Original article

Cone Beam Computed Tomography (CBCT) Evaluation of Age-related Upper Airway Changes

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Abstract:

Background: Upper airway morphology is associated with facial development and occlusion. Treatment of maxillofacial and occlusal disorders requires sufficient knowledge of related functional variables, including upper airway morphology. In order to determine upper airway obstruction and its exact site, three-dimensional (3D) reconstruction of the airway can be beneficial. The aim of the current study