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RESEARCH ARTICLE

Observational Study Cone Beam Computed Tomographic Evaluation Of Pharyngeal Airway In Tamil Nadu Population With Different Skeletal Patterns.

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Abstract

Background: Early assessment of functional factors can be vital for restoring normal craniofacial growth in growing patients with skeletal discrepancies.

Aim: To compare airway volumes in patients with mandibular retrognathism with the normal anteroposterior skeletal relationship, thereby assessing the association between cephalometric variables and airway morphology.

Methods: Cone Beam Computed Tomography volume scans, lateral cephalograms, 3-dimensional airway volume, and cross-sectional areas of 100 healthy children (46 boys and 54 girls mean age 15.19 ± 1.28) which were done for orthodontic assessment were evaluated. The subjects were divided into 2 groups based on the angle formed between point A, Nasion, and point B (ANB) values, and cephalometric variables (such as anterior and posterior facial height, gonial angle, etc.) airway volumes, and cross-sectional measurements were compared using independent t-tests. Pearson's correlation coefficient test was used to detect any relationship between different parts of the airway and between airway volume and 2- 2-dimensional cephalometric variables.

Results: Means and standard deviations for cephalometric, cross-sectional, and volumetric variables were compared. ANB, mandibular body length, and facial convexity were statistically highly significant ($P < 0.01$) whereas condyle on point A, nasal airway, and total airway volume ($P < 0.05$) were statistically significant. The nasal airway volume and the superior pharyngeal airway volume had a positive correlation ($P < 0.01$), the nasal airway was correlated to the middle ($P < 0.05$) and total airway superior had a relation with the middle ($P < 0.05$), inferior and total airway ($P < 0.05$), the middle was related to all other airways; inferior was also related to all the airways except nasal. Lateral cephalometric values were positively correlated with the airway volume with Frankfurt Mandibular Plane Angle and facial convexity showed significant correlations with total airway volume ($P < 0.05$). Additionally, ANB angle was significantly correlated with total airway volume and superior airway ($P < 0.05$).

Conclusion: The mean total airway volume in patients with a retrognathic mandible was significantly smaller than that of patients with a normal mandible.

Keywords: Pharyngeal airway; Cone beam computed tomography; Skeletal pattern; Malocclusion; Retrognathic; Airway volume.

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INTRODUCTION

The diagnostic and treatment planning of orthodontics heavily depends on respiratory function. Numerous cephalogram investigations have found a relationship between the respiratory mode and facial shape (Gholinia et al. 2019). Furthermore, Angle established in 1907 a connection between Class II Division 1 malocclusion and upper pharyngeal airway obstruction in addition to mouth breathing. The features of blocked breathing have been described by several authors (Gholinia et al. 2019). Ricketts (1968) described the following as the primary clinical symptoms of respiratory obstruction syndrome: small nostrils, open bite, crossbite, tongue pushing, and growth of the tonsils and adenoids.

It is generally accepted that the upper anatomy plays a significant influence in the formation of the craniofacial complex (Martin et al. 2006). Narrowing of the pharyngeal airway can cause breathing difficulties; in addition, it can cause reduced growth hormone levels in developing children or obstructive sleep apnea in adults. Patients with Angle class II malocclusion typically have diminished airway associated with obstructive sleep apnea, with retrognathic mandible and sagittal discrepancy (Uslu-Akcam, 2017; Bollhalder et al., 2013)

Restoring appropriate craniofacial growth and treatment outcome stability may depend critically on the early diagnosis and assessment of the functional factors in developing children with skeletal discrepancy and characteristics of adenoid hypertrophy (adenoid faces). To measure the pharyngeal airway, landmarks are typically identified, and then various pharyngeal lengths and regions are measured (Arun T et al., 2003; Kirjavainen et al., 2007; Joy et al., 2020)

Despite the abundance of research on airway morphology and how it affects craniofacial growth, most of these studies have employed frontal or lateral cephalograms, which are two-dimensional (2D) methods that provide insufficient information about length and area. Computed tomography is often used to visualize data in three dimensions (Barrera et al., 2017).

However, the high radiation dose is a major barrier to its use (Ayoub et al., 2019). Cone beam computed tomography (CBCT) is becoming more and more popular since it may reduce the radiation dose to one-fifth without sacrificing quality (Kim, 2015).

