Three Dimensional Study of Upper Airway in Different Antero-posterior Jaw Relationships through Cone Beam Computed Tomography

Original Article

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Abstract

Introduction: This study aims at examining the difference of pharyngeal airways in patients with different occlusion postures, hoping to improve diagnostic methods and provide a stable treatment plan for orthodontic patients.

Materials and Methods: The data were gathered through CBCT radiographies of patients from a specialized center for radiology. In each occlusion group according to the performed pilot study, 30 people (90 people in 3 groups of class I, II and III, male and female each) were chosen as the sample.

The two-dimentional cephalometric radiographs were obtained from 3D-radiographs, and the patients' malocclusion postures were determined according overjet and ANB angle, and finally grouped. Next, airway volume and dimensions were measured in cross sectional.

Results: Statistical studies showed there is a significant relationship between anteroposterior positions of mandible and the volume of pharyngeal airway. Also, the volume of pharyngeal airway in class III patients is more than those of patients in class I. The volume of pharyngeal airway in class II patients is also less than those of class1 patients.

Conclusion: Pharyngeal airway in class III is larger and in class II smaller. Therefore, considering this subject can lead to improving diagnostic ways, especially orthognatic surgery treatments, and providing a stable treatment plan for patients who need orthodentic treatment

Key words: •Airway volume •Pharengeal airway •Cone-Beam Computed Tomography (CBCT)

Introduction

According to the studies, respiration function is mostly related to diagnosis and orthodontic treatments[1,2] and the diversity in skeletal malocclusion and pharyngeal airway are two interactional factors. Many studies also have confirmed the certain relationship between pharyngeal structures and dentofacial and craniofacial structures.[2,3] Moreover, lots of studies have also reported a certain relationship between airway space and facial morphology.[4-6]

The morphological measurement of pharyngeal airway has mostly been performed by using current cephalometric films through defining the specific landmarks and measuring the lengths and different parts of pharynx.[7,8] The previous studies for measuring the airway width and cross section were on the basis of lateral cephalometry (two-dimensional), although lateral cephalogram offer valuable information about airway evaluation, it has some limitations due to anatomic variations of the complex structure of the airway.[9] Nowadays, modern technology of three-dimentional computed tomography(CT) has led to improvement in diagnostic abilities and has provided the possibility of airway volume evaluation.[10] Most three-dimentional studies of this field have been done by CT which provides high quality images for anatomic diagnosis of hard and soft tissues. But due to high radiation dose of CT, There will be some limitations for patients with severe craniofacial deformities and those who undergo surgical orthodontic treatment.[11-13]

Recently Cone-Beam Computed Tomography(CBCT) systems are maxillofacial specific, and as the method used in CBCT scan is different from Multi Slice method in which the CT is used, its radiation dose would decrease and it can be used in a wide range of patients.[14] By developing the CBCT, the cross sectional and volumetric examinations about complicated anatomy of Pharyngeal airway have been possible, and the related researches confirm that airway volumetric measurements by CBCT is more accurate.[15-17]

By considering the existence of discrepancies in relation between pharyngeal airway (upper) and malocclusion form, we decided to study and examine this hypothesis that pharyngeal airways are different in patients with different occlusion postures and hoping to improve diagnostic methods and to provide a stable treatment plan for orthodontic patients.[17]

Materials and Methods

The research method is cross-sectional. The subjects consist of 90 adult patients who visited one of the oral and maxillofacial radiology centers of Tehran in 1391.

The data (CBCTs) gathering was done randomly among the adult patients who were 18 to 40 years old (with a mean age of 25) with complete dentition of permanent teeth without any experience of pharyngeal disease or nasal obstruction. The patients with any kind of craniofacial syndromes or adenoidectomy or tonsillectomy were excluded from the experiments.

The subjects were classified into3 groups: class I:29 people (14 females, 15 males), skeletal class2: 30 people (16 females, 14 males) and skeletal class III: 31 people (16 males, 15 females).

All CBCT scans were performed by Newtom VG system (QR, Verona Italy) as follows: 90 KV, 3.6 mAs with radiation time of 15 seconds and field of view 20×19 inch.

