Airway in Class I and Class II skeletal pattern: A computed tomography study

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Abstract

Background and Objectives: A normal airway is required for the normal growth of the craniofacial structures. The present study was designed to evaluate and compare the airway in Class I and Class II skeletal pattern and to see if there is any association between the airway and maxillomandibular relationship. **Materials and Methods:** Peripheral nervous system computed tomography scans of 30 patients were divided into two groups as Class I (ANB ≤ 4.5°), Class II (ANB ≥ 4.5°). The Dolphin three-dimensional version 11 was used to assess the airway. **Statistical Analysis:** Correlations between the variables were tested with the Pearson correlation coefficient. Independent sample *t*-test was performed to compare the averages between the two groups. $P < 0.05$ was considered as statistically significant. **Results:** The ANB angle was negatively correlated with all the airway parameters. The airway area and volume was significantly reduced in Class II subjects compared to Class I. **Conclusion:** The results suggest a strong association between the airway and skeletal pattern showing a reduced airway in Class II patients with a high ANB angle.

Keywords: Airway, ANB angle, computed tomography

Introduction

The growth of each compartment of the craniofacial skeleton is integrated with the others, and coordinated growth is required for normal development to occur. Growth and function of the nasal cavities, the nasopharynx and the oropharynx are closely associated with the normal growth of the skull. Obstructions of the nasal passage cause a functional imbalance that would result in an oral breathing pattern. Consecutively, there will be changes in the tongue and lip positions, downward and backward rotation of the mandible, long face, constricted maxillary arch, incompetent lip seal, flat nose, and narrow nasal base.[1]

Despite the vast amount of research concerning airway and its influence on craniofacial growth and development, most studies have been two-dimensional (2D). A number of authors[2-6] have evaluated the airway using lateral cephalograms. Lateral cephalometric films have severe limitations, such as distortion, difficulties in landmark identification, differences in magnification, and the superimposition of bilateral craniofacial structures.[7] Computed tomography (CT) has the advantage of providing a better accuracy in identifying the boundaries of soft tissues and empty spaces and, therefore, helps in better airway visualization.[8]

Volumetric studies provide a new perspective on the airway, and constrictions of the airway might be a precipitating factor for different dentofacial skeletal patterns.

By considering the existence of discrepancies in relation to pharyngeal airway (upper) and malocclusion form, it was decided to do a preliminary, retrospective study to compare and evaluate the pharyngeal airway of patients in Class I and Class II skeletal pattern.

Materials and Methods

Peripheral nervous system CT (PNS CT) scans of 30 patients were selected from the files of patients registered at the Department of Radiology, Amrita Institute of Medical Sciences. The conventional tomography scan per person had to be taken for various medical concerns unrelated to this project. All scans were taken by the same operator, and specific instructions were given to the operator regarding the patient positioning.

The patients were divided into two groups with 15 subjects in each group:

- Class I group (ANB ≤ 4.5)
- Class II group (ANB ≥ 4.5).

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The sample size was calculated based on the formula described by Pandis.[9]

PNS CT scans of subjects having the following conditions were excluded:

- Patients below 18 years of age
- Previous history of adenoidectomy or tonsillectomy
- Patients having severely enlarged adenoids
- Patients with cleft lip/palate or any syndromes
- Patients who had undergone any orthodontic treatment or orthognathic surgery.

All PNS CT scans of patients were performed with a Somatom DRH scanner (Siemens sensation 64, Germany) using the following parameters 130 kV, 220 mA, matrix size of 250 × 250 and scan time of 5 s. Sagittal and coronal cuts of 2 mm slice thickness were taken in all patients.

The patients were instructed to bite with maximum interdigitation and not to swallow and not to move their heads or tongues during scanning. A rigid head-holding device was used to control neck extension. All images were taken in a standard supine position.

The SYNGO software, was used to create three-dimensional (3D) images. These images were then imported as Digital Imaging and Communications in Medicine files into Dolphin 3D®, which is an orthodontic imaging and analysis software program.

