Original Article

Cone-beam evaluation of pharyngeal airway space in adult skeletal Class II patients with different condylar positions

Jintao Xu[a]; Ruonan Sun[a]; Linna Wang[b]; Xiaoying Hu[c]

ABSTRACT

Objectives: To test the null hypothesis that there is no significant difference in pharyngeal airway space among adult skeletal Class II patients with different condylar positions using cone-beam computed tomography (CBCT).

Materials and Methods: The CBCT records of 60 patients with skeletal Class II malocclusion (ANB angle $\geq 4°$, Wits ≥ 0) were selected from the CBCT database. According to the condyle position, the patients were divided in three groups: anterior group (CD $\leq -12\%$), centric group ($-12\% \leq$ CD $\leq +12\%$), and posterior group (CD $\geq +12\%$). Three-dimensional (3D) pharyngeal airway models were reconstructed using InvivoDental software 5.1.3. The volume and area of the pharyngeal airway space were measured in the 3D airway model.

Results: The volume and area of the pharyngeal airway space in the centric group were significantly smaller than those in the posterior group ($P < .01$). The volume and area of the pharyngeal airway space were smallest in the anterior group and significantly increased in the centric and posterior groups ($P < .001$).

Conclusions: The null hypothesis was rejected. Significant differences were noted in pharyngeal airway space among adult skeletal Class II patients with different condylar positions. (*Angle Orthod.* 2019;89:312–316.)

KEY WORDS: Pharyngeal airway; Condylar position; CBCT

INTRODUCTION

Obstructive sleep apnea (OSA) is a sleep disorder characterized by pauses in breathing or shallow breathing during sleep and has an incidence of 2%–4% in adults.[1] The pathogenesis of OSA includes narrowing and obstruction of the upper airway, in particular the pharyngeal airway. Previous studies have demonstrated that obstruction of the pharyngeal airway is associated with mandibular retrognathism, a vertical growth pattern, and a tendency for skeletal Class II malocclusion.[2–8] Therefore, a correlation between the position and morphology of the mandible and the pharyngeal airway has been established.[9–11] Yuen et al[12] reported an increase in pharyngeal airway space after condyle replacement and mandibular advancement surgery, indicating a possible underlying correlation between the pharyngeal airway and the position of the mandibular condyles. Knowledge of the morphology of the pharyngeal airway in adult patients with skeletal Class II malocclusion and the different condyle positions is essential when formulating an orthodontic treatment plan for these patients, given their risk of pharyngeal airway obstruction.

Most of the studies conducted in the past used lateral cephalograms (LC) to investigate the morphology of the pharyngeal airway. Lateral cephalograms are two-dimensional (2D) images generated by scanning three-dimensional (3D) anatomic structures. This method cannot fully assess the size of the airway or reflect the complexity of the airway morphology because of the effects of malformation, magnification,

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lack of transverse dimensions, and overlap of bilateral craniofacial structures.[13] However, the 3D morphology of the airway can be evaluated by cone-beam computed tomography (CBCT), which provides more accurate and reliable measurements than those obtained by traditional methods.[14,15] Furthermore, additional anatomic measurements, such as airway volume and lateral anteroposterior diameter, can be acquired on CBCT.[16,17]

The aim of this study was to test the null hypothesis that there is no difference in pharyngeal airway space among adult skeletal Class II patients with different condylar positions using CBCT.

MATERIALS AND METHODS

Subjects

CBCT scans of adult patients with skeletal Class II malocclusion that had been obtained routinely for initial diagnosis were retrieved from the archives of the Department of Orthodontics. The study protocol was approved by the Medical Ethical Commission of the Hebei Medical University and Hospital of Stomatology. All patients signed the informed consent.

Inclusion and Exclusion Criteria

The inclusion criteria were: (1) adult patients (aged 18 years and above); (2) skeletal Class II malocclusion (ANB angle $\geq 4°$, Wits ≥ 0); (3) mandibular symmetry; (4) no temporomandibular joint (TMJ) disease; (5) no history of TMJ or pharyngeal surgery; and (6) clear 3D images. Exclusion criteria were: (1) OSA; (2) systemic diseases; and (3) mouth breathing.

