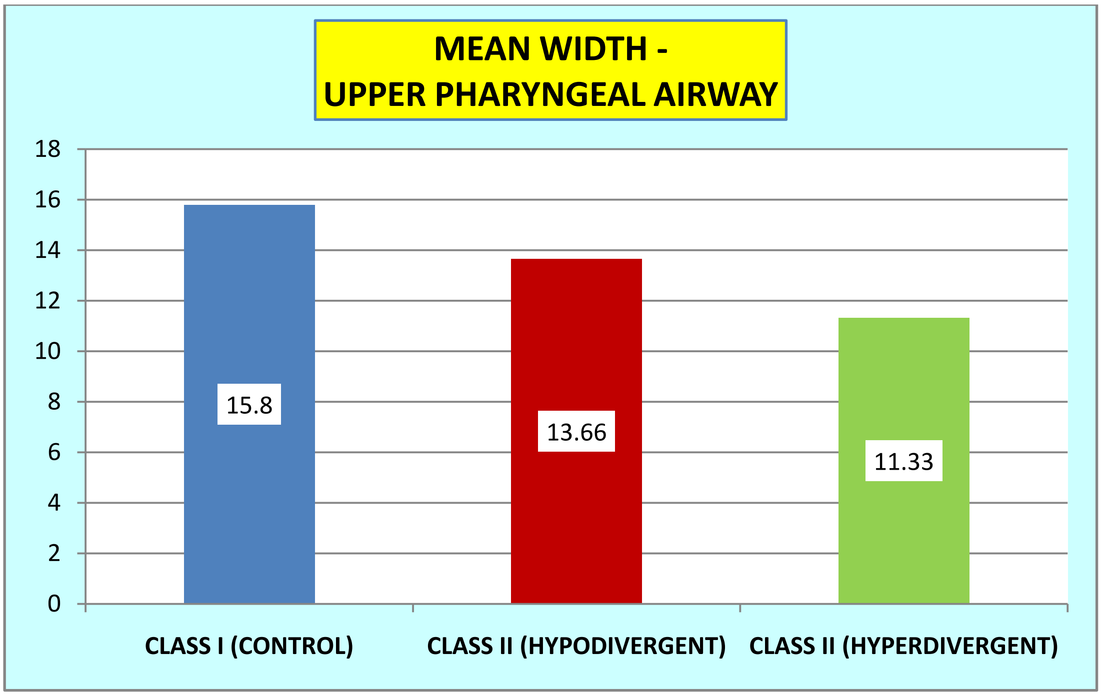
Tukey'spost hoc test to find individual pair wise comparison			
GROUP	**COMPARISON GROUP**	**MEAN DIFFERENCE**	**p value, Significance**
CLASS I (CONTROL)	CLASS II (HYPODIVERGENT)	2.13	p < 0.001**
	CLASS II (HYPERDIVERGENT)	4.46	p < 0.001**
CLASS II (HYPODIVERGENT)	CLASS II (HYPERDIVERGENT)	2.33	p < 0.001**

p >0.05 – not significant p <0.05 – significant p <0.001 – highly significant

On individualpair wise comparisonof volumetric analysis of width ofupper pharyngeal airway in skeletal class I with different vertical growth patterns using

Tukey's post hoc test , it was found that there exist highly significant statistical difference (p <0.001) between any twotypes of group.

Table 4 providedthe mean width of upper pharyngeal airway for class I (Control group) was found to be 15.80 with standard deviation of 0.82. For Class II hypodivergent, it was 13.66 with a standard deviation of 0.49 & for Class II hyperdivergent, it was 11.33 with a standard deviation of 0.62. The difference of mean volume was statistically evaluated using Anova F test. The analysis resulted into a p value < 0.001, indicating statistically significant differences between the groups. It showed lowest mean width in skeletal Class II hyperdivergent group when compared with the skeletal Class II hypodivergent and the skeletal Class I.



Graph 4: Comparison of mean width of upper pharyngeal airway in skeletal Class I(control) and Class II with different growth patterns.