The pharyngeal airway space (PAS) can be measured volumetrically, and CBCT can be used to locate constriction or obstruction (Torres et al., 2020). This analysis can be helpful in the orthodontic diagnosis and planning of orthognathic surgery because narrowing or obstruction of the pharyngeal airway can be present in patients with altered maxillo-mandibular relationship

and can be associated with sleep as well as Obstructive Sleep Apnea Syndrome (Major et al., 2006). To investigate potential correlations between various cephalometric variables and the airway morphology in these children, the current study compared the pharyngeal airway volumes in children with varying anteroposterior maxillomandibular relationships (ANB angles, or the angle formed between point A, Nasion, and Point B).

MATERIALS AND METHODS

Following the ethical clearance from the institutional review board, records of 120 children who visited the outpatient Department of Orthodontics were examined. After applying the following exclusion criteria, any history of upper respiratory infections, pharyngeal pathologies (such as tonsillitis and adenoid hypertrophy), or a history of tonsil or adenoid excision. CBCT scans of 100 healthy Tamil Nadu youngsters (mean age 15.19 ± 1.28; 46 boys and 54 girls) were chosen (Table 1).

Table 1 Sample characteristics

	Group IANB <4		Group II ANB>4		Total
	Male	Female	Male	Female	
Subjects (n)	21	23	25	31	100
Age (yr)	13-17	13-17	13-17	13-17	15.19±1.28

ANB: The angle formed between point A, Nasion and point B.

Using a 16 cm x 17 cm field of view, the imaging technique encompassed the complete craniofacial anatomy. CBCT volume images were collected for each patient using the Carestream 9600 CBCT device.

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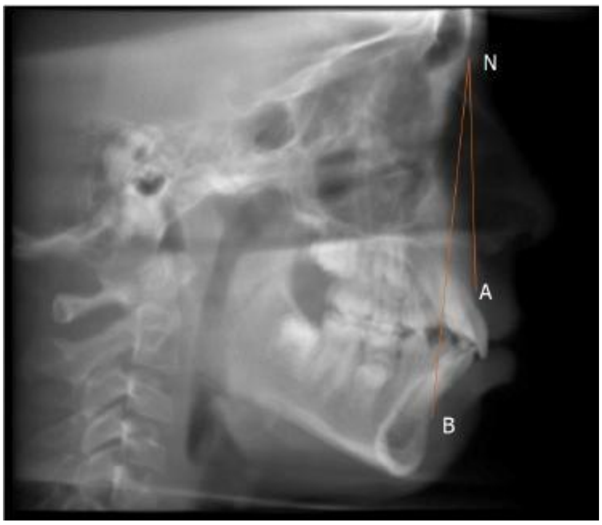

Figure 1 Cone beam computed tomography derived cephalogram and analysis.

The images were standardized with the subject standing, machine settings of 120 kV-5 mA-0.25 mm voxel, and a scan time of 20 s. Patients, following the standard protocol of acquiring the scans in a natural head position, and their jaws in maximum intercuspation with the lips and tongue in resting position were used. The axial pictures were imported into In Vivo Dental software for cephalometric analysis and volume evaluation/measurement. For uniformity and error reduction, the 3D pictures were reoriented using the Frankfort horizontal (FH) plane as the reference plane. The FH plane was created by linking the left and right sections at the most lateral-superior location of the external auditory meatus to the right orbitale. Using the In Vivo Dental software's SUPER CEPH function, 2D cephalometric pictures were created from the CBCT scans and transferred into CMOS® (Figure 1). It was the same investigator who identified landmarks and took measurements. To categorize patients, Downs, Steiner, Jarabak, Mc Namara, and Tweed Merrifield analysis were performed using the program.

