Evaluation of the Relationship between Airway Volumes and Vertical Facial Growth Patterns in Adult Patients

Original Article

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Abstract

Introduoction:
This study investigated the potential relationship between vertical facial growth patterns and airway volumes in a sample of Iranian adult patients.

Materials and methods:
This cross sectional study was conducted on 72 adult patients (44 females, 28 males), ages 18–45 years, who had been referred to the Department of Oral and Maxillofacial Radiology at the Shiraz University of Medical Science. The vertical growth pattern was assessed by a lateral cephalometric radiograph using two indices: morphological facial index (defined as the ratio of N-Mn and Zy-Zy distance) and Jarabak index (defined as the ratio of S-Go and N-Gn). The sizes of the superior and inferior airway compartments were measured by employing cone beam computed tomography.
Data were analyzed on SPSS 21 using the Shapiro–Wilk test, p-p plot test, one-way ANOVA, t-test, and chi square tests ($P < 0.05$).

Results:
The total airway volume for all individuals was 21.72 ± 6.69 mm. There were no statistically significant differences between subjects with long, medium, or short faces regarding lower ($p = 0.160$) or upper ($p = 0.183$) airway sizes. The gender of the participants did not have a significant relationship with the lower, upper, or total airway sizes.

Conclusion:
Based on the findings of the current study, we found that the cone beam computed tomography data did not indicate any correlation between airway volume and vertical facial growth pattern.

Key words:
•Tidal Volume •Cone Beam Computed Tomography •

Introduction

The size and the shape of the pharyngeal space and the influences of these dimensions on craniofacial growth has always been a matter of controversy among orthodontic researchers. Although postural relationships of the head, jaws, and tongue are established in the first moments after birth, the size of the pharyngeal space is determined primarily by its surrounding soft tissue and relative growth.[1,2]

The soft tissue–stretching hypothesis was first described by Solow and Kreiborg.[3] According to this hypothesis, oral and pharyngeal soft tissue is influenced by the posture of the head, jaws, and tongue. Based on this theory, alterations in jaw posture would cause mandibular backward and downward rotation and alterations of the head posture (such as head extension) would lead to stretching of the lips, cheeks, and muscles. The results of these types of soft tissue stretching would be upright incisors and narrow dental arches, which are often observed in long face and open bite patients.[3,4]

Some studies have noted variables that may affect airway size or ventilation. These variables include mandibular deficiency, bimaxillary retrusion, short mandibular body, increased mandibular plan angle, and caudally-positioned hyoid bone.[5,6] These variables would reduce the pharyngeal airway space and cause retrusion of the soft palate and tongue.

These changes may lead to impairments of the respiratory functions including snoring, upper airway resistance syndrome, and obstructive sleep apnea (OSA).[7] An intimate relationship between pharyngeal and dentofacial structures in subjects with OSA is clear; hence, we may expect a mutual association between pharyngeal structure and dentofacial pattern in the general population. Jung et al.[8]found a significant relationship between airway space and facial morphology. Moreover, other studies suggested that airway space could be affected by the head posture,[9] functional anterior shifting,[10] sagittal skeletal relationships,[11] and maxillary protraction.[12] Therefore, it would be possible for healthy subjects with skeletal class I malocclusions and vertical facial growth patterns to have narrower airways than people with healthy horizontal growth patterns. Several studies[13–15] have demonstrated that the sagittal section of the jaws had a relationship with airway size, while other studies[16,17] have implied an association between the vertical facial growth pattern and obstruction of upper and lower pharyngeal airway and mouth breathing. If such a relation has existed, vertical growth pattern and class II malocclusion are anatomical contributing factors for mouth breathing.

The value of lateral cephalometric radiographs to evaluate the upper airway is limited because this modality provides 2-dimensional (2-D) images of complex 3-dimensional (3-D) anatomic structures.

The recent development of cone beam computed tomography (CBCT) and computer simulation in treatment planning provide opportunities to evaluate individuals more precisely compared to using standard radiographs. This new imaging modality is less expensive and exposes the patients to less ionizing radiation than computed tomography (CT) scans.[18–22] The airway extending from the tip of the nose to the epiglottis can be visualized using conventional CBCT.[23]

The aim of this study was to examine the theory that pharyngeal volume and shape differ among people with various facial morphologies, even

Materials and Methods

This cross-sectional study used CBCT images of patients who visited the Department of Oral and Maxillofacial Radiology at Shiraz University of Medical Sciences from June 2013 to June 2014. We selected the images of 72 patients (44 females, 28 males) aged 18–45 years. The patients had CBCT scans of the head performed with reconstructed cephalometric radiographs. By a precise inspection of the images, patients who had craniofacial anomalies, previous orthognathic surgeries, tonsillectomies, previous orthodontic treatment, or detectable pathological problems in their upper airway were excluded from the study.