As proposed by Grauer,[10] each 3D-rendered image was then reoriented using the Frankfort horizontal plane as its horizontal reference plane, which was constructed from the right and left porions, which are located in the most latero-superior point of the external auditory meatus and the right orbitale, the most inferior point of the lower margin of the bony orbit. The sagittal reference plane was constructed from nasion and the midorbital point, perpendicular to the horizontal reference plane. The axial plane was constructed from nasion, perpendicular to the horizontal and sagittal planes [Figure 1].

The boundaries of pharyngeal airway analysis, proposed by Grauer[11] [Figure 2] were chosen for this study.

- The anterior border, which is a vertical plane through the posterior nasal spine, perpendicular to the sagittal plane
- The posterior border was the posterior wall of the pharynx
- The inferior border was a plane tangent to the most caudal medial projection of the third cervical vertebra, perpendicular to the sagittal plane
- The pharynx was further partitioned into nasopharynx and oropharynx.

A plane perpendicular to the sagittal plane through the posterior nasal spine and the lower medial border of the first cervical vertebra divided the pharyngeal airway into two segments: Upper (nasopharyngeal airway) and lower (oropharyngeal airway).

After defining the borders, a yellow marker (seed point) was placed within the selected boundary, and 73 was chosen as the threshold value as proposed by alves *et al*.[12] [Figure 3].

Lateral cephalograms were constructed from the CT scans using the Dolphin software. These were then digitized, and the patients were divided into Class I (≤4.5) and Class II (≥4.5) group depending on the ANB angle. Both the lateral cephalometric variables and airway dimensions of all patients were repeated by the same investigator at a 2-week interval.

Results

The intra-examiner correlation coefficient was above 0.85 for all the five parameters measured.

A negative correlation was observed between the ANB angle and all other airway parameters [Figures 4-7]. The highest negative correlation was found with the oropharyngeal volume with a Pearson correlation coefficient of −0.59 [Table 1]. All the airway parameters except for the nasopharyngeal volume were found to be statistically significant.

The Class I group showed a mean total airway area of 1043.9 mm^2 and the Class II group showed a mean total airway area of only 856.3 mm^2 [Table 2]. The independent two sample *t*-test performed for comparison between the Class I and Class II group revealed that the airway measurements were significantly different between the groups ($P = 0.01$) [Table 3 and Figure 8].

The total airway volume was also statistically significant between the groups. The Class I group showed a mean total airway volume of 24237.0 mm^3 and the Class II group showed a mean total airway volume of 18740.13 mm^3 [Figure 9 and Table 2].

The nasopharyngeal airway volume showed no statistically significant differences between the groups [Table 3]. The mean nasopharyngeal volume was 10042.76 mm^3 and 9344.87 mm^3 in Class I and Class II group respectively [Figure 9 and Table 2].

The oropharyngeal volume difference between the groups showed a high level of significance ($P = 0.001$). The mean oropharyngeal volume in Class I group was 13240.12 mm^3 and the Class II group showed a mean oropharyngeal volume of 7816.89 mm^3 [Figure 9 and Table 2].

Discussion

The main objective of this study was to compare the area and volumes of the pharyngeal airway (nasopharynx and