Moreover, all the scans were done in standing position and the head was on Natural Head Position (NHP), and the patients were asked not to swallow or breathe during scanning. This was possible since the radiation time was about 15 seconds. The slice thickness was set at 0.3 mm, and the voxel size was 0.3×0.3×0.3 mm. The digital image files were exported with DICOM format, and at the end they were available by

QR-MNT Viewer software version 300 (Verona, Italy) as 3D volumetric images in three dimensions of Coronal, Axial and Sagittal.

-*ANS plane:* coronal plane from ANS;

-*PNS plane:* coronal plane from PNS;

-*Posterior PNS plane:* coronal plane;

-*PNS axial plane:* the axial plane which is perpendicular to PNS plane;

-*Soft palate plane:* axial plane which passes along the lowest point of soft palate and;

-*Epiglottis plane:* axial plane which passes through epiglottis base.

To isolate the airway space, the threshold value was set to a range of -300 to -1024 Hounsfield units. The volume of upper air way was measured automatically by an executor by using QR-MNT Viewer Version software (Verona, Italy). As this work is performed by software, to separate the airway from neighboring structures of a domain, the differences between atmosphere and surrounding structures are considered; therefore, the software can calculate the airway volume in a given section. In other words, the software considers the volume of the given domain and omits the outside volume (Figure 2).

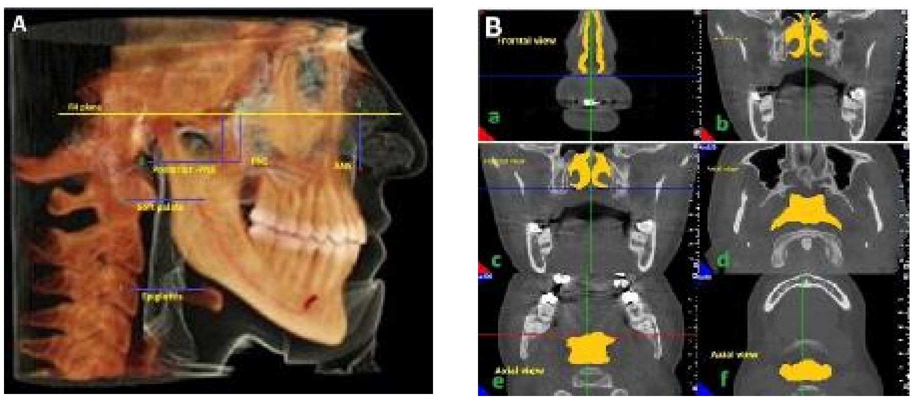

Figure1. (A) Schematic and, (B) CBCT view of all reference planes and studied areas.

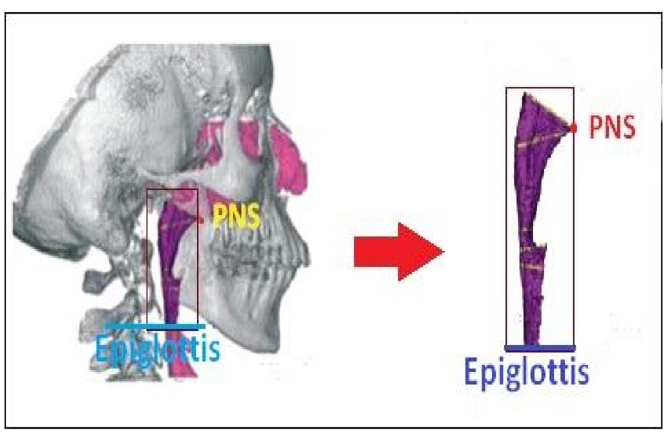

Figure 2. Schematic view of pharyngeal airway boundaries and neighboring.

Anterior boundaries that were used for upper airway analysis include: posterior border of vomer bone, soft palate, PNS, base of tongue and anterior wall of the pharynx. Posterior boundary: posterior wall of pharynx, lateral walls of pharynx with lateral structures and uppermost point of nasopharynx next to posterior concha of anterior chain considered as upper boundaries.

A horizontal plane through the base of the epiglottis was used as the interior boundary. Pharyngeal upper airway is divided into upper and lower sections by a horizontal line passing through PNS.

In order to define the skeletal pattern, we used ANB angle by using derived lateral cephalometery by applying QR-MNT Viewer version 300(Verona, Italy), and the obtained images entered in to V-Ceph (Version 5.5) program for cephalometeric analysis.