Groups

A sagittal slice of the CBCT image showing the central part of the glenoid fossa was selected for evaluation of the condyle position (Figure 1A,B). The method devised by Pullinger et al.[18] was used for measurement and classification of the condyle position in the glenoid fossa (Figure 2). Using this method, the variation in condyle position was expressed as $CD = (A - P)/(A + P) \times 100\%$, where CD is the percentage displacement of the condyle, A is the anterior joint space, and P is the posterior joint space. Sixty randomly selected subjects were divided in anterior, centric, and posterior groups according to the CD value. The anterior group comprised 20 subjects (12 females, eight males, mean age 22.3 $\pm$ 2.6 years) with an anterior condyle position (CD $\leq -12\%$). The centric group included 20 subjects (nine females, 11 males, mean age 21.8 $\pm$ 3.2 years) with a centric condyle position ($-12\% \leq$ CD $\leq +12\%$). The posterior group comprised 20 subjects (11 females, nine males, mean age 19.6 $\pm$ 2.2 years) with a posterior condyle position (CD $\geq +12\%$). There was no significant difference in patient age or sex distribution, ANB, SNB, Wits, or MP-FH between the groups (Table 1).

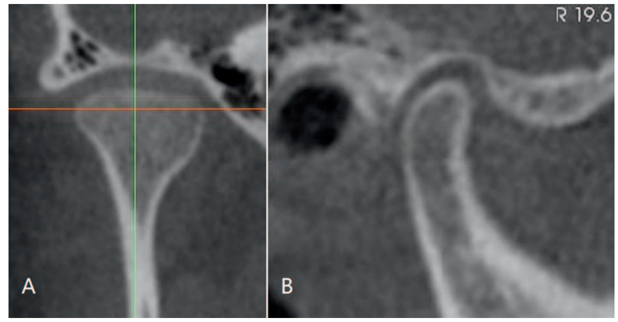

Figure 1. (A) The glenoid fossa shown in the coronal view. Determination of the central part of the glenoid fossa according to the vertical reference line. (B) The sagittal slice of the CBCT image of the mandibular condyle in the glenoid fossa.

CBCT

The CBCT scans were acquired using the Dental Volumetric Tomograph KaVo 3D eXam (Imaging Sciences International LLC, Hatfield, PA) set at 120 kVp and 18.54 mA with a field of view of 23 $\times$ 17 cm, 0.3 mm voxel size, and scan time of 8.9 seconds. The CBCT data were exported in DICOM (Digital Imaging and Communications in Medicine) format to Invivo-Dental software 5.1.3 (Anatomage, Inc, San Jose, CA). A 3D virtual model was created in a 3D coordinate system for each CBCT image. The position and orientation of the 3D model in the coordinate system depended on the head position of the patient when the CBCT was scanned. In the "section" module, using axial, coronal, and sagittal views on the left side, the 3D virtual model was oriented: in the lateral view, bilateral structures, such as the orbits, external auditory canals, and other structures were overlapped

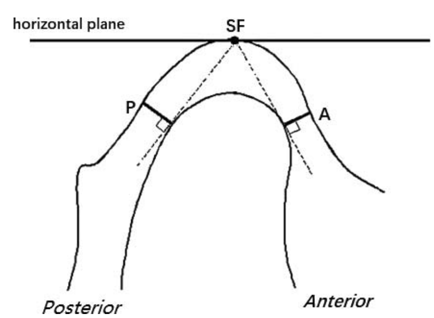

Figure 2. Landmarks and linear measurements of the space between the condyle and the glenoid fossa. Lines tangent to the most prominent anterior and posterior aspects of the condyle were drawn from SF. Distances from the anterior and posterior tangent points to the glenoid fossa were measured as the anterior joint space (A) and posterior joint space (P).