The CBCT images were obtained with a NewTom VGi Cone Beam CT machine (QR SRL Company, Verona, Italy) with the subject in an upright position for maximum intercuspation. The Frankfort horizontal (FH) plane was measured parallel to the floor. The maxillofacial regions were scanned by using a tube voltage of 110 kVp, tube current of 6.35 mAs, and scan time of 18 s. All images had a full field of view that allowed for the visualization of both the cranial base and the face. The images were oriented as a line 6° down from the sella-nasion plane as the horizontal axis.Using a lateral cephalometric radiograph, two indices were used to classify the vertical groups: the morphological facial index, defined as the ratio of morphologic facial height (N-Mn) to the bizygomatic width (Zy-Zy); and the Jarabak index, which is the ratio of posterior facial height (S-Go)to anterior facial height (N-Gn) (Figure 1).Using the NewTom NNT viewer software, the desired points were determined and the required distances between the points were measured. The points were then verified by an orthodontic resident to find out the accuracy of the measurements. Landmark identification and segmentation were measured by the same investigator, who made two separate measurements at a 1-month interval to calculate intra-observer error. The measurement precision in the study was 0.1 mm. The patients were then sorted into 3 groups based on the aforementioned indices: long face (Jarabak index >65° and Bjork >400°), medium face (Jarabak index 62–65° and Bjork 390–400°) and short face (Jarabak index <62° and Bjork <390°).The airway volumes of each group were then calculated. The semi-automatic segmentation was characterized by employing the section competition snake. The segmentation process had several phases. The first was the preliminary threshold assortment to define the anterior border as a vertical plane through the posterior nasal spine perpendicular to the sagittal plane.

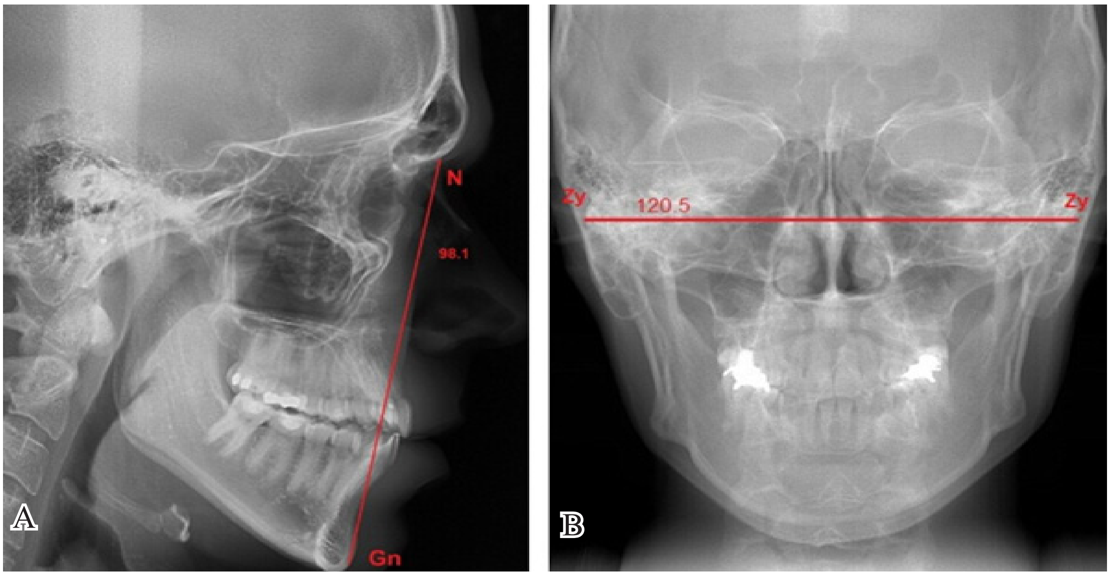

Figure 1.A: Jarabak index, the ratio of posterior facial height (S-Go) to anterior facial height (N-Gn), B:Morphological facial index, defined as the ratio of morphologic facial height (N-Mn) to the bizygomatic width (Zy-Zy).

It also defined the posterior border as the posterior wall of the pharynx; along with the lateral border, consisting of the lateral walls of the pharynx; and the lower border, a plane from the most caudal medial projection of the third cervical vertebra perpendicular to the sagittal plane (Figure 2).

The software also assigned the reference points (Figure 3). Due to the contrast between the airway and its surrounding structures, enlarging the reference points would fill up the airway structure (Figure 4). After segmentation, the airways were split into superior and inferior compartments by a plane, which incorporated the posterior nasal spine and the lower medial border of the C1 vertebra (Figure 5). Following the segmentation procedure, the software constructed a 3-D replica image of the volumetric compartment. Using the replica image, the volume of the segmented 3-D model was obtained in 3mm and the data were collected.The means ± SDs were calculated for quantitative variables and the relevant percentages for qualitative variables were obtained. The data distributions were analyzed using Shapiro–Wilk, p-p plot, and one-way ANOVA tests.