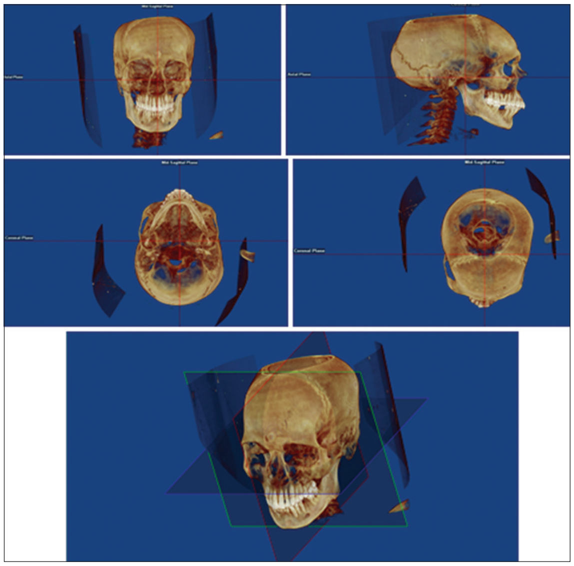

Figure 1: Orientation of three-dimensional images

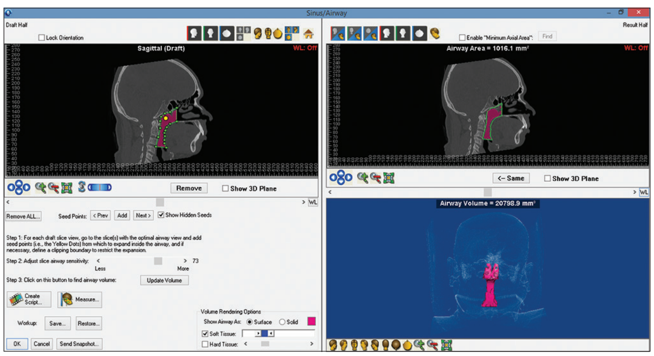

Figure 3: Airway evaluation using Dolphin three-dimensional

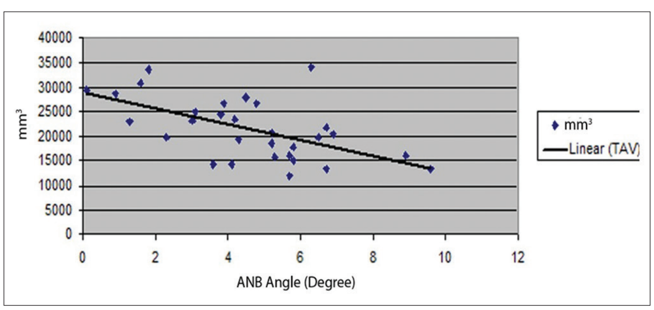

Figure 5: Correlation between ANB angle and total airway volume

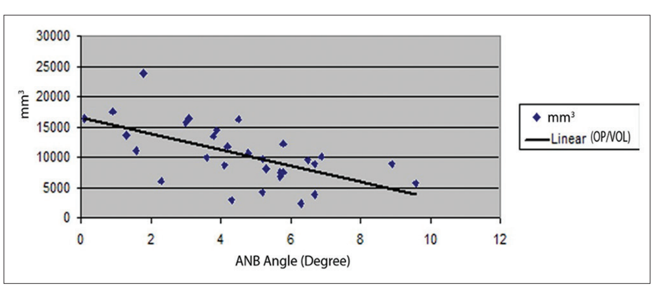

Figure 7: Correlation between ANB angle and oropharyngeal volume

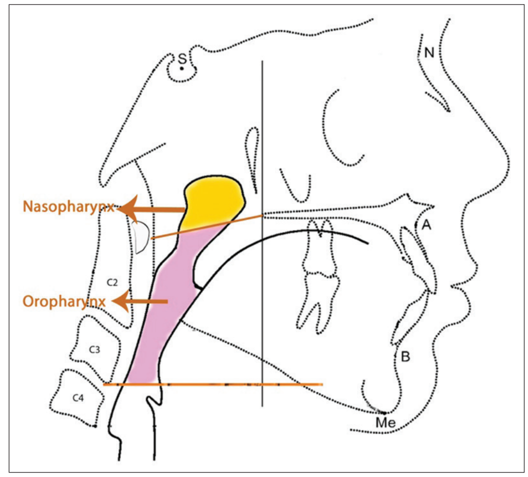

Figure 2: Borders used for airway analysis

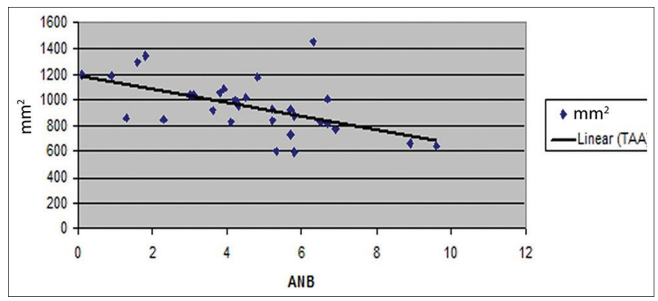

Figure 4: Correlation between ANB angle and total airway area

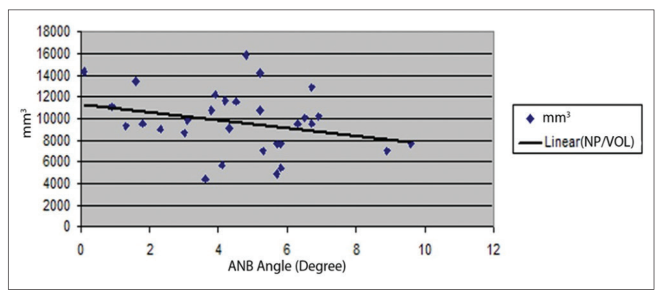

Figure 6: Correlation between ANB angle and nasopharyngeal volume

oropharynx) of adult subjects with skeletal Class I and Class II malocclusion and to see if there is any correlation between the ANB angle and airway.