Table 1. Descriptive Statistics and Comparisons of Craniofacial Measurements Among Groups

	Anterior (n = 20)	Centric (n = 20)	Posterior (n = 20)	Total	P
Sex					.626[a]
Female	12	9	11	32	
Male	8	11	9	29	
Age, years	22.3 ± 3.6	21.8 ± 3.2	19.6 ± 4.2		.176[b]
Craniofacial measurements					
ANB, °	6.47 ± 1.64	6.29 ± 1.23	6.83 ± 1.55		.507[b]
SNB, °	78.32 ± 3.86	77.94 ± 2.47	78.52 ± 3.05		.834[b]
MP-SN, °	28.92 ± 7.35	27.68 ± 6.83	28.30 ± 8.49		.875[b]
Wits, mm	5.79 ± 3.54	6.87 ± 3.68	5.98 ± 4.04		.627[b]
CD-R, %	−27.82 ± 12.79	−1.86 ± 8.20	24.38 ± 10.63		.000[b]
CD-L, %	−23.51 ± 9.34	0.96 ± 8.93	26.05 ± 11.26		.000[b]

[a] Results of Pearson χ^2 test; MP indicates mandibular plane; R, right condyle; L, left condyle.
[b] Results of one-way analysis of variance.

as much as possible and the Frankfort horizontal plane was oriented horizontally.

3D Pharyngeal Airway Reconstruction and Measurements

The 3D pharyngeal airway models were reconstructed using the InvivoDental software. The pharyngeal airway space was outlined in midsagittal sections (Figure 3A) and the cross-sectional areas were measured. Regions of interest were defined and used to measure the volume of the pharyngeal airway (Figure 3B). The upper limits of the regions of interest were set at the posterior nasal spine (PNS) level and the lower limits were set at the level of the anteroinferior point of C2. All measurements were done by a single operator.

Statistical Analysis

The least significant difference (LSD) test was used for multiple comparisons between the three groups. The significance level was set at $P < .05$. Twenty randomly selected CBCT records were measured on two occasions separated by an interval of 3 weeks. The paired-samples *t* test and intraclass correlation coefficients (ICCs) were used to evaluate the reliability of the measurements. There was no statistically significant difference ($P > .05$) between the two measurements. The ICCs for all measurements were >0.935, suggesting good intra-examiner reliability. All of the statistical analyses were performed using Statistical Package for the Social Sciences software (version 21.0, IBM Corp., Armonk, NY).

RESULTS

The area of the pharyngeal airway space in the centric group (479.4 ± 73.3 mm^2) was significantly ($P < .01$; Table 2) smaller than that in the posterior group (557.7 ± 83.7 mm^2). The area of the pharyngeal airway space was smallest in the anterior group (355.7 ± 54.8 mm^2) and significantly ($P < .001$; Table 2) increased in the centric and posterior groups.

A significant difference in the volume of the pharyngeal airway was detected between the centric group (11,807 ± 1256 mm^3) and posterior group (16,927 ± 5889 mm^3), with the volume being smaller for the centric group ($P < .01$). The volume of the pharyngeal airway space was smallest in the anterior

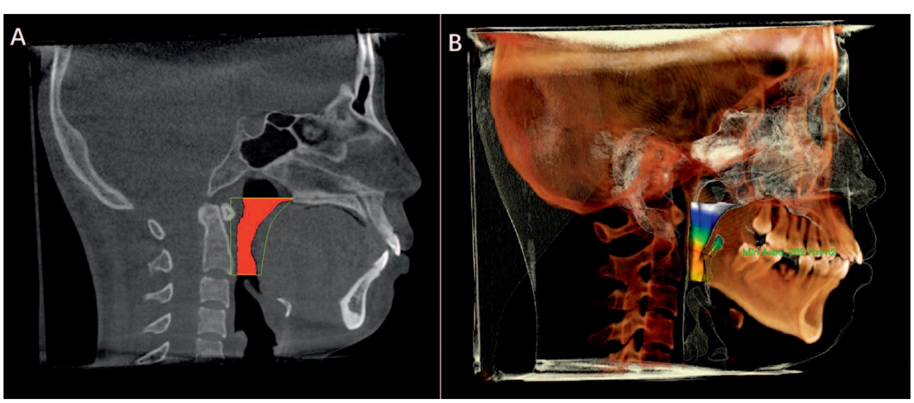

Figure 3. (A) The pharyngeal airway spaces were defined: the upper limits were set at the posterior nasal spine (PNS) level; the lower limits were set at the level of anteroinferior point of C2. (B) 3-dimensional evaluation of the pharyngeal airway volume with InvivoDental software.