Cross-sectional views of the pharyngeal airway in the five planes: (a) which is the airway's height (frontal slice) or length (axial slice) determined by the airway's greatest distance in the vertical or anteroposterior directions; (b) which is the airway's width determined by the airway's greatest distance in the left and right directions; and five volumes Volume rendered images are shown in A-right lateral view, and B-frontal view. Table 3 and Figure 2 show the nasal planes in order of ascending, descending, middle, and erecting the voice box: (a) anterior, (b) posterior, (c) upper,(b) middle, and (e) lower airway. The pharyngeal cross-sections are parallel to the FH plane, while the nasal cavity's cross-sectional planes are perpendicular to it. The FH plane was utilized as a reference plane to standardize the plane orientation and reduce error in identifying the cross-sectional planes under study, even though these cross-sections are not exactly perpendicular to the long axis of the airway (Figure 2). To ensure linear accuracy, cross-sectional measurements (width and length) were computed in both frontal and axial views. We used the In Vivo Dental software to obtain volumetric renderings of the participants' CBCT scans, and then we carried out volumetric analysis of the identified airways. Since the airway is a space, 3D image inversion was done to transform the negative image into a positive value.

The airway spaces of the craniofacial region, including the paranasal sinuses and other empty spaces, are embodied by this technique, which also removes the hard and soft tissues of the image around the airway.

In addition, sculpting a function of the software itself was used to separate the vital airway portion from superfluous constructions. After that, threshold values were changed to eliminate artifacts and improve the chosen airway region. Finally, the volume of the specified airway was calculated in cubic millimeters.

Statistical analysis

Using SPSS for Windows (version 20), descriptive statistics were computed for each group, including the mean and standard deviation. Using independent t-tests, group differences were examined. To find any connections between the various components of the airway and between the airway volume and 2D cephalometric variables, the Pearson's correlation coefficient test was employed.

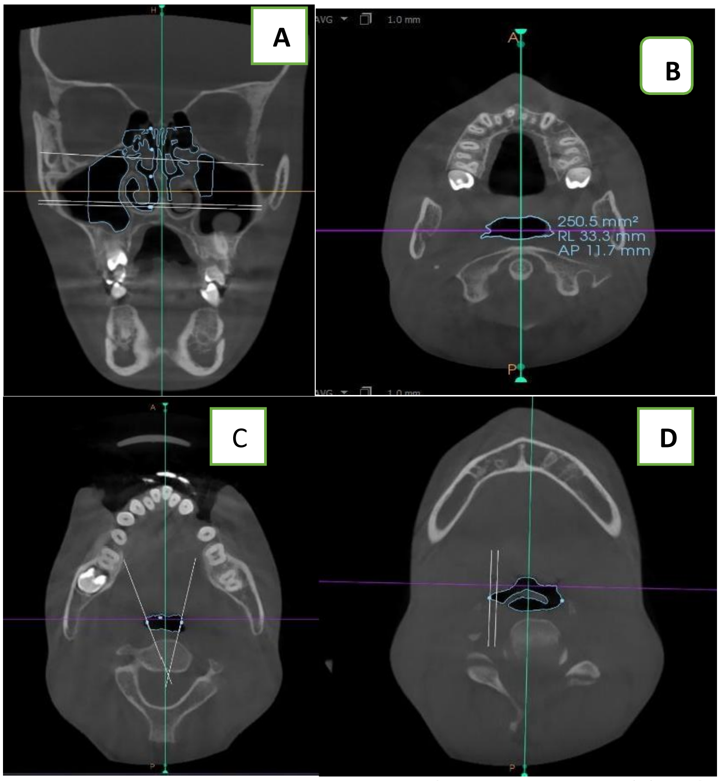

Figure 2 Horizontal section showing airway. A: Nasal & Superior; B: Middle; C and D: Inferior airway.

RESULTS

The volumetric, cross-sectional, and cephalometric variable means, and standard deviations were compared. Table 2 gives the comparison results of groups I and II. ANB, mandibular body length, facial convexity were statistically highly significant ($P < 0.01$) whereas condylion to point A, nasal airway, and total airway volume ($P < 0.05$) were statistically significant. Comparing cross-sectional and volumetric measurements at various levels were statistically insignificant. However, total airway volume was significantly greater in group I ($P < 0.05$). Table 2 shows the correlations among the studied variables.