Table 5(a): Comparative analysis of width of lower pharyngeal airway in skeletal Class I (control) and ClassII with different growth patterns

GROUPS	MEAN	Standard Deviation (S.D)	ANOVA F TEST	P value, Significance
CLASS I (CONTROL)	11.61	0.53	F = 597.94	p < 0.001, highly significant
CLASS II (HYPODIVERGENT)	8.21	0.35		
CLASS II (HYPERDIVERGENT)	6.47	0.51		

p >0.05 – not significant p <0.05 – significant p <0.001 – highly significant

On comparison of volumetric analysis of width oflower pharyngeal airway in skeletal class I with different vertical growth patterns using Anova F test, it was found that there exist highly significant statistical difference (p < 0.001) between group.

Table 5(b): Individual pair wise comparison related to width of lower pharyngeal airway

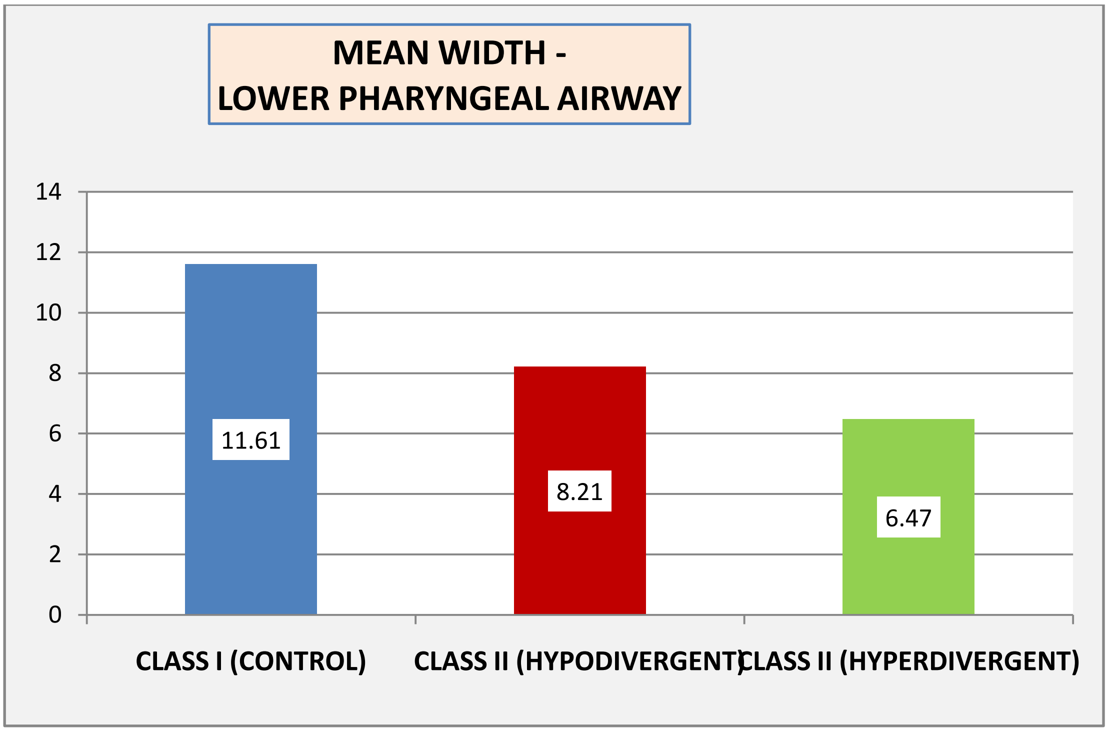
Tukey'spost hoc test to find individual pair wise comparison			
GROUP	**COMPARISON GROUP**	**MEAN DIFFERENCE**	**p value, Significance**
CLASS I (CONTROL)	CLASS II (HYPODIVERGENT)	3.4	p < 0.001**
	CLASS II (HYPERDIVERGENT)	5.14	p < 0.001**
CLASS II (HYPODIVERGENT)	CLASS II (HYPERDIVERGENT)	1.73	p < 0.001**

p >0.05 – not significant p <0.05 – significant p <0.001 – highly significant

On individualpair wise comparisonof volumetric analysis of width oflower pharyngeal airway in skeletal class I with different vertical growth patterns using

Tukey's post hoc test, it was found that there exist highly significant statistical difference (p <0.001) between any twotypes of group.