Table 2. Mean and Standard Deviation for Volume and Area of the Pharyngeal Airway Space, and the Results of the Least Significant Difference Test[a]

	Anterior		Centric		Posterior				
Measurement	Mean	SD	Mean	SD	Mean	SD	A and C	A and P	C and P
Area, mm^2	355.7	54.8	479.4	73.3	557.7	83.7	***	***	**
Volume, mm^3	7993	2658	11807	1256	16927	5889	**	***	**

[a] A indicates Anterior Group; C, Centric Group; P, Posterior Group.
* $P < .05$; ** $P < .01$; *** $P < .001$; NS indicates not significant.

group (7993 $\pm$ 2658 mm^3) and significantly ($P < .01$) increased in the centric and posterior groups. The results are shown in Table 2.

DISCUSSION

In previous studies, CBCT images demonstrated higher accuracy for assessment of pharyngeal airway space than lateral cephalograms.[19,20] Airway volume and area can be computed automatically using the 3D imaging software, which reduces the operating time and manual measurement error. CBCT has great advantages of less radiation, higher resolution, and lower cost than conventional computed tomography.[21] Furthermore, CBCT produces 3D images without magnification and distortion that can be used to evaluate mandibular condylar position,[22,23] which is impossible when using conventional radiographs.

The pharyngeal airway in adult patients with skeletal Class II malocclusion was previously reported to be closely related to the position of the mandible and its growth pattern (low, normal, or high angle).[3,8] The skeletal parameters measured in the present study are shown in Table 1. There was no statistically significant difference in the SNB, ANB, or MP-SN between the anterior, centric, and posterior groups, which suggests that mandibular position and growth pattern did not affect the pharyngeal airway space. Similarly, there was no significant difference in patient sex or age between the study groups (Table 2), minimizing any possible effects of these factors.

Several previous studies have evaluated the condyle positions in patients with skeletal Class II malocclusion using CBCT.[24–30] The method devised by Pullinger et al.[18] was used to classify the condylar position by most previous studies, including the present study. Paknahad et al.[29] compared the condyle positions in patients presenting with different skeletal patterns and found them to be anterior in patients with skeletal Class II malocclusion compared to those with skeletal Class I and III. They suggested that this finding reflected the adaptation response of the masticatory system or the limited adaptive capacity of condylar cartilage. However, their result could also be explained in terms of the reduced airway volume in patients with skeletal Class II malocclusion in that mandibular advancement is needed in these patients to increase the patency of the upper airway and improve breathing and may cause anterior displacement of the condyles. More precisely, this is a compensatory phenomenon that occurs in patients with narrowing of the upper airways. Clinically, mandibular advancement devices (MADs) are used to treat this compensatory phenomenon in patients with OSA.[31] In the present study, this phenomenon may explain why patients in the anterior group had smaller pharyngeal airway areas and volumes than those in the centric and posterior groups. In contrast, patients with an adequate airway space can still maintain good airway conditions, even if the mandible and condyle are posteriorly positioned, which may explain the finding that the volume and area of the pharyngeal airway space was largest in the posterior group and was significantly decreased in the centric and anterior groups.

In summary, the position of the mandibular condyles may affect the volume and area of the pharyngeal airway. The condition of the upper airway should be considered when formulating an orthodontic treatment plan for a patient with skeletal Class II malocclusion and an anterior condyle position. Changing the position of the condyles in a patient with narrowing of the upper airway may increase the risk of a potentially life-threatening airway obstruction.

CONCLUSIONS

- The null hypothesis was rejected. Significant differences were noted in pharyngeal airway space among adult skeletal Class II patients with different condylar positions (anterior, centric, and posterior position) using CBCT.
- The volumes and areas of the pharyngeal airway space in the anterior group were significantly smaller than those in the centric and posterior group.
- The volumes and areas of the pharyngeal airway space were largest in the posterior group.

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