Original Research

Relationship of the Airway Size to the Mandible Distance in Chinese Skeletal Class I and Class II Adults with Normal Vertical Facial Pattern

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Abstract

Objective: This study aims to evaluate the pharyngeal airway dimensions among Chinese adults in relation to Class I and Class II facial skeletal patterns using three-dimensional cone-beam computed tomography (CBCT) images. **Materials and Methods:** A total of 156 initial CBCT images were evaluated, which were classified into skeletal Class I and Class II according to ANB angle with mean (SD) age being 22.56 ± 4.0 years and 22.32 ± 3.6 years. The pharyngeal airway volume, airway area, minimum cross-sectional area (MCA) and the distance from uvula (tip of the soft palate) to mental spine (U-MS distance) were assessed with Dolphin imaging software. **Results:** Compared with Class I group, Class II group displayed significantly smaller pharyngeal airway volume, airway area and MCA (P <.01, P =0.03, and P =0.008, respectively), and shorter U-MS distance (P <.001). Comparing gender subgroups, the female subgroup showed the smallest airway measurement. Spearman correlation test results showed that the airway volume and area had a significant positive correlation with U-MS distance (r = 0.22, P = 0.005, and r = 0.28, P < 0.005, respectively) and negative correlation with ANB angle (r = −0.23, P = 0.002, and r = −0.21, P = 0.007, respectively). **Conclusions:** Pharyngeal airway volume, airway area, MCA, and the U-MS distance were smaller in skeletal Class II than Class I Chinese adult subjects and lower in female Class II subgroup. Additionally, there was a correlation observed between the mandibular distance (U-MS), ANB angle and airway size.

Keywords: *Adults, cone-beam computed tomography, mandible, pharyngeal airway*

Introduction

The upper airway complex is a dynamic, multifunctional neuromechanical system.[1,2] Its configuration and dimensions are determined by its surrounding anatomical structures such as soft tissue, muscles and craniofacial skeleton.[3,4] In the past few decades, there has been an increased interest in the relationship between upper airway and craniofacial morphology.[5,6] Still, no certain relationship has been identified.[7]

Studying upper airway and its relationship with craniofacial morphology is extremely important in orthodontic diagnosis and treatment planning because of their association with obstructive respiratory disorders.[8] Some authors reported that abnormal respiratory function can lead to longer facial height, incompetent lips, constricted maxilla and open bite.[9,10] According to Borzabadi-Farahani *et al.*[11] those with severe skeletal Class II with small mandible can develop sleep apnea, which is not amenable to orthodontic treatment and would require orthognathic surgical intervention. Nevertheless, it is incorrect to relate different skeletal patterns and dental malocclusions only to upper airway pathologies.[12] Several studies have tried to correlate the upper airway dimensions of patients with normal nasorespiratory functions and no upper airway disease with different malocclusions. Grauer *et al.*[7] and El and Palomo[12] had confirmed that airway dimensions and shape vary among patients with different anteroposterior jaw relationships and different skeletal patterns.

However, most studies conducted were based on western population; further data for different ethnic groups and gender are required.[7,13-15] Chinese adults may have morphological features different from other ethnic groups.[2,16] Samman *et al.*[17] and Gu *et al.*[18] provided reference values for pharyngeal airway among the Chinese

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population; however, both studies were based on lateral cephalograms. Compared with three-dimensional CBCT, the disadvantage of lateral cephalograms is the degradation of three-dimensional entity into two dimensions.[12,19] CBCT also provided many advantages over the conventional (CT) such as lower radiation dose, lower cost and faster image acquisition.[20-22] With the help of computer software, it is possible to assess the upper airway with good accuracy using CBCT in three dimensions.[23,24] Still, there is limited data based on CBCT images of upper airway measurements for Chinese population. Thus, this study is designed to provide data concerning the airway measurements in three dimensions among Chinese adults with different skeletal patterns.