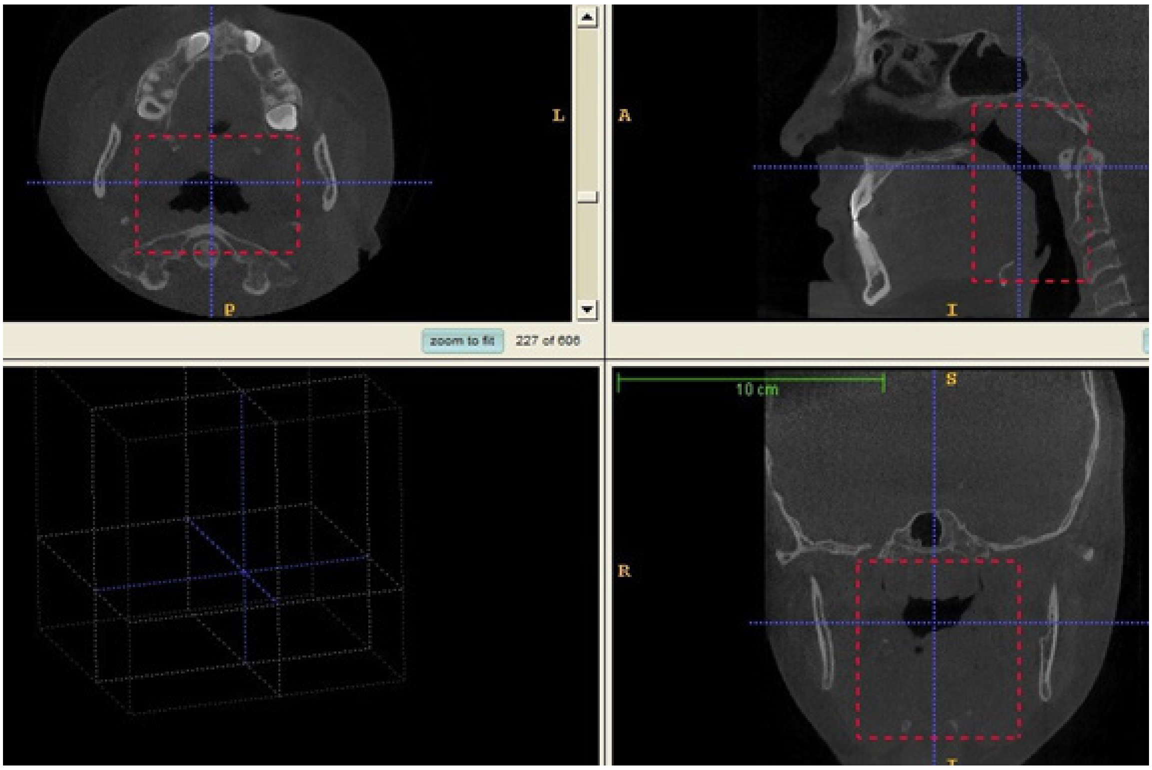

Figure 2. Definition the borders of pharynx

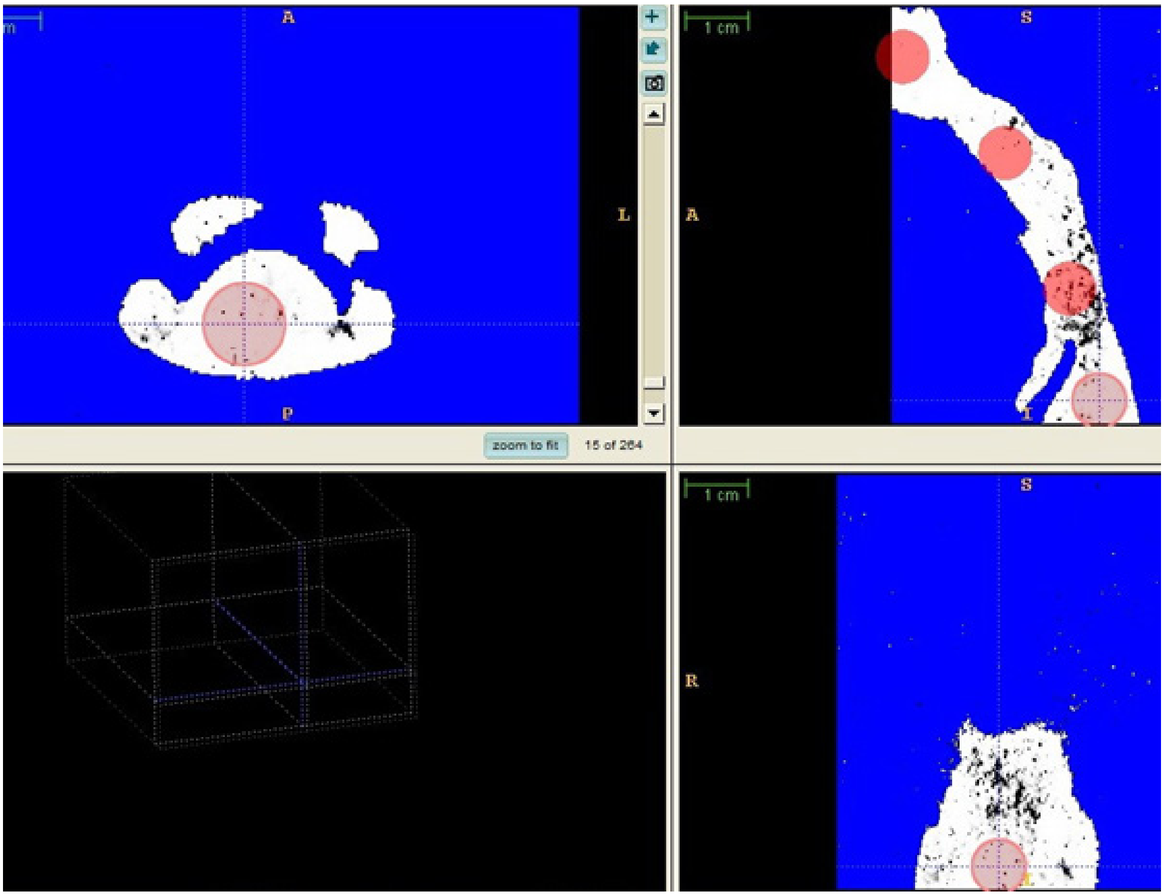

Figure 3. Assigning the reference points

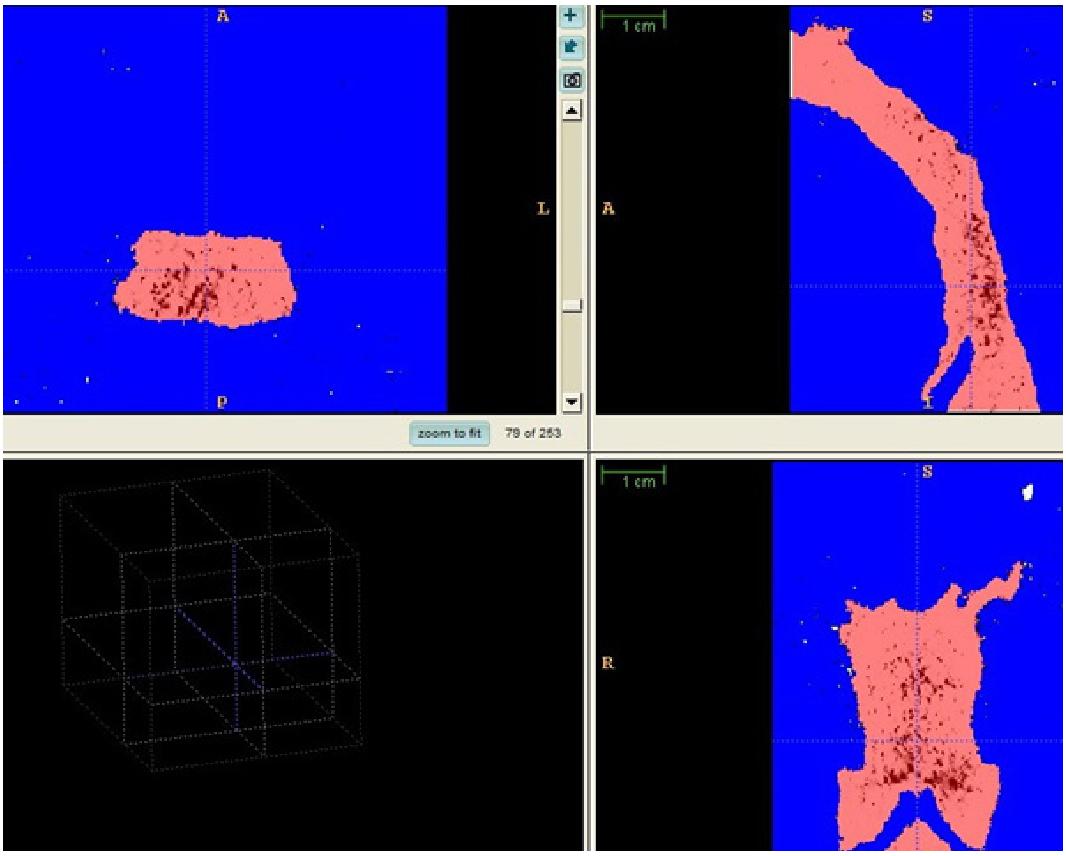

Figure 4. Enlargement of the reference points until fill up the airway structure

To compare the airway volumes between males and females, a t-test was used, and the chi square test was employed to compare facial height and gender.

P value of <0.05 was considered to denote statistical significance.