Table 2 Descriptive statistics of groups I and II

Group	Group I ANB < 4		Group II ANB > 4		P value
	Mean	**SD**	**Mean**	**SD**	
Ana height	29.63	4.69	15.24	6.73	0.034
Ana width	13.81	1.98	15.24	3.61	0.273
Ana C. area	194.41	13.93	218.14	52.41	0.221
Pna height	29.95	7.85	28.73	8.70	0.744
Pna width	21.76	2.66	23.34	2.84	0.764
Pna C. area	246.73	72.15	266.13	71.11	0.668
Uph length	17.69	3.19	16.99	3.98	0.814
Uph width	27.86	3.79	26.01	7.02	0.634
Uph C. area	263.17	58.23	293.67	89.16	0.002
Mph length	13.47	2.43	13.12	3.60	0.998
Mph width	21.56	4.86	19.79	6.16	0.369
Mph C. area	216.48	80.16	219.12	100.48	0.696
Lph length	15.16	6.13	7.92	1.07	0.611
Lph width	20.13	3.18	26.67	5.48	0.326
Lph C. area	219.96	63.76	209.14	69.36	0.455
Gonial angle	120.16	6.79	124.18	6.33	0.548
AFH	106.18	5.08	110.12	4.66	0.148
PFH	70.99	4.99	70.16	6.43	0.566
PFH/AFH, %	65.43	4.39	60.16	4.63	0.166

FMA	24.98	3.19	26.59	5.99	0.264
ANB	2.66	1.46	6.11	1.01	0.001
MAND-BL	65.16	3.46	56.71	4.16	0.007
Facial convexity	4.17	3.14	9.96	4.36	0.006
Co-pt A	80.09	5.99	80.61	2.99	0.691
Co-pt GN	106.73	5.52	99.99	6.18	0.111
Nasal airway	35400.06	2416.39	32441.07	6070.81	0.041
Superior airway	5463.17	1240.60	4119.63	1362.34	0.001
Middle airway	5112	2020.71	4209.59	1372.67	0.001
Inferior airway	5367	2176.14	5166.62	1420.35	0.008
Total airway	54671.6	6314.34	43689.13	8554.39	0.031

A Correlation is significant at 0.05 level and B Correlation is significant at 0.01 level. ANB: The angle formed between point A, Nasion, and point B; Ana: Anterior nasal; Pna: Posterior nasal; Uph: Upper pharyngeal; Mph: Middle pharyngeal; Lph: Lower pharyngeal; AFH: Anterior facial height; PFH: Posterior facial height; FMA: Frankfurt Mandibular Plane Angle; Mand-BL: Mandibular body length; Co-PtA: Condylion to point; GN: Gnathion; SD: Standard deviation.

The nasal airway volume and the superior pharyngeal airway volume had a positive correlation ($P < 0.01$), the nasal airway was correlated to the middle ($P < 0.05$) and the total airway superior had a relation with the middle ($P < 0.05$), inferior and total airway ($P < 0.05$), the middle was related to all other airways, inferior was also related to all the airways except nasal (Table 3).

Table 3 Correlations of sections of the airway with each other

	Nasal Airway	Superior Airway	Middle Airway	Inferior Airway	Total Airway
Nasal airway					
Pearson correlation	1	0.086	0.471[a]	0.383	0.880[b]
Sig.(2-tailed)		0.728	0.035	0.095	0
N	100	100	100	100	100
Superior airway					
Pearson correlation	0.861	1	0.495[a]	0.650[b]	0.4622[a]
Sig.(2-tailed)	0.07		0.026	0.002	0.04
N	100	100	100	100	100
Middle airway					
Pearson correlation	0.472[a]	0.493[a]	1	0.762[b]	0.781[b]
Sig.(2-tailed)	0.035	0.025	-	0	0
N	100	100	100	100	100
Inferior airway					
Pearson correlation	0.386	0.652[b]	0.765[b]	1	0.743[b]
Sig.(2-tailed)	0.092	0.002	0	-	0
N	100	100	100	100	100
Total airway					
Pearson correlation	0.877 [b]	0.4622[a]	0.780[b]	0.745[b]	1
Sig.(2-tailed)	0	0.04	0	0	-
N	100	100	100	100	100

a Correlation is significant at 0.05 level. b Correlation is significant at 0.01 level.