A prerequisite for accurate 3D reconstructions is a high geometric accuracy of the image data.[13] A study by Abboud *et al*.[14] comparing the accuracy of cone beam CT (CBCT) and medical CT revealed that medical CT provided more accurate images. The contrast of CBCT scanner is lower than that of CT. Furthermore, a CBCT unit rotates with a slight wobble, providing an additional source of image distortion. A correction algorithm is then used to remove the distortion prior to the image reconstruction. When the slice thickness of CT is decreased to obtain more accurate data, higher doses of radiation are needed for a similar visualization quality.

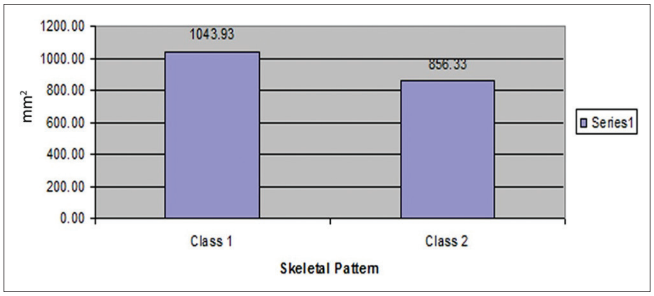

Figure 8: Comparison of total airway area between Class I and Class II

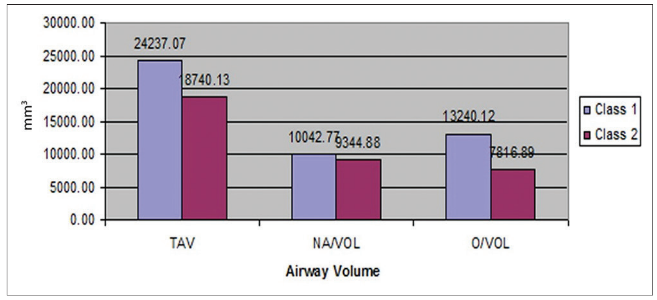

Figure 9: Comparison of airway volume between Class I and Class II

Table 1: Correlation between ANB angle and airway

	Total area	Total volume	NP volume	OP volume
Correlation coefficient	−0.54	−0.55	−0.28	−0.59
P	0.002	0.002	0.134	0.000

OP: Oropharyngeal; NP: Nasopharyngeal

Table 2: Mean values of airway in Class I and Class II

	Group	Mean value	SD
Total airway area (mm²)	Class 1	1043.93	156.51
	Class II	856.33	229.78
Total airway volume (mm³)	Class I	24,237.07	5622.03
	Class II	18,740.13	5713.55
NP volume (mm³)	Class I	10,042.76	2626.52
	Class II	9344.87	3167.04
OP volume (mm³)	Class I	13,240.12	5112.14
	Class II	7816.89	2767.98

SD: Standard deviation; OP: Oropharyngeal; NP: Nasopharyngeal

Table 3: Mean difference between Class I and Class II

Airway parameters	Mean difference between class I and class II	*P*
Total airway area (mm²)	187.60	0.014
Total airway volume (mm³)	5496.94	0.013
NP volume (mm³)	697.89	0.517
OP volume (mm³)	5423.22	0.001

OP: Oropharyngeal; NP: Nasopharyngeal

CBCT, therefore, has an advantage in this regard. However, in this study for more precise diagnosis, the PNS CT scans of patients referred to the Department of Radiology, for various other medical concerns were used. The patients were not subjected to additional CT scans for the purpose of the study.