The patients with ANB angle of about 0 to 4 degrees were classified into skeletal class I group, those with ANB of more than 4 and ANB of less than 0 were classified under skeletal malocclusion class II and III, respectively.

Cephalometric analysis was performed for 3 angular antero-posterior measurements (SNA: Angle between the anterior cranial base (SN) and NA line; SNB: Angle between the anterior cranial base (SN) and NB line; and ANB: Difference between SNA and SNB).

To determine the differences between the performed cephalometeric measurements, 15 cephalometery were randomly selected, retraced, reanalyzed and reevaluated by the same investigator.

Moreover, the measurements of 15 randomly selected CBCTs were repeated by the study evaluator after 2 weeks. The T-test was used to estimate the systematic errors. Finally the random errors were calculated by using Dahlberg formula. The random errors for regional and volumetric measurements varied from 39.7 to 76.38 mm^2 in area measurements and 96.2 to 166.8 mm^3in volumetric measurements.

T-test was also used to determine the differences between clinicians' cephalometeric measurements ($P<0.05$) which was not statistically significant.

Results

ANB, SNB and Wits showed specific differences between three skeletal groups for two genders (Tables 1 & 2). The statistical analysis results of volumetric measurements in males showed a significant relation between three occlusion groups in upper and lower parts and showed the total volume of pharyngeal airway ($P<0.05$). The linear and angular measurements of ANB and SNB showed a significant relation between different occlusion groups ($P<0.01$). But SNA had no significant relation with different occlusion groups ($P=0.35$).

There was no significant difference between cross sectional area of coronal PNS and ANS, and soft palate plan area and the epiglottis plan area. But posterior coronal plane of PNS and PNS axial plane were significantly different ($P<0.05$) (Table 1).

The statistical analysis obtained by volumetric measurements in female groups showed a significant relation among occlusion groups in pharyngeal airway total volume and its upper and lower parts ($P<0.01$). The linear angular measurements of ANB, SNB and Wits showed a significant relation with different occlusion groups ($P<0.05$), but SNB did not ($P=0.25$).

The cross sectional area except soft palate axial plane ($P<0.01$), showed no significant relation with different occlusion groups either (Table 2).

Soft palate plane and epiglottis plane regions were specifically larger in female class III ($p=0$, $p=0.03$). The upper pharyngeal airway was specifically larger in female class III compared to those of female class II and 1 ($P<0.05$). The analysis shows that there is a specific statistical difference in airway volume and cross sectional regions considering gender (Tables 1&2).

The volume of upper pharyngeal airway was also larger than those of two other groups (P<0.01), and the volume of upper airway was less than those of class III and I(Table 3).

The measurements also revealed that the volume of pharyngeal airway in comparison between males and females in all cases was larger in men, except in class II that the volume of upper airway in females was larger than those of male class II. According to statistical analysis, there are specific statistical differences in volumetric and cross sections of upper airway among different occlusion groups (Table 3).

The volume of upper pharyngeal airway was specifically larger in class III compared to those of class II and 1 (P<0.01).

The lower pharyngeal airway in patients class III showed the largest and least volume in this section were related to patients class II (P<0.03).

In general, the patients class III and class II demonstrated the largest and the least volume of pharyngeal airway in different occlusion groups, respectively (P<0.03). Spearman correlation coefficients between the pharyngeal airway volume and the cephalometric measurements are shown in Table 4. SNB showed positive correlation with upper pharengeal airway volume, but ANB angle showed the opposite result (p<0.01). In other words, the pharyngeal airway volume revealed a negative correlation with the ANB angle (P<0.05)(table 4).

Table 1. The comparison between cephalometric (linear and angular) and volumetric measurements of pharyngeal airway among skeletal malocclusion class I, II and III in male groups