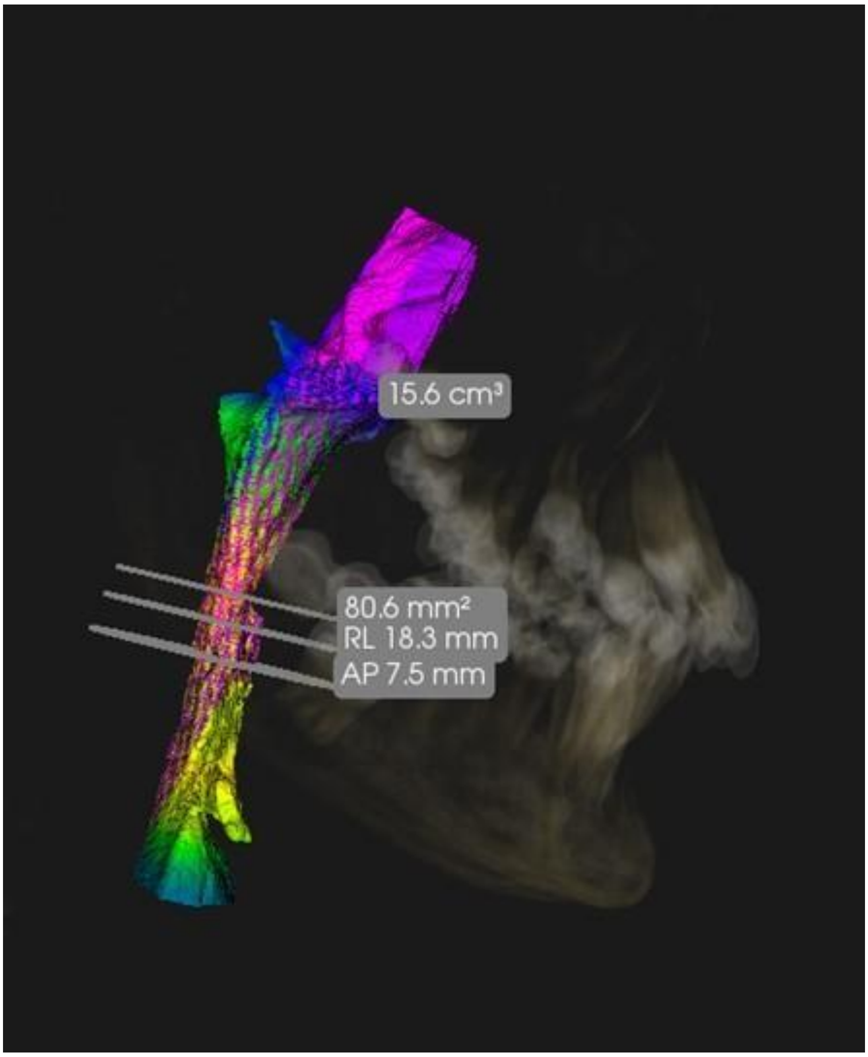

Figure 3 Airway isolated with the software

Figure 3 illustrates a 3D CBCT analysis of the pharyngeal airway, showing a total volume of 15.6 cm^3 with cross-sectional area and specific dimensions (80.6 mm^2 area, 18.3 mm RL width, 7.5 mm AP depth). It highlights the spatial characteristics essential for comparing airway volumes between skeletal patterns.

Lateral cephalometric values were positively correlated with the airway volume with Frankfort Mandibular Plane Angle (FMA) and facial convexity showed significant correlations with total airway volume ($P < 0.05$). Additionally, ANB angle was significantly correlated with total airway volume and superior airway ($P < 0.05$) (Table 4).

Table 4 Correlations between the 2-dimensional cephalometric variables and the 3-dimensional volumetric measurements of the airway

	Nasal airway	Superior airway	Middle airway	Inferior airway	Total airway
Gonial angle					
Pearson correlation	-0.124	0.115	0.132	0.111	0.098
Sig.(2-tailed)	0.653	0.765	0.199	0.897	0.786
N	100	100	100	100	100
AFH					
Pearson correlation	0.634	0.199	0.097	0.744	0.166
Sig.(2-tailed)	0.344	0.265	0.761	0.001	0.617
N	100	100	100	100	100
PFH					
	0.166	0.112	0.123	0.316	0.130