The upper airway studies and its relationship with mandibular position, size and length are also extremely important. Many authors reported that mandibular retrognathism, short mandibular body and downward rotation cause a decrease in airway size.[25,26] In their study based on lateral cephalograms, Ceylan and Oktay[27] noticed a negative correlation between the oropharynx (OP) size and ANB angle. Despite the negative correlation, the ANB angle is the most commonly used criteria in orthodontic practice; still, it is insufficient to evaluate the airway only from the skeletal point of view depending on the ANB angle and further detailed analysis could be required.[12,28-30] Based on their study using CBCT images, El and Palomo[12] confirmed the correlation observed by Ceylan and Oktay. Also, with a more detailed jaw-specific skeletal relationship, they reported that the Class II mandibular retrusion group had smaller airway volume. However, none of the mentioned studies used a measurement directly linking the mandible to the pharyngeal airway. Therefore, we have applied a new criteria to measure the distance between the mandible and the airway directly.

In this study, we evaluated the pharyngeal airway relationship in Class I and Class II skeletal patterns and gender subgroups using three-dimensional CBCT Images. We obtained data concerning airway measurements for each group specific to Chinese adults, and investigated the distance between the mandible and the pharyngeal airway.

Materials and Methods

A total of 164 CBCT images of Chinese adults who came to the Department of Orthodontics of Stomatology Hospital of Nanjing Medical University between 2014 and 2016 were evaluated. Inclusion criteria were adult subjects in the age group of 18–39 years without any previous orthognathic surgery, respiratory disorders, pharyngeal pathology, history of snoring, nasal obstruction, obstructive sleep apnea, adenoidectomy,[31] and any syndrome or detectable pathology along the pharyngeal airway through CBCT images inspection. Exclusion criteria included images that did not show the fourth cervical vertebra (C4),[32] severe hypodivergent (FMA < 23.5°) and severe hyperdivergent (FMA > 30.5°) growth patterns.[33,34] Informed consent was obtained from all patients before participation in the study. The study was carried out in accordance with the Helsinki Declaration and approved by the Ethics Committee of the Stomatology School of the Nanjing Medical University in China (PJ2014-045-001).

All DICOMs were scanned by Newtom 5 g system (Verona, Italy) according to a standard protocol (16 × 18 cm FOV, 0.30 mm Voxel resolution, FSV: 110 kV: 8 mA. SSV: 110 kV: 10 mA, 4.8S scan time). All CBCT scans were taken while patients were in the supine position with head fitted into molded pillow and with teeth in maximum intercuspation.

The images were imported in DICOM format into Dolphin imaging software (version 11.8 Premium; Dolphin Imaging, Chatsworth, CA). ANB and FMA values of every subject were collected, sample was divided into two skeletal groups according to the ANB angle (Class I: 0.7°–4.7°, Class II: >4.7°) (Class I n = 88, Class II n = 68). These groups were further divided into four subgroups according to the subjects' gender. To define the pharyngeal airway margins, we used the limits proposed by Anandarajah *et al.*[35] with the line between the anterior nasal spine ANS) and posterior nasal spine (PNS), extending to posterior pharynx wall as upper margin, and the line between anterior-superior edge of fourth cervical vertebra (C4) and menton (Me) as lower margin [Figure 1]. Using Dolphin 3D airway measurement tool, we evaluated the airway volume, airway area and the minimum cross-sectional area (MCA) according to the margins. The software calculated the airway volume, airway area and MCA automatically after manually checking CBCT images slice by slice horizontally to assure that all areas of the pharyngeal airway were included [Figure 2a-c]. To measure the distance between the pharyngeal airway and mandible,