Table 5 providedthe mean width of lower pharyngeal airway for Class I (Control group) was found to be 11.61 with standard deviation of 0.53. For Class II hypodivergent, it was 8.21 with a standard deviation of 0.35 & for class II hyperdivergent, it was 6.47 with a standard deviation of 0.51. The difference of mean volume was statistically evaluated using Anova F test. The analysis resulted into a p value < 0.001, indicating statistically significant differences between the groups. It showed lowest mean width in skeletal Class II hyperdivergent group when compared with the skeletal Class II hypodivergent and the skeletal Class I.



Graph 5: Comparison of mean width of lower pharyngeal airway in skeletal Class I (control) and Class II with different growth patterns.

DISCUSSION

The relationship between pharyngeal dimensions and the dentofacial pattern in OSA patients has been of interest to orthodontists. Numerous studies have reported on the relevance of pharyngeal dimensions to various sagittal and vertical facial growth patterns at varying degrees [73,74] like hyperdivergent patients with certain skeletal features, such as retrusive mandible and vertical maxillary excess, may have narrower anterioposterior airway dimensions [30]. Thus, knowledge of pharyngeal dimensions amongst the sagittal and vertical facial types is of great importance for orthodontist, especially for orthodontic diagnosis and treatment planning.

Solow and Sandham et al (2002) [75] showed that the craniocervical angle is relatively small in subjects with mandible prognathism and large in subjects with mandible retrognathism. They hypothesized that a change in head posture affects the craniocervical angle and the position of the jaw and tongue. A postural change such as head extension causes a down-backward rotation of the mandible which leads to stretching of the lips, cheeks, and musculature and affects malocclusion and growth pattern. Then, the airway is opened and stabilized as necessary to compensate for the reduced respiratory function caused by the constricted airway and to maintain the airway.

During last decades, numerous ways have been used for airway assessing[76-80]. At first, airway measurement was performed on the lateral cephalograms by linear measurement. But this method had severe limitations such as using 2-D representations of 3-D structures, differences in magnifications, superimposition of bilateral craniofacial structures, and low reproducibility due to difficulties in landmark identification[81].New 3-D imaging approaches including CBCT have become efficient modalities for airway assessments as its images have negligible magnification with a 1:1 ratio in all three planes of space[82]. However, it exposes patients to radiation and poor contrast resolution;magnetic resonance imaging (MRI)[83] has been introduced which can characterize and discriminate among tissues using their physical and biochemical properties and produces sectional images of equivalent resolution in any projection which adds to its versatility and diagnostic utility and does not use ionizing radiation.

In this study, MRI was performed with the patient in an supine position. In the supine position, there is a decreaseoropharyngeal airway whereas the thickness of both the tongue and soft palate increases due to either gravitational force or changes in upper airway reflexes, which may predispose to increased collapsibility of the upper airway[83]. The nasopharynx is surrounded by bony structures, whereas the oropharyngeal airway is surrounded by soft tissues, which probably explains why the oropharynx is more predisposed to external factors such as posture. A supine MRI thus provides more physiologic information since it is obtained in the usual sleeping posture.

The age of the individuals taken for the study were from 16-30years, so all measurements performed on them were taken with the airway growth complete, as previously described by (Sheng et al, 2009)[84].

The aim of the present study was to assess a relationship between airway dimension in its volume, area and width according to the different craniofacial skeletal pattern morphologies of patients, both anteroposterior that is skeletal class I and II and vertical growth pattern.

In this study, the results showed that there is a significant relationship between airway volume, anteroposterior and vertical facial dimensions. The comparison of volumetric analysis of upper and lower pharyngeal airway in skeletal Class I (control group) and skeletal Class II hypodivergent and hyperdivergent growth patterns was evaluated using Anova F test and was found that there exist highly significant statistical difference ($p < 0.001$) between groups.