	Class I=15		Class II=14		Class III=16		
Measurement	Mean	SD	Mean	SD	Mean	SD	P
SNA(degree)	81.26	2.21	81.01	4.77	82.47	5.12	0.35
SNB(degree)	79.99	1.91	75.12	2.75	87.12	4.21	0.01
ANB(degree)	2.77	1.04	5.11	2.26	-5.28	3.01	0.01
Wits (mm)	-0.69	1.67	4.77	2.22	-10.42	4.9	0.01
FMA(degree)	24.22	3.95	22.34	2.12	27.54	5.34	0.06
SA(mm^2)	281.22	61.22	270.56	60.59	270.12	59.55	0.45
SP(mm^2)	343.75	102.22	330.34	105.22	350.67	105.22	0.74
SPP(mm^2)	408.23	125.44	370.33	114.77	470.22	152.36	0.05
SPA(mm^2)	691.32	150.46	696.87	150.55	580.2	150.22	0.05
SSP(mm^2)	259.12	87.80	212.24	83.5	373.45	234.43	0.12
SE(mm^2)	410.08	78.88	355.34	71.2	405.19	115.62	0.90
VUP(mm^3)	3562.48	820.58	3062.33	800.55	4674.5	987.29	0.03
VLP(mm^3)	29680.45	7023.32	25465.87	5893.55	29396.79	11841.21	0.05
VT(mm^3)	33242.93	7843	25528.2	6693	34070.79	12828	0.05

SA, ANS plane area;SP, PNS plane area;SPP, PNS-posterior plane area;SPA,PNS-axial plane area; VUP, upper pharyngeal airway volume; SSP, soft palate plane area;SE, epiglottis plane area; VLP, lower pharyngeal airway volume; VT, pharyngeal airway volume. P<0.05, P<0.01

Table 2. The comparison between cephalometric (linear and angular) and volumetric measurements of pharyngeal airway among skeletal malocclusion class I, II and III in female groups

	Class I=14		Class II=16		Class III=15		
Measurement	Mean	SD	Mean	SD	Mean	SD	P
SNA(degree)	79.30	3.85	79.1	0.88	80.65	4.91	0.25
SNB(degree)	77.56	3.95	75.1	2.55	84.12	3.01	0.05
ANB(degree)	2.13	0.55	5.55	2.22	-4.34	1.85	0.00
Wits (mm)	-1	1	4.45	2.12	-8.4	3.9	0.00
SA(mm^2)	230.6	39.12	269.1	60.11	258.56	71.23	0.39
SP(mm^2)	318	62.22	331.1	105.1	312.31	62.37	0.81
SPP(mm^2)	390	87.33	381.34	113.49	409.61	101.22	0.57
SPA(mm^2)	695	120.01	699.45	150.34	710.12	132.73	0.83
SSP(mm^2)	204.06	60.25	188.71	55.02	380.60	112.56	0.00
SE(mm^2)	280.28	67.47	260.67	60	365.38	100.22	0.03
VUP(mm^3)	2885	550.08	3362.27	800	4116.22	990.3	0.00
VLP(mm^3)	20772.4	5233.45	18225.87	4895.88	26737.75	4515.21	0.00
VT(mm^3)	23657.4	5783.53	21588.14	5695.88	30853.97	5505	0.00

SA; ANS plane area, SP; PNS plane area, SPP; PNS-posterior plane area, SPA;PNS-axial plane area, VUP; upper pharyngeal airway volume, SSP; soft palate plane area, SE; epiglottis plane area, VLP; lower pharyngeal airway volume, VT; pharyngeal airway volume. $P<0.05$, $P<0.01$

Table 3. The comparison between upper airways in class I, II and III skeletal groups

	Class I=29		Class II=30		Class III=31		
	Mean	SD	Mean	SD	Mean	SD	P
SA(mm^2)	255.61	50.17	269.83	60.35	264.34	65.39	0.49
SP(mm^2)	489.87	82.22	330.72	105.16	331.49	83.79	0.79
SPP(mm^2)	397.61	106.38	380.83	114.13	439.91	126.79	0.69
SPA(mm^2)	693.16	135.23	696.65	150.44	650.2	141.47	0.46
SSP(mm^2)	231.59	74.02	200.47	69.26	377.02	173.49	0.01
SE(mm^2)	345.54	73.17	308	65	385.28	107.92	0.05
VUP(mm^3)	3223	685.33	3212.3	800.27	4395.36	988.79	0.01
VLP(mm^3)	25226.42	6128.38	21845.87	5394.71	28067.27	8178.21	0.03
VT(mm^3)	2845.16	6813	23558	6194	32461.5	9166	0.03

SA, ANS plane area; SP, PNS plane area; SPP, PNS-posterior plane area; SPA,PNS-axial plane area;VUP, upper pharyngeal air way volume; SSP, soft palate plane area;SE, epiglottis plane area; VLP, lower pharyngeal airway volume; VT, pharyngeal airway volume.