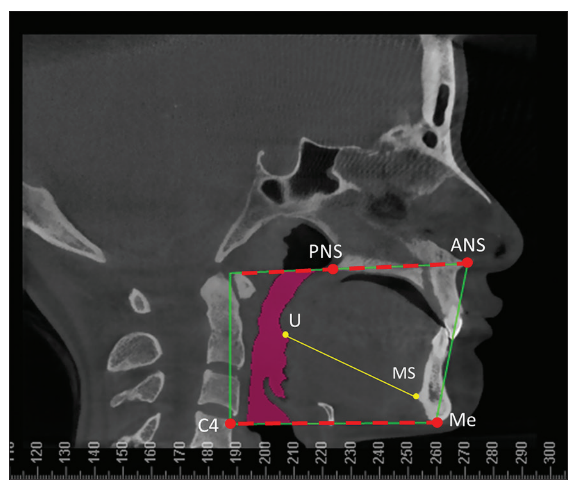

Figure 1: Upper airway delineating margins and landmarks those were proposed according to the study by Anandarajah S.34: Superior: The line passing from the anterior nasal spine to posterior nasal spine (ANS to PNS) extended to the posterior wall of the pharynx, Inferior: The passing line from the anterior-superior edge of the fourth cervical vertebrae to the menton (CV4 to Me) Anterior: The anterior wall of the pharynx, Posterior: The posterior wall of the pharynx, Laterally: Lateral pharyngeal walls. Tip of soft palate (U) and mental spines (MS) forming the U-MS line

Dolphin imaging measurement tool was used to draw a line from the tip of the soft palate (U) to the middle of the mental spines (MS) [Figure 2d]. All variables and measurements used are shown in Table 1.

Statistical analysis

All measurements were repeated after a two-week interval by the same investigator. Investigator calibration was assessed with intraclass correlation coefficient (ICC), investigator's calibration was confirmed, as the results of the ICC were higher than 0.85 for all variables. A descriptive statistical analysis, including mean and standard deviation was performed for all pharyngeal airway measurements. The *t*-test was used to determine the difference between Class I and Class II measurements of the airway volume, area, MCA, and U-MS distance. Correlations among different variables and pharyngeal airway measurements were tested by Spearman correlation coefficient test.

Results

One hundred and fifty-six CBCT images of Chinese adult subjects were enrolled, 72 males (46 in Class I and 26 in Class II) and 84 females (42 in Class I and 42 in Class II), as shown in Table 2. Since this study targeted adult subjects, the mean age for Class I subjects was (22.56 ± 4.0 years) and for Class II subjects, it was (22.32 ± 3.6 years), and there was no statistical difference in age between the two groups (P = 0.7). The mean values of ANB and FMA for Class I subjects were (3.1° ± 0.9° and 24.66° ± 0.61°, respectively) and for Class II subjects, it was (6.1° ± 1.6° and 28.35° ± 0.72°, respectively). The FMA angle for all subjects was within normal (23.5° and 30.5°).

Pharyngeal airway dimensional measurements, including the mean values and standard deviations for the airway volume, airway area, MCA, and U-MS distance in Class I and Class II skeletal patterns and gender subgroups are shown in Table 3. Skeletal Class II subjects showed significantly smaller airway dimensions (volume, area, and MCA) (P <.01, P =0.03 and P =0.008) than Class I as following: airway volume (12770 ± 4345 vs. 14890 ± 5591 mm^3), airway area (614 ± 157 vs. 670 ± 160 mm^2), airway MCA (109 ± 54 vs. 138 ± 75 mm^2). While Class II female subgroup showed the smallest mean values for the airway dimensions (11760 ± 3732 mm^3, 576 ± 135 mm^2 and 106 ± 47 mm^2, respectively). Comparing gender subgroups, airway measurements (volume, area, and MCA) for female subgroup showed statistically significant difference between different skeletal patterns (P <.01, P =.04 *and* P <.01), but no significant difference in male subgroup. Those results are summarized in Figure 3.

Additionally, the U-MS distance was significantly shorter in skeletal Class II than skeletal Class I (51 ± 4 vs. 54 ± 4 mm)

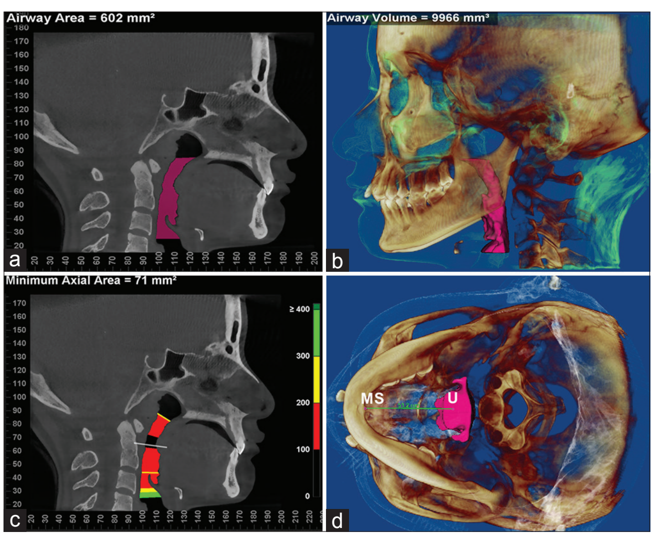

Figure 2: (a) Two-dimensional view of the upper airway. (b) Three-dimensional view of the upper airway. (c) Minimum cross-sectional area (MCA). (d) Transverse view for the U-MS distance, the line from (U) uvula or tip of soft plate to (MS) mental spines