In this study, the value found for volume of upper pharyngeal airwayin skeletal Class I (control group) was 8682.9, in skeletal Class II hypodivergent it was 7575.3 with a standard deviation of 29.24 and in skeletal Class II hyperdivergent it was 7109.4 with a standard deviation of 20.58. This concluded that skeletal Class II hyperdivergent group has the lowest mean volumewhen compared with the skeletal Class II hypodivergent and the skeletal Class I.

When the mean volume of upper pharyngeal airway of skeletal Class I control group was compared with the skeletal Class II hypodivergent, the mean difference was 1107.6, which was found to be highly significant with p value <0.001. So, there was reduced mean volume in skeletal Class II hypodivergent when compared with skeletal Class I. Similarly, when skeletal Class I control group was compared with the Class II hyperdivergent, the mean difference was 1573.5, which showed reduced airway volume in skeletal Class II hyperdivergent. When skeletal class II hypodivergent was compared with the skeletal Class II hyperdivergent, the mean difference of the group was 465.92, which showed reduced airway volume in skeletal Class II hyperdivergent.

Joseph et al[30] reported that the nasopharyngeal airway in hyperdivergent individuals was significantly narrower than normodivergent individuals. However, they suggested that this difference occurred because of the relative bimaxillary retrusion exhibited by the hyperdivergent group. Their conclusions were similar to those of the present study where smaller nasopharyngeal airway space was found in high angle subjects when compared with low angle and normal growth subjects.

MG Lenza (2010)[45] et al performed a 3D evaluation of the upper airway and showed similar result with high correlations between sagittal, transversal, and cross-sectional area with reduced volumein nasopharynx in skeletal Class II.

Kim et al (2010)[44] assessed pharyngeal volume and cross-sectional areas with CBCT in 27 children. They reported that total pharyngeal volume (nasal cavity, nasopharynx and oropharynx) in retrognathic children were significantly smaller than those with a normal skeletal pattern. They also noted that pharyngeal volumetric measurements significantly correlated with the ANB angle and anterior facial height.

Ucaret al (2011)[46] studied on Class I subjects with different vertical growth patterns. They reported larger nasopharyngeal airway space in low angle subjects than in high angle subjects. Also, when the craniofacial skeleton was assessed it demonstratedreduced SNA, SNB, and posterior facial height this can be attributed to the fact that there is decrease in dimensions of the superior part of the upper airway in high angle subjects.

The mean volume of lower pharyngeal airway in Class I (Control group) was found to be 11694.4 with standard deviation of 15.10, in Class II hypodivergent it was 9771.9 with a standard deviation of 24.23 & in Class II hyperdivergent it was 9617.4 with a standard deviation of 26.58. The analysis resulted into a p value < 0.001, indicating statistically significant differences between the groups. It showed lowest mean volume in skeletal Class II hyperdivergent group when compared with the skeletal Class II hypodivergent and the skeletal Class I. The highest mean volume was seen in skeletal Class I.

When the mean volume of lower pharyngeal airway of skeletal Class I control group was compared with the skeletal Class II hypodivergent, the mean difference was 1922.20, which was found to be highly significant with p value <0.001. So, there was reduced mean volume in skeletal Class II hypodivergent when compared with skeletal Class I. Similarly, when skeletal Class I control group was compared with the Class II hyperdivergent, the mean difference was 2076.67, which showed reduced airway volume in skeletal Class II hyperdivergent. When skeletal class II hypodivergent was compared with the skeletal Class II hyperdivergent, the mean difference of the group was 154.47, which showed reduced airway volume in skeletal Class II hyperdivergent.

Similar result was found in other study, Grauer et al (2009)[42] observed differences in airway volume and shape according to different maxillary relationships. They analyzed the total pharyngeal volume in 62 CBCT scans after classifying them into Class I, II and III skeletal patterns. They also divided the same sample into long, short and normal face types based on the facial index. The pharyngeal volume did not correlate with the subject's age or gender. The volume of Class II subjects in the inferior compartment was significantly smaller, but it did not statistically differ among the short, normal and long face types.