Pearson correlation					
Sig.(2-tailed)	0.417	0.167	0.612	0.161	0.129
N	100	100	100	100	100
PFH/AFH, %					
Pearson correlation	0.122	0.066	0.087	0.122	0.132
Sig.(2-tailed)	0.616	0.133	0.167	0.676	0.660
N	100	100	100	100	100
FMA					
Pearson correlation	-0.273	-0.366	-0.366	-0.466	-0.473
Sig.(2-tailed)	0.116	0.169	0.112	0.071	0.034
N	100	100	100	100	100
ANB					
Pearson correlation	-0.361	-0.408	-0.169	-0.166	-0.316
Sig.(2-tailed)	0.116	0.031	0.411	0.521	0.220
N	100	100	100	100	100
Mand-BL					
Pearson correlation	0.116	0.413	0.016	0.174	0.125
Sig.(2-tailed)	0.666	0.017	0.763	0.136	0.143
N	100	100	100	100	100
Facial convexity					
Pearson correlation	-0.312	-0.316	-0.216	-0.221	-0.197
Sig.(2-tailed)	0.106	0.177	0.166	0.166	0.096
N	100	100	100	100	100
Co-pt A					
Pearson correlation	0.116	0.144	0.289	0.479	0.345
Sig.(2-tailed)	0.694	0.153	0.117	0.036	0.177
N	100	100	100	100	100
Co-pt GN					
Pearson correlation	0.317	0.197	0.112	0.221	0.173
Sig.(2-tailed)	0.166	0.144	0.756	0.144	0.174
n	100	100	100	100	100

Correlation is significant at 0.05 level. AFH: Anterior facial height. PFH: Posterior facial height; FMA: Frankfurt Mandibular Plane Angle; Co-PtA: Condylion to point; GN: Gnathion; ANB: The angle formed between point A, Nasion and point B; Mand-BL: Mandibular body length.

DISCUSSION

Over the past few decades, lateral cephalograms, nasal endoscopy, and nasal resistance and airflow tests have all been used in the examination of airways (Neelapu et al., 2017). In the current investigation, CBCT yielded anatomically correct pictures that were rebuilt in three dimensions (sagittal, transverse, and frontal) without the need for magnification or distortion (Ayoub et al., 2019; Major et al., 2006). This allowed for a thorough understanding of the pharyngeal airway anatomy of growing children. Typically, supine positioning of the patient is required for 3D imaging methods like magnetic resonance imaging or traditional CT. Nonetheless, there are significant structural changes in the airway because of gravity's effect on the soft tissues surrounding the oropharyngeal cavity (Hsu et al., 2019).

Hsu et al. (2019) also discovered that when the body positions itself from an upright to a supine posture, the minimum PAS and linear distance along a perpendicular vary from the upper anterior point of the hyoid bone to the mandibular plane.

However, more pertinent to our investigation, axial CT scans can now be obtained while sitting upright thanks to recent developments in CBCT. Because of the retrospective nature of this study, subjects were chosen based on diagnoses for orthodontic treatment rather than on a direct examination of their nasopharyngeal functions.

However, a study by Laine-Alava et al. (1999) found that when measurements are taken during an asymptomatic period, there is no impact of upper respiratory disease history or symptoms on variables related to naso-respiratory function, which supports the retrospective design of our study (Sam et al., 2019).

To assign the participants to the two groups and evaluate correlations between the pharyngeal airway volumes and the cephalometric parameters, 2D lateral cephalometric images were generated from the CBCT scans. Previous research has looked into the linear accuracy of the lateral cephalometric images obtained from CBCT (Kochhar et al., 2021; Grewal et al., 1994).

The North Indian norms for the ANB angle were used to classify the participants according to their anteroposterior skeletal relationships (Li et al., 2014). Furthermore, it has been shown in the past that the prepubertal ANB angle and the measured angle of convexity have a good forecast accuracy for the anteroposterior jaw relationships in the postpubertal period (Kochhar et al., 2021; Kamaruddin et al., 2019).

The anteroposterior analyses of the current investigation showed statistically significant differences, supporting the validity of the ANB angle as a trustworthy metric for subject classification (Kamaruddin et al., 2019). Because InVivo software has demonstrated strong intra-rater reliability values in previous investigations, the pharyngeal volume was analyzed using this software in the current study (Major et al., 2006; Ceylan et al., 1995).