Results

The means and standard deviations of the lower, upper, and total airway sizes in subjects with long, medium, and short faces are summarized in table 1. The ANOVA found no statistically significant differences between subjects with long,medium, or short faces in terms of their lower (P = 0.160) or upper (P = 0.183) airway volumes. However, lower airway volumes in the medium face group and upper airway volumes in the long face group tended to be larger than those of two other groups. The mean total airway volume for all groups was 21.72 ± 6.69. Total airway volumes in the long face group were higher than the other groups, but the difference was not statistically significant (P = 0.168). There were no statistically significant differences in the lower, upper, or total airway sizes between the males and females (table 2). Moreover, the chi square test demonstrated that there was not a statistically significant relation between facial height and gender. The results of this analysis are summarized in table 3 (P = 0.468). The Pearson correlation coefficient revealed there was a significant positive correlation between the upper and lower airway sizes (γ = 0.336, P = 0.004). Figure (5-9).

Table 1: The mean and standard deviation of the lower, upper and total airway size in subjects with long, medium and short face using ANOVA test

	Airway size (mean±SD)			P value*
	Long face	Medium face	Short face	
Lower airway	9.88±1.63	10.39±2.20	9.25±2.21	0.160
Upper airway	13.62±6.94	10.96±3.79	10.84±5.00	0.183
Total airway	23.7±8.37	21.36±4.85	20.09±6.13	0.168

* ANOVA

Table 2. The mean and standard deviation of airway size for males and females

	Airway size (mean±SD)		
	Male	Female	P value*
Lower airway	9.9±1.95	9.75±2.25	0.767
Upper airway	12.08±6.20	11.54±4.93	0.696
Total airway	21.99±7.29	21.29±5.72	0.671

* t-test

Table 3. The mean and standard deviation of airway size for males and females using chi-square

	N(%)			P value*
	Short face	Medium face	Long face	
male	11 (39.3%)	7 (25%)	10 (35.7%)	0.468
female	13 (39.5%)	17 (38.6%)	14 (31.8%)	

* Chi-square

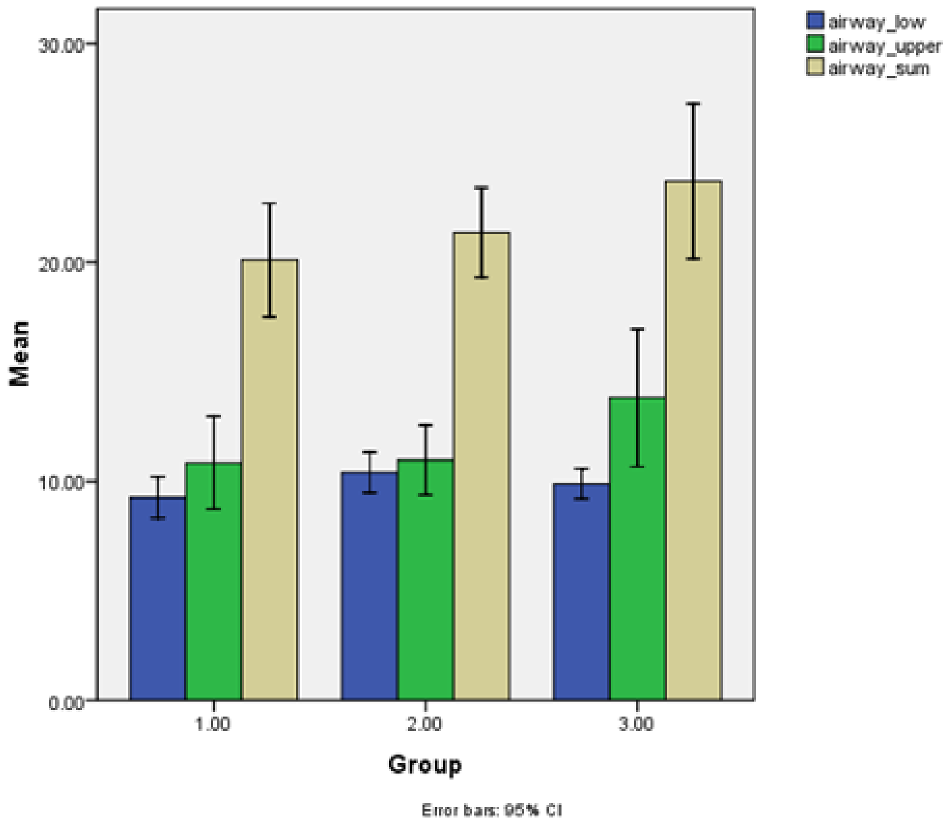

Figure 5. Comparing the mean of lower, upper and total airway size in three groups