Posture has a significant effect on pharyngeal size. In the supine position, the oropharyngeal airway decreases while the thickness of both the tongue and soft palate increases due to either gravitational force or changes in upper airway reflexes. This may predispose to increased collapsibility of the upper airway. The nasopharynx is surrounded by bony structures, whereas the oropharynx is surrounded by soft tissues, which probably explains why the oropharynx is more predisposed to external factors such as posture.[15] Hence, a supine CT provides more physiologic information since it is obtained in the usual sleeping posture. However, this was a comparative study and all patients in both groups were scanned with the same conditions for standardization.

Although direct measurements on 3D images have marked advantages over other methods, cephalometric analysis using 3D images still have the characteristics and limitations of a traditional cephalometric examination. Taking 3D measurements directly from 3D images such as CBCT or even 3D photographs allow an examiner to accurately quantify the right and left sides of the patient's jaw and face, separately. A diagnosis can then be reached by comparing the deviation of those measurements from the "normal values." Unfortunately, the exact nature of such "normal values" for 3D measurements remains undefined.[16]

Kumar *et al*.[17] stressed that, because assessment of anatomic landmarks in 3D is still under development, the transition from the 2D to the 3D analysis could be achieved using CBCT synthesized cephalograms. Therefore, in this study also lateral cephalograms were constructed from the CT volumetric data with the help of Dolphin 3D (Dolphin imaging and management solutions version 11.7) in order to distinguish the skeletal pattern.

The sample division into Class I and Class II skeletal patterns according to the ANB angle was chosen because this is one of the most used criteria in the determination of the anteroposterior relationship between the maxilla and the mandible.[18,19] Nevertheless, this angle might be influenced by the anteroposterior position of nasion relative to Points A and B, among other factors, and some authors have suggested that the diagnosis of such discrepancies must be based on more than one anteroposterior appraisal.[20,21] Despite its limitation, the ANB angle was used because the use of two criteria to eliminate such limitations is not always coincident.

The results of airway volume can vary according to the threshold chosen. An increase of the threshold value can result in an overflow of the volume into the surrounding soft tissues, affecting the accuracy of airway measurements with CT. Previous studies[22-24] evaluated airway volumes with the Dolphin software using thresholds of 25, 51, and 52, respectively, whereas few studies[24,25] did not report it. The standardization of the threshold value to achieve the airway volume is important because the use of different thresholds can result in different volumes. Since volumes measured with different thresholds might not represent the actual volumes, the comparisons among studies could become worthless if the same threshold was not used.[26]

Alves *et al*.[12] found that the threshold value of 73 used in Dolphin 3D software was the most accurate to measure airway volume. Hence, in our study, threshold value of 73 was used for all patients.

In this study, we observed that oropharyngeal volume was significantly reduced in Class II patients compared to Class I, this agrees with the findings of Ceylan and Oktay.[27]

Kim *et al*.[18] stated that patients with retrognathic mandible tended to have a smaller airway volume compared with patients with a normal anteroposterior skeletal relationship. Relatively short and/or posteriorly placed mandibles might force the tongue and the soft palate back into the pharyngeal space, causing a reduction in oropharyngeal volume. de de freitas *et al*.[3] measured the dimensions of the upper and lower oropharynx and found no significant difference between Class I and Class II malocclusions. But that study classified its sample by molar relationships, which does not represent the true skeletal pattern of the patients.

Additionally, studies[28] have shown that most patients with obstructive sleep apnea, airway constriction occurred at the level of the oropharynx, near the occlusal plane. Here, the Class II group had smaller oropharyngeal volumes. This finding 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.

Orthodontists and pedodontists, being the early detectors of malocclusion, 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. 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. Early Class II correction using functional appliances can help in reducing the chances of airway problems in future. Even though CBCT is less accurate than CT, it could be used for airway analysis due to its comparatively reduced radiation doses.

Conclusion

As the ANB angle increased, the airway dimensions were reduced. The Class II subjects had significantly lower airway volume than the Class I subjects. Hence, it can be concluded that there is an association between the airway and ANB angle. Considering this information, it is necessary to define the best treatment for each patient, avoiding treatments that could compromise airway dimensions in those who are already prone to have smaller airway dimensions. Longitudinal studies of airway changes in subjects with different skeletal patterns during specific craniofacial growth and development periods should be performed to elucidate detailed knowledge on the relationship between upper airway morphology, function, and craniomaxillofacial characteristics.

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