Zhong et al (2010)[85] showed that the vertical and sagittal skeletal patterns could contribute to the variation of the airway dimensions.

El and Palomo(2011) [86]using a sample of adolescents between 14–17 years reported that Class II subjects had a significantly lower oropharyngeal volume than Class I and Class III subjects. These volumes were significantly smaller in individuals with retruded mandibles than those with a high SNB angle. The most constricted region of the oropharynx was located at the level of the tongue base.

Alves et al(2012)[87] found that patients with deficient mandibular growth had a lower airway volume.Although the mandible has both retruded and rotated in downward and backward directions, the tongue base might be positioned more posteriorly and inferiorly; thus, the oropharyngeal airway space may have decreased.

Claudino et al(2015)[51] stated that Class II subjects had smaller volume and minimum and mean areas (lower pharyngeal portion, velopharynx, and oropharynx) than the Class III group. Oh et al(2011)[47] found similar results, since children with Class II malocclusion had more backward orientation and smaller volume of the pharyngeal airway than children with Class I and III malocclusion.

The mean area of pharyngeal airway in Class I (Control group) was found to be 151.69 with standard deviation of 3.09. In Class II hypodivergent it was 110.05 with a standard deviation of 4.90 & in Class II hyperdivergent it was 79.82 with a standard deviation of 3.94. The analysis resulted into a p value < 0.001, indicating statistically significant differences between the groups. It showed lowest mean area in skeletal Class II hyperdivergent group when compared with the skeletal Class II hypodivergent and the skeletal Class I.

Kerr[88]investigated the relationship between the nasopharyngeal and dentofacial structures on the subjects with normal and Class II malocclusions and found that the subjects with Class II malocclusion had a larger nasopharyngeal airway area than the subjects with normal occlusions.

Ceylan and Oktay[4] found that changes in the ANB angle may affectthe oropharyngeal space which was reduced in subjects with an increased ANB angle. This can be explained with the Balters philosophy [89] which states that Class II malocclusions have the following predisposing factors such as backward position of the tongue that disturbs the cervical region which in turn reduces the airway dimension, whereas Class III malocclusions are due to forward positioning of the tongue and result in greater airway dimensions.

Joseph et al [30]reported that aretropositioned maxilla can lead to anarrowing of the nasopharynx and oropharynx. Thisfeature is compounded by a more horizontal angulationof the soft palate in thehyperdivergent group, which reduces the anteropoteriordimension of this region of the airway.

Ucar and Uysal [46] reported a significant difference between low angle and high angle in Class I groups at the level of the nasopharyngeal airway space. The nasopharyngeal airway space decreased from low-angle to normal to high-angle cases and highlighted the effect of the vertical pattern on upper airway space.

The mean width of upper pharyngeal airway in Class I (Control group) was found to be 15.80 with standard deviation of 0.82. In Class II hypodivergent, it was 13.66 with a standard deviation of 0.49 & in Class II hyperdivergent, it was 11.33 with a standard deviation of 0.62. The difference of mean volume was statistically evaluated using Anova F test. The analysis resulted into a p value < 0.001, indicating statistically significant differences between the groups. It showed lowest mean width in skeletal Class II hyperdivergent group when compared with the skeletal Class II hypodivergent and the skeletal Class I.

The mean width of lower pharyngeal airway in Class I (Control group) was found to be 11.61 with standard deviation of 0.53. In Class II hypodivergent, it was 8.21 with a standard deviation of 0.35 & in Class II hyperdivergent, it was 6.47 with a standard deviation of 0.51. The difference of mean volume was statistically evaluated using Anova F test. The analysis resulted into a p value < 0.001, indicating statistically significant differences between the groups. It showed lowest mean width in skeletal Class II hyperdivergent group when compared with the skeletal Class II hypodivergent and the skeletal Class I.

Similar result was found where Joseph et al[30] reportedthat decrease in oropharyngeal width may be due to the posterior vertical maxillary excess which is common to hyperdivergent patients. The resultant rotated mandible causes the base of the tongue to be positioned more posteriorly and inferiorly.