Table 1: Definitions of variables and measurement

Variable	Definition
ANB angle (°)	A point-Nasion-B point or calculated by ANB=SNA-SNB
FMA angle (°)	Frankfort Mandibular-Plane angle
Airway volume (mm^3)	Three-dimensional evaluation for the airway volume
Airway area (mm^2)	Airway cross-sectional space area
Airway MCA (mm^2)	MCA
U-MS distance (mm)	The line between tip of the soft palate (U) to the middle of MS

MCA=Airway minimum cross-sectional area, MS=Mental spine, U-MS=Mandibular distance between Uvula (tip of soft plate) to MS

Table 2: Subjects distribution by gender and sagittal skeletal patterns

	Class I	Class II	Total
Female (%)	42 (26.9)	42 (26.9)	84
Male (%)	46 (29.4)	26 (16.6)	72
Total	88	68	156

The images were classified into Class I and II according to the ANB angle (Class I: 0.7°–4.7°, Class II: >4.7°)

Table 3: Mean and range for airway dimensions and mandibular distance

Classification	Means±SD			
	Volume (mm^3)	Area (mm^2)	MCA (mm^2)	U-MS (mm)
Total Class I	14,890±5591	670±160	138±75	54±4
Total Class II	12,770±4345	614±157	109±54	51±4
Female Class I	13,800±4048	634±127	132±49	52±3
Female Class II	11,760±3732	576±135	106±47	50±4
Male Class I	16,780±6586	704±181	144±92	55±5
Male Class II	14,420±4816	677±171	115±64	53±4

Values are presented as mean and standard deviation. MCA=Airway minimum cross-sectional area, MS=Mental spines, U-MS distance=Mandibular distance between Uvula (tip of soft plate) to MS, SD=Standard deviation

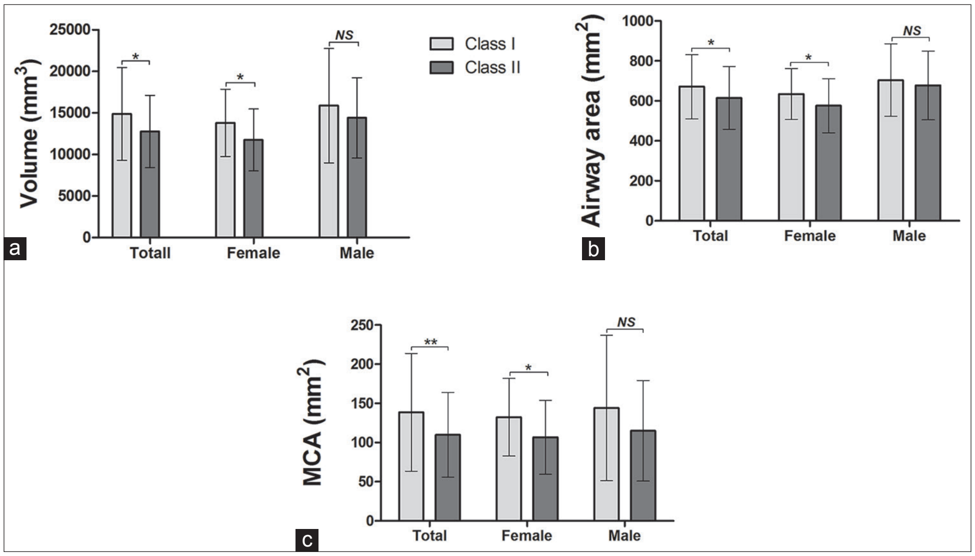

Figure 3: Comparison of Airway measurements; (a) Volume (mm³), (b) Area (mm²), (c) minimum cross-sectional area (mm²) between Class I and Class II groups and gender subgroups. (P* < 0.05; ***P* < 0.01; ****P* < 0.001 and NS: No significance)**

(*P <.001*). Meanwhile, when comparing U-MS in gender subgroups, the female subgroup displayed statistically significant difference (*P* =0.007), but not male subgroup [Figure 4].