Table 4. Correlation coefficients between pharengeal airway volume and cephalometric measurements

	VUP(mm^3)		VLP(mm^3)		VT(mm^3)	
	Correlation Coefficient	P Value	Correlation Co-efficient	P Value	Correlation Coefficient	P Value
SNA^0	0.07	0.05	0.05	0.66	0.05	0.65
SNB^0	0.28	0.00	0.25	0.27	0.21	0.11
ANB^0	-0.34	0.00	-0.31	0.08	-0.30	0.03
Wits (mm)	-0.38	0.00	-0.12	0.3	-0.25	0.12

VUP, Upper pharyngeal airway volume; VLP, lower pharyngeal airway volume; VT, pharyngeal airway volume. $P<0.05$, $P<0.01$

Discussion

The airway has been evaluated in many studies by using lateral cephalometery and soft and hard tissues landmarks, but as this is a two-dimentional method, the accuracy of estimating the airway space decreases. Arun et al. by studying the lateral cephalometric images of 90 patients and their related factors concluded that there was more perpendicular growth pattern in those with adenoidectomy. They explained that increasing the height of 1/3 lower face due to the development of mandible and neuromuscular factors such as mouth breathing defines mandible posture.(18) In this study, the relation between airway and mandible posture has been suggested but as previously mentioned, the lateral cephalography method was used for three-dimentional studying which relatively compromises the results of the above mentioned study.

Graure et al. in their study, using CBCT reported that the volume of the lower part of upper airway has a significant relation with antero-posterior position of mandible.(19) The results of this study is in consistence with our research. Although Graure et al. reported a significant relation between pharyngeal lower airway and different positions of malocclusion, in our study the relation between pharengeal upper airway and different positions of malocclusion was more significant. The difference in results is due to the difference in choosing the reference line in lower border of pharengeal airway. As mentioned before, in our study the lower border of upper airway (pharengeal) was considered as an imaginary line from the base of epiglottis parallel to Frankfort plane, but in Graure et al., the imaginary line is drawn from the lowest point of the third cervical vertebrae parallel to FH. The difference in selecting the lower border of upper airway led to different but corresponding results.

In our study, it is demonstrated that pharyngeal upper airway is specifically larger in both male and female of class III compared to class I, but the unexpectedly the pharyngeal upper airway in female of class II is larger than that of class I. Moreover, the volume of upper airway has a positive relation with antero-posterior measurements that is explained by prognathism.

In general, previous studies show that the researches based on airway measurements by using 2D methods such as lateral cephalometery, due to estimating the volume by using linear and cross sectional measurements, are not of high accuracy, so not reliable.

The explanation for using such methods is that there is no 3D imaging method during performing these kind of researches. On the other hand, the recent studies by using 3D methods show rather corresponding results, and the studies of Graure et al.(19) Kim Y J et al.(2)and our research have shown similar results. The evolution of skeletal class III due to increasing the SNB and mandible length is reported that is resulted from mandibular prognathism.(19) On the other hand, it was shown that malocclusion class II was the result of decreasing mandible length and SNB angles which indicates decreasing the mandible development. Our study revealed that there is no specific difference in SNA angle degree in patients.

At the other hand, SNB is specifically larger in patients class III which indicates a positive correlation. Increasing the volume of upper airway in patients class III shows a positive relation with prognathism, and decreasing the volume of upper airway in patients class II compared to class I, a significant relation with mandibular retrognathism. Mandibular setback surgery with or without Lefort can result in decreasing the airway space and this can effect on after surgery stability.(20-22)

Bimaxillary surgery compared to set back surgery has less tendency to narrowing effect.[23,24] To protect the airway, the postural relation between jaws and tongue needs to be adjusted. The changes in airway effects after surgery stability.[25,26]

Conclusion

Anatomical knowledge about pharengeal upper and lower airway can be effective in predicting the improper development of mandible and its treatment especially in patients class II and III. According to this research, pharyngeal airway in class III is larger and in class II smaller. Therefore, considering this subject can affect improving diagnostic ways and can also be helpful, especially in orthognatic surgery treatments, by providing a stable treatment plan for patients who need orthodentic treatment.[27]

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