Opdebeeck and Bell[90] in a comparative study of short and long face individuals concluded that a short ramus in the long face syndrome might be accompanied by a decreased crossection of the lower pharynx.

Akcamet al[34]reported a decrease in the upper airway dimensions of subjects who had posterior mandibular rotation. This reveals a close association between the pharyngeal airway and jaw position.

Juhi Ansar [91]et al found that Subjects with vertical growth patterns have significantly narrower upper and lower pharyngeal airways than those with Class II malocclusions and horizontal and normal growth patterns. These patients may be more prone to mouth breathing as a result of their relatively diminished pharyngeal dimension.

Increased nasopharyngeal linear widths in brachyfacial pattern, in comparison to other vertical facial patterns, might be the result of a deficient anteroposterior development of the craniomaxillary complex in brachyfacial pattern. Facial growth changes may also be related to differences in the direction of condylar growth, and may result from differences in development of anterior facial height and posterior facial height[68].These differences in vertical development may lead to rotational growth or positional changes of the mandible, which could affect the airway dimensions. This resulted that the mandibular positional changes are more likely to affect the oropharynx than the nasopharynx.

These finding of present study led to the conclusion that Class II subjects are more susceptible to the development of obstructive sleep apnea syndrome than patients with other skeletal patterns.

So, Orthodontists must be aware of the risk factors pertaining to reduced airway and should define an appropriate treatment plan by not compromising on the airway dimensions especially on patients who are prone to it[92]. Airway analysis should be a part of diagnosis and treatment planning especially in patients prone to reduced airway like skeletal Class II pattern so that the risk of developing OSA in these patients can be minimized. Correcting early Class II using functional appliances can help in reducing the chances of airway problems in future.

Longitudinal studies of airway changes in subjects with different skeletal patterns in specific craniofacial growth and development periods should be performed to know the detailed knowledge of the relationship between upper airway morphology and function and craniomaxillofacial characteristics.

LIMITATION

1. Limitation of present study is the lack of control group due to ethical issues, relatively high cost, as well as the limited availability of MRI technique.

2. MRI images were obtained when patients were awake and there is no way to find out whether their tongue was in the standard position as patients were in supine position.

3. In order to find the relationship of structural information with function, it would be ideal if these MRI findings would have been correlated with the findings of polysomnography. Due to cost considerations and the fact that polysomnography requires overnight hospital admission this was not feasible.

SUMMARY

The nasopharynx and the oropharynx have a significant locations and functions because both of them form a part of the unit in which respiration and deglutition are carried out. A significant relationship exists between the pharynx and Dentofacial and skeletal structures. The nasopharyngeal airway has been claimed to affect the growth of craniofacial structures. It is also established that the posture of the tongue can also influence the dental relationship and facial skeletal pattern of an individual and vice versa can also happen.

Hence, the present study was carried out to evaluatepharyngeal airway dimensions andcompare the volumetric analysis of pharyngeal airway in skeletal class I and II individuals with different vertical growth patterns.A total of 60 patients between the age group of 16 to 30 years having skeletal Class I , Class II hypodivergent and Class II hyperdivergentgrowth pattern were selected from those visiting the Department of Orthodontics and Dentofacial Orthopaedics of our institute.

Studies were performed using a 1.5 Tesla magnetic resonance imaging scannerand the MRI data were loaded in the software for 3D models of airway which were analysed. Following observations were seen –

1. Lowestmean volume, area and width of upper and lower pharyngeal airway in skeletal Class II hyperdivergent group when compared with the skeletal Class II hypodivergent and the skeletal Class I..

2. This is due to the retruded mandible and downward and backward directions of mandible which resulted posterior and inferior position ofthe tongue base.

CONCLUSION

The findings for the study lead to following conclusion –

1. There is a significant relationship between airway volume, anteroposterior and vertical facial dimensions.

2. Lowest mean volumeand width of upper and lower pharyngeal airway in skeletal Class II hyperdivergent group was seen when compared with the skeletal Class II hypodivergent and the skeletal Class I.