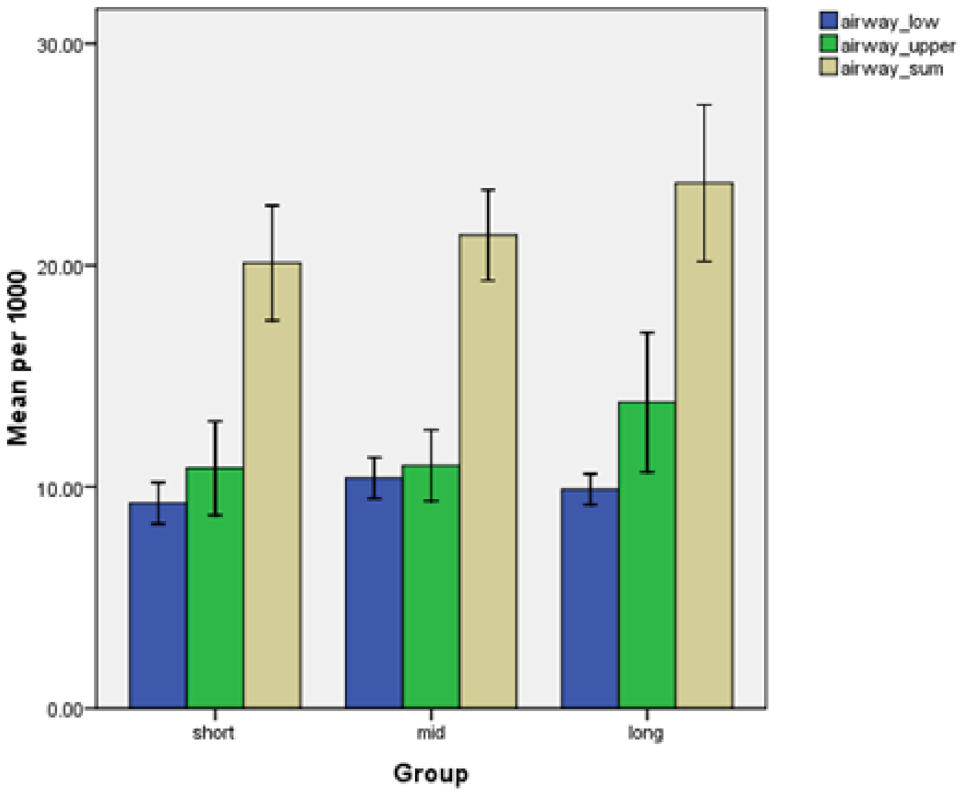

Figure 6. Comparing the mean per 1000 of lower, upper and total airway size in three groups