Correlations between pharyngeal airway dimensions, U-MS distance, and ANB angle were evaluated using Spearman coefficient correlations as shown in Table 4. U-MS distance showed significant positive correlations with both airway volume and airway area but not MCA. Furthermore, there were negative correlations between ANB angle and pharyngeal airway volume and area, but no significant correlation with MCA. Accordingly, there was a significant negative correlation between ANB angle and U-MS distance.

Table 4: Correlations coefficient between: Mandibular distance between Uvula (tip of soft plate) to mental spines, ANB angle and airway (volume, area and airway minimum cross-sectional area)

	r	*P*
U-MS/V	0.2222	0.0055**
U-MS/A	0.2837	0.0003***
U-MS/MCA	0.1354	0.0929
ANB/V	−0.2388	0.0027**
ANB/A	−0.2122	0.0078**
ANB/MCA	−0.05101	0.5272
U-MS/ANB	−0.2381	0.0028**

MS=Mental spines, U-MS=represents the mandibular distance between uvula (tip of soft plate) to MS, V=Airway volume, A=Airway area, MCA=Airway minimum cross-sectional area (*P*<0.01, *** *P*<0.001 **)

Discussion

The objective of the study was to evaluate pharyngeal airway volume size, airway area and MCA within defined bony landmarks that adequately encompass the area of interest. All subjects were divided into two skeletal groups—Class I and Class II groups, according to the ANB angle (Class I: 0.7°–4.7°, Class II: >4.7°).[34,36] The ANB angle is reliable criteria to determine the anterior-posterior discrepancies, despite its limitations; it is widely used in orthodontic practice.[33,34,37,38]

All subjects in our study had a normal FMA angle (23.5° and 30.5°),[34] as reported mandibular angle can influence the pharyngeal airway dimensions.[33,39]

Patient positioning from upright to supine or changing in head position during data acquisition could affect airway dimensions.[40,41] For our study, the CBCT scanner used was (Newtom 5 g system Verona, Italy), patients were scanned in a supine position with patient head fitted into a molded pillow. Perhaps in future prospective studies, more measures should be considered to control head position during CBCT scanning.

Schendel *et al*.[22] investigated normal pharyngeal airway changes during growth and development from the age of 6–60 years. They had mentioned that the length of PAS increases until the age of 20 years, followed by a variable period of stability. There is then a slow decrease in airway size up to the age of 50 years following which there is a rapid decrease in airway size. As for this study, the mean age for Class I group was 22.56 years, for Class II group, it was 22.32 years and the upper limit of age was 39 years. It is unlikely that age had significantly affected our study results.

Many studies have tested for CBCT accuracy and reliability in evaluating the airway dimensions. It was concluded that CBCT digital measurements are accurate and reliable for airway morphological assessment with low cost as well as low radiation dose.[23,24,42,43] Our study observed the simplicity

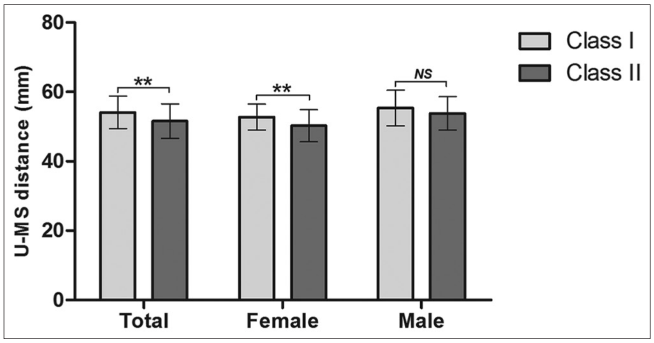

Figure 4: Comparison of U-MS distance (mm) between Class I and Class II groups and gender subgroups. (P* < 0.05; ***P* < 0.01; ****P* < 0.001 and NS: No significance)**

of evaluating CBCT images in association with Dolphin imaging software to evaluate the pharyngeal airway. It has the capability to provide three-dimensional assessments, which cannot be obtained with conventional lateral radiographs.