3. The highest mean area was seen in skeletal Class I group followed by skeletal Class II hypodivergent and lowest seen in skeletal Class II hypodivergent

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ANNEXURE

Department of Orthodontics and Dentofacial Orthopaedics

Informed Consent Form

(Confidential)

"Evaluation, comparison and volumetric analysis of pharyngeal airway in skeletal class I and II individuals with different vertical growth patterns: A MRI Study".

Mr./Mrs./Miss.____

Resident of: ____

____aged _____ years,

Exercising my free will/choice, without any pressure/lure of incentive in any form, hereby give my consent to be included as a subject in the said clinical study.

I acknowledge the receipt of "patient's information sheet", and also that the doctor has informed me about this research project suitably and sufficiently to my satisfaction. I agree to take part in this project and will not mix any other projects during the period of this trial. I permit to publishing the results of my participation in this study. I shall not be given any reimbursement or compensation. I hereby record my consent for participation in the said trial.

I hereby record my consent for participation in the said trial.

1. __________________ __________________ ______ _____

Patient's Name Signature/Thumb Print Date Time

2. __________________ __________________ ______ _____

Witness' Name Signature/Thumb Print Date Time

3. _________________ __________________ ______ _____

Principal/ InvestigatorName Signature/Thumb Print Date Time

CLASS I CONTROL GROUP

Patient number	Volume of upper pharyngeal		Volume of lower pharyngeal		Area		Width of upper pharyngeal		Width of lower pharyngeal	
	Obs 1	**Obs 2**	**Obs 1**	**Obs2**	**Obs 1**	**Obs2**	**Obs 1**	**Obs 2**	**Obs 1**	**Obs2**
1	8572	8574	11659	11657	154.61	153.64	14.81	14.83	12.24	12.22
2	8623	8620	11712	11711	147.76	147.78	15.24	15.26	11.83	11.89
3	8594	8592	11678	11679	152.18	152.16	15.73	15.7	12.51	12.5
4	8699	8700	11697	11699	148.65	149	15.29	15.26	11.56	11.54
5	8710	8709	11710	11711	149.92	149.94	16.45	16.48	12	12.1
6	8687	8685	11693	11692	150.83	150.85	15.91	15.87	12.43	12.4
7	8695	8693	11702	11700	153.47	153.5	16.68	16.66	11.37	11.4
8	8715	8712	11717	11718	148.56	148.58	14.54	14.53	11	11.3
9	8712	8722	11684	11685	150	150.23	17	17.1	11.34	11.32
10	8702	8700	11697	11695	149.23	149.5	15.93	15.9	11.96	12
11	8683	8682	11681	11684	156.33	156.33	16.78	16.75	11.53	11.55
12	8696	8700	11695	11692	155.77	156.21	17.19	17.2	11.77	11.79
13	8685	8688	11704	11702	152.44	152.41	15.33	15.43	12.27	12.29
14	8679	8680	11675	11671	151.02	151.05	16.27	16.25	10.82	10.8
15	8714	8711	11699	11700	154.09	154.01	16	16.4	11.21	11.23
16	8704	8700	11687	11684	152.82	153	14.84	14.85	10.75	10.77
17	8692	8696	11679	11680	146.02	146.04	15	15.2	11.97	12
18	8711	8710	11707	11709	157.29	157.32	16.74	16.45	10.88	10.87
19	8678	8680	11711	11713	154.09	154.11	15.76	15.75	11.44	11.42
20	8705	8707	11697	11700	153.83	153.86	16.02	16.04	11.69	11.7