There was no evidence of sexual dimorphism between the two sexes in any of the cross-sectional and volumetric measurements in the current investigation. These results concurred with the research conducted by de Freitas et al. (2006) and Ceylan et al. (1995).

In a similar vein, neither patient age nor sex was found to significantly differ in a 2019 study conducted by Xu et al. (2019). While condylion to point A, nasal airway, and total airway capacity ($P < 0.05$) were statistically significant, mandibular body length and facial convexity were statistically highly significant ($P < 0.01$) in groups I and II ANB.

Even though group I showed larger volumetric measures and cross-sectional areas of the pharyngeal airway subregions, these findings were statistically insignificant, indicating that there was no relationship between mandibular deficits and segmental airway capacity.

This was in line with the findings of Di Carlo et al. (2015) who failed to discover a connection between the general morphology of the upper airways and specific skeletal patterns. Furthermore, earlier 2D research claimed that there was no connection between the size of the airway and the malocclusion class (Freitas et al., 2006; Xu et al., 2019).

According to Ceylan et al. (1995), postural variations in the pharyngeal structures maintain the airway dimensions constant despite changes in the skeletal anteroposterior relationship. Nonetheless, other publications highlighted that gender, developmental age, and various skeletal classes all affect upper airway dimensions (Gholinia et al. 2019).

The middle and total airways showed a positive correlation with the nasal airway. This could be explained by the fact that the two regions are directly correlated in terms of volumetric dimensions, despite being located just superior to the hard palate and not anatomically contiguous. There are notable relationships between the sections on the superior airway with the middle, inferior, and total airway and the inferior airway with the superior, middle, and total airway.

Restrictions in the diameter of the nasopharyngeal airway are linked to mouth breathing, as adenoid hypertrophy can easily clog it, as per Ricketts (1968) and Dunn et al (1973). All superior, middle, and inferior airways in our investigation showed a positive correlation with total airways.

Group I (ANB less than 4) has a much larger airway capacity than group II (ANB more than 4), which explains the negative association between the ANB angle and the total airway. Group I had considerably higher mandibular body length and overall airway volume, indicating a positive association.

The study found that there was a substantial correlation between total airway volume and mandibular body length and the anterior-posterior discriminants. This correlation supported the intergroup comparison of the various anterior-posterior skeletal patterns.

Comparable outcomes were noted by Lopatienė et al. (2016), who discovered that individuals with ANB greater than 4 had statistically significant narrower airways. Patients with skeletal Class II showed lower glossopharyngeal airway volume, greater total minimum constricted area in average faces, and higher nasal minimum constricted area in long faces, according to studies by Alhammadi et al. (2019) and Xu et al. (2019).

According to Hwang et al. (2008) retruded mandible and maxilla are linked to a constricted nasopharyngeal airway. An investigation by Shokri et al. (2020) found a substantial relationship between the skeletal facial pattern and upper airway dimensions, with class III patients having higher mean airway area and total airway volume than class II patients.

Limitations in the present study are that we did not assess class III malocclusion patients in this investigation, and all patients were scanned while standing upright, making it impossible to conclude obstructive sleep apnea. However, the huge sample size provides compelling evidence that a mandible rearward posture is associated with a narrower airway.

CONCLUSION

In this study, individuals with an ANB (A point-Nasion-B point angle) greater than four had smaller mean total airway volumes than those with an ANB less than four. Reduced pharyngeal airway space is observed in individuals with more pronounced mandibular retrognathism, which in theory, may have implications for respiratory function. The study also identified favorable interrelationships between different pharyngeal airway subvolumes, indicating a proportional relationship between different airway regions. Specifically, the analysis also revealed that total airway volume was significantly associated with the Frankfurt Mandibular Plane Angle (FMA), facial convexity, and mandibular body length. These findings emphasize the need to account for craniofacial structure, especially mandibular position when assessing airway volume and potential respiratory implications for orthodontic treatment planning and early intervention in craniofacial growth management.

Institutional Review Board statement: Our Institutional Review Board reviewed and approved the study (Approval No. KIDS/IEC/2024/I/032).

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