Several studies were conducted to evaluate pharyngeal airway in relation to dento-maxillofacial morphology using lateral cephalometric or CBCT images.[7,32-34,44,45] Some studies were based on a two-dimensional airway evaluation using lateral cephalograms, which is not an accurate representation for such a three-dimensional complex.[19,46,47] Some other 3D studies only assessed a segment of the pharyngeal airway, which is not necessarily a complete representation of the pharyngeal airway.[35,37]

Our results showed that pharyngeal airway volume, airway area, and MCA were significantly smaller in Class II than Class I subjects. Cabral *et al*.[44] assessed the pharyngeal airway space in 42 CBCT images for adult patients, where they found that the volume and MCA in Class II subjects were smaller than the same measurements for Class I subjects. Grauer *et al*.[7] compared airway volume and shape to facial morphology in 62 non-growing patient CBCT records. Their results showed that Class II group subjects had smaller measurements than the other groups. Castro-Silva *et al*.[48] evaluated the pharyngeal airway for 60 patients and they found that Class II subjects have smaller airway volume than Class I and Class III, while Class III had the greatest airway volume. These are in line with our findings, but they have not mentioned the differences among gender subgroups in their studies. This study showed that in Chinese population the female subgroup showed a statistically significant difference for airway dimensions but not the male subgroup. Our study was much more comprehensive in terms of subjects' number.

Ceylan and Oktay[27] classified 90 subjects according to the ANB angle and investigated pharyngeal size on lateral cephalograms. They noticed a negative correlation between ANB angle and the oropharynx size. Based upon CBCT images with a bigger sample size and different limits used to delineate the pharyngeal airway in our study, we found out that among Chinese adults there were a significant correlation between ANB angle and airway dimensions (volume and area).

The relationship between pharyngeal airway and mandibular position, length and size have a great importance in orthodontic diagnosis,[8,26] many studies had addressed that mandibular retrognathism or back/downward rotation can induce a retro-displacement of the tongue position and hyoid bone, which may lead to a concomitant decrease in the upper airway volume.[25,33,42,44,48-52] El and Palomo[12] investigated pharyngeal airway dimensions of 101 Caucasian patients aged between 14-18 and concluded that Class II mandibular retrusion group had the lowest values. Still, there is a need to evaluate mandible relationship with airway not just from the skeletal point of view; as ANB angle is a skeletal indicator to determine the anteroposterior relationship between maxilla and mandible,[53] more detailed analysis could be required to link the mandible directly to the airway. Therefore, we had applied special measurement by linking the mandible directly to the airway to confirm the direct correlation between mandible and pharyngeal airway in conjunction with ANB angle. The U-MS distance showed a statistically significant difference between the different skeletal pattern groups and in female gender subgroups. Further, we noticed that there was a significant positive correlation between airway volume and airway area, and mandibular distance (U-MS distance) but not with airway MCA. Moreover, there was a significant negative correlation with ANB angle, which confirmed the reciprocal relationship between mandible position and airway size. These results might support what Trenouth and Timms[26] observed in their study, which was that the airway size was correlated with mandible length (menton to gonion) and that the mandibular length could influence the distance between the airway and mandible. However, our study targeted adult subjects with normal respiratory function in a different population.

Limitations of this study were the small sample size of male Class II subjects compared to female subjects. There were no attempts made to control respiratory movement or head position during CBCT acquisition. It would be interesting to consider the respiration phase, head position and body measurements in future studies. Furthermore, because of the nature of the airway structure, (U) point was used as a landmark to measure the distance between the airway and the mandible, which is not an immobile bony landmark.

Conclusions

Pharyngeal airway volume, airway area, MCA and U-MS distance are smaller in Class II subjects than Class I skeletal patterns, and smaller in female subgroup among the Chinese population. A positive correlation between the airway (volume and area) and mandibular distance, and a negative correlation with jaw anteroposterior discrepancies were observed.

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Conflicts of interest

There are no conflicts of interest.

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