CLASS II HYPODIVERGENT GROUP

Patient number	Volume of upper pharyngeal		Volume of lower pharyngeal		Area		Width of upper pharyngeal		Width of lower pharyngeal	
	Obs 1	**Obs2**	**Obs 1**	**Obs2**	**OBS 1**	**OBS 2**	**Obs 1**	**Obs2**	**Obs 1**	**Obs2**
1	7512	7510	9723	9720	108.1	108.11	13.34	13.2	8.52	8.53
2	7564	7565	9757	9756	112.43	112.4	13.96	14	8.75	8.77
3	7590	7593	9784	9783	110.3	110.33	14	14.1	8.47	8.5
4	7567	7568	9772	9770	104.8	104.9	13.63	13.65	8.21	8.25
5	7601	7603	9762	9763	113.5	113.53	14.38	14.2	7.98	8
6	7611	7612	9746	9745	102.2	102.26	14.62	14.6	8.14	8.16
7	7599	7597	9739	9735	112.7	112.7	13.18	13	7.67	7.7
8	7537	7535	9791	9793	114.9	115.02	12.97	12.95	8.42	8.44
9	7523	7521	9756	9757	111.64	111.6	13	13.1	7.85	7.87
10	7572	7571	9778	9776	103.7	103.75	13.42	13.45	8.67	8.7
11	7603	7605	9801	9803	101.6	101.63	12.87	12.85	7.61	7.64
12	7588	7585	9792	9794	110.8	110.8	13.59	14	8.47	8.49
13	7546	7547	9789	9790	104.4	104.41	13.87	13.84	7.75	7.78
14	7607	7605	9805	9806	109.2	109.23	14.23	14.24	7.97	8
15	7559	7560	9764	9768	117.7	117.77	13.85	13.84	7.84	7.86
16	7583	7584	9781	9784	116.98	117	14.37	14.39	8.17	8.18
17	7597	7600	9803	9805	109.76	109.78	13.41	13.44	8.48	8.49
18	7561	7563	9795	9796	115.21	115.24	13.56	13.56	7.93	7.96
19	7606	7607	9748	9750	106.31	106.32	13.28	13.24	8.68	8.69
20	7577	7579	9750	9748	114.7	114.74	13.63	13.65	8.41	8.44

CLASS II HYPERDIVERGENT GROUP

Patient number	Volume of upper pharyngeal		Volume of lower pharyngeal		Area		Width of upper pharyngeal		Width of lower pharyngeal	
	Obs 1	**Obs2**	**Obs 1**	**Obs2**	**Obs 1**	**Obs2**	**Obs 1**	**Obs2**	**Obs 1**	**Obs2**
1	7080	7082	9605	9606	82.1	82.4	11.26	11.24	6.93	6.94
2	7112	7111	9599	9598	84.43	84.48	10.88	10.86	5.87	5.9
3	7097	7096	9635	9634	80.3	80.36	12.53	12.52	6.52	6.54
4	7104	7103	9659	9657	79.8	79.83	11.59	11.6	6.87	6.85
5	7126	7128	9644	9645	73.5	73.7	12	12.02	5.99	6
6	7092	7094	9609	9608	82.2	82.27	12.45	12.42	6.53	6.57
7	7134	7135	9611	9615	79.7	80	11.32	11.34	6	6.02
8	7116	7118	9664	9668	84.9	85.06	11	11.03	5.95	6
9	7085	7086	9626	9626	71.6	71.64	11.36	11.38	6.78	6.79
10	7094	7099	9586	9586	83.7	83.72	10.99	11	6.89	6.91
11	7141	7144	9587	9584	81.6	81.63	11.52	11.54	6.33	6.35
12	7129	7130	9594	9593	80.8	80.92	10.78	10.79	7.67	7.7
13	7114	7115	9609	9610	74.4	74.43	12.24	12.26	5.82	5.85
14	7086	7088	9635	9633	75.2	75	10.86	10.88	6.27	6.3
15	7110	7114	9652	9650	81.7	81.77	11.28	11.03	5.81	5.84
16	7131	7133	9629	9630	82.98	83	10.73	10.75	6.89	6.86
17	7138	7139	9583	9585	78.76	78.76	11.97	11.12	7.14	7.12
18	7122	7120	9593	9590	76.21	76.2	10.83	10.81	6.75	6.71
19	7078	7076	9581	9580	77.3	77.31	10.46	10.47	5.81	5.83
20	7089	7087	9632	9629	84.7	84.73	10.52	10.5	6.53	6.54