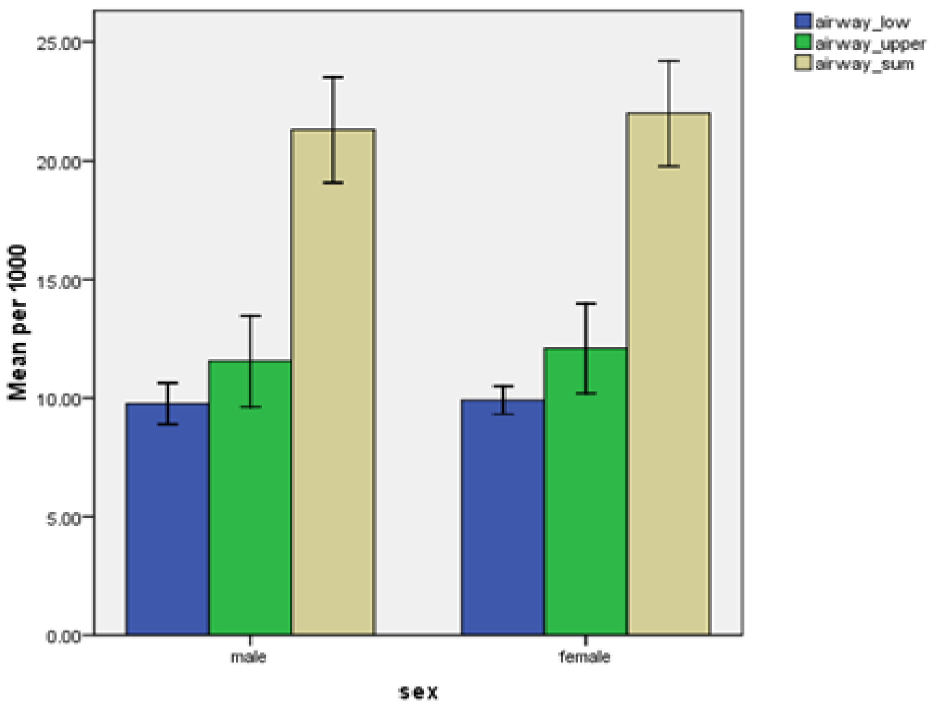

Figure 7. Comparing the mean per 1000 of airway size in males and females

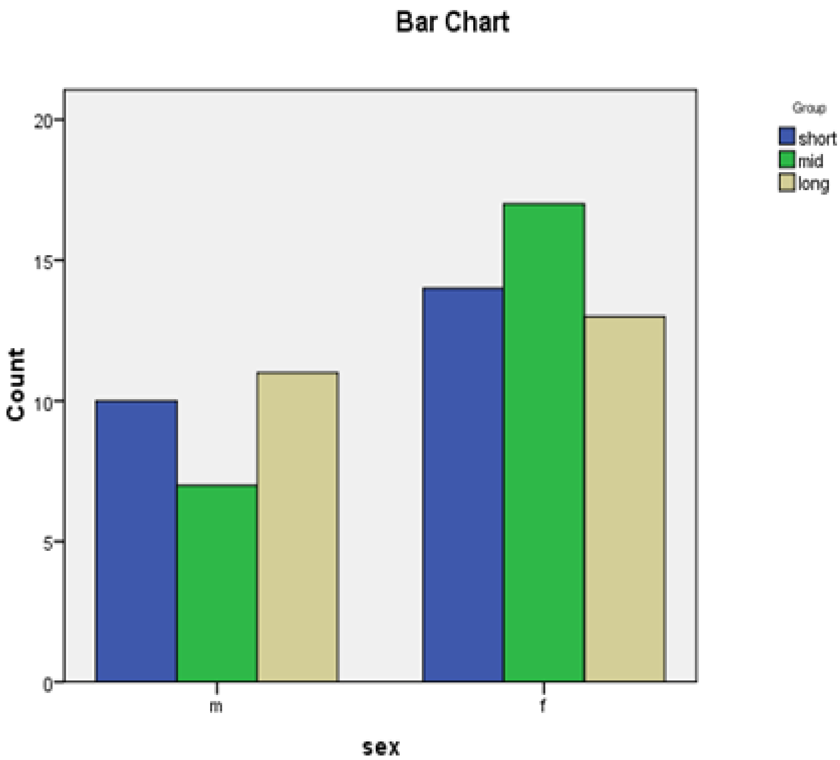

Figure 8. Comparing the size of the facial height between genders

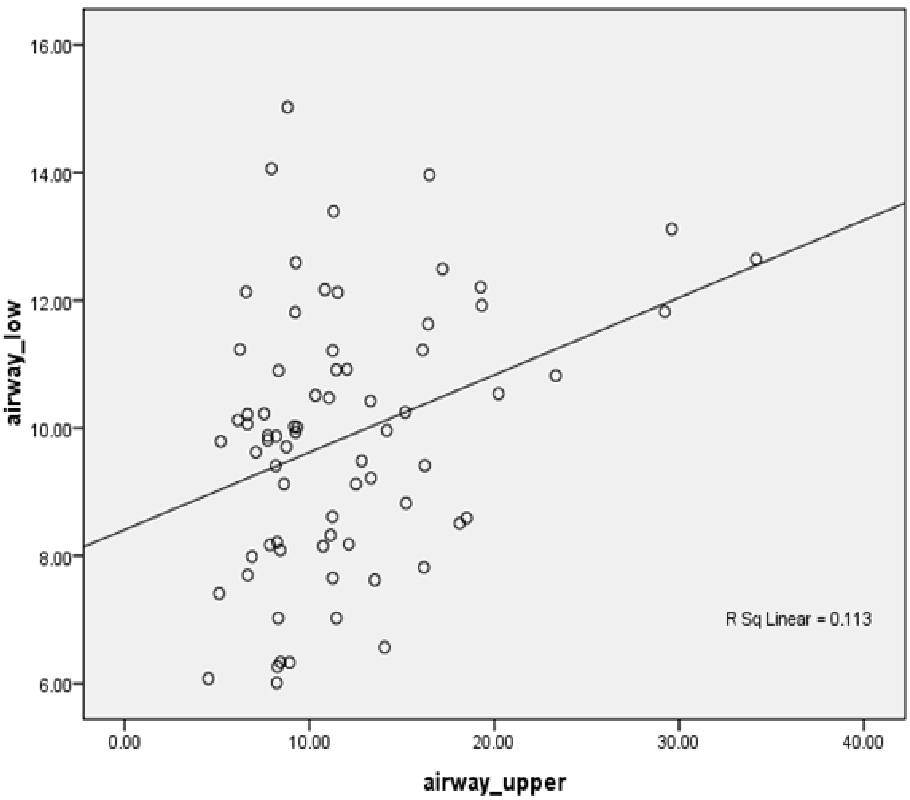

Figure 9. There was a significant positive correlation between the upper and lower airway size

Discussion

The skeletal support for airways is provided by the cranial base (superior), nasal septum (antero-superior), spine (posterior), jaw, and hyoid bone (anterior). Accordingly, any abnormality in the jaw's position or the cranial base can affect the airway's size. The reciprocal growth and positions of the supporting skeletal structures would also be influenced by any disturbances in airway size. These effects were described by Solow and Kreiborg in their soft tissue–stretching hypothesis.[3, 4]

According to this theory, factors such as mandibular deficiency, bimaxillary retrusion, and high mandibular angle may influence the tongue's position and cause airway obstruction conditions such as OSA.[5–7] Although OSA could not be diagnosed solely with imaging, our findings suggest that airway measurements identify the individuals at risk for it.

During last decades, numerous ways have been used for airway assessing.[24–28] At first, airway measurement was performed on the lateral cephalograms by linear measurement. 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.[29]

New 3-D imaging approaches including CBCT have become efficient modalities for airway assessments.[30] CBCT images have negligible magnification with a 1:1 ratio in all three planes of space.[31] However, 3-D imaging exposes patients to radiation and is expensive.

This study employed CBCT (rather than 2D imaging modalities) to improve image quality and accuracy. To reduce the radiation doses, we utilized the NewTom 3G scanner.

Jane et al.[32] and Abramson et al.[33] asserted that nasopharyngeal size has a close relationship with skeletal growth and age. Sheng et al.[34] reported that developmental changes to the pharyngeal airway take place between childhood and young adulthood. The sample in this study was selected from individuals with ages of 18 years or older to prevent errors related to rapid changes in facial skeletal dimensions and airway structures during puberty. During previous decades, studies had reported relationships between the pharyngeal dimension and different sagittal and vertical growth patterns.[11–17] Anterior-posterior airway dimensions could be narrower for hyperdivergent subjects with mandibular retrusion or vertical maxillary excess. Therefore, skeletal class II malocclusions and vertical growth patterns had been considered to be the contributing factors in pharyngeal airway obstruction.[35] Therefore, orthodontic treatments of dentofacial anomalies in adult subjects with skeletal class II malocclusions or vertical growth patterns would prevent or mitigate obstructive airway disturbances, and meet patients' esthetic and functional needs.

Some studies considered the role of the vertical facial dimension to be more relevant to airway volume than the sagittal-jaw relationship.[15,36,37] Along with the same opinion, the current study assessed the effects of vertical facial height by using two indices, the Jarabak index and morphological facial index, on airway volume. Although we found no significant relationship between airway volume and vertical facial dimensions; however, lower airway sizes in the medium face group and upper airway sizes in the long face group were larger compared to the respective airway sizes in other groups, but the difference was not significant. In addition, the total airway size in long face group was larger than in the other groups, but this was also not significant (P = 0.168).

These findings contrast with the results of the previous studies, such as Ulas Oz,[36] Yang et al.,[38] Ucar and Uysal,15 and Zhong et al.[39] In Ulas Oz's study,[36] the airway space sizes in class II low-angle and neutral-angle subjects did not differ from those in the class I control group, but the upper airway space in high angle subjects was significantly smaller. A study by Yang et al.[38] showed that adult skeletal class II subjects with vertical growth patterns had significantly narrower pharyngeal airways than those with class II normal or horizontal growth patterns.In the last two studies mentioned, the assessments were performed on skeletal class II subjects. According to some studies,[15,36,37] the sagittal jaw relationship has greater effects on airway volume than the vertical jaw relationship. Therefore, it cannot be concluded that only a vertical growth pattern can affect airway volume.

Ucar and Uysal[15] found significant differences between craniofacial morphologies and the orofacial airway dimensions of class I subjects with different growth patterns. In Zhong et al.[39] , the upper airway was measured among non-snoring Chinese children who had various skeletal craniofacial patterns. They found that the sagittal and vertical skeletal patterns might be the contributory factors in variations of the inferior and superior parts of the upper airway, respectively. However, both of these studies utilized 2-D lateral cephalometry in airway assessments, and used samples of youth who were still growing.

Unlike the studies discussed above, Grauer et al.[14] assessed the pharyngeal airway volume and shape, and their relationships with facial morphology. They concluded that airway volume and shape vary among patients with different antero-posterior jaw relationships, and that airway shape, but not volume, varies with vertical jaw relationships.

In this study, a good compatibility with age and gender was observed because only healthy pharyngeal subjects with class I malocclusion were selected. Some authors [40,41] had reported gender differences in airway sizes, but we did not find any significant relationships between gender and airway size. Our findings support those of some

Conclusion

The current study found no correlation between airway volume and vertical growth pattern. Moreover, we did not find any differences in airway size between male and female participants.

Acknowledgments

This report is based on a thesis of Dr. Betina Majdi which was submitted to the School of Dentistry, International Branch, Shiraz University of Medical Sciences, Shiraz, Iran, in partial fulfillment of the requirements for the DDS degree.

List of abbreviations:

CBCT: Cone Beam Computed Tomography
OSA: Obstructive Sleep Apnea
FH: Frankfort Horizontal

Competing interests

The authors declare that they have no competing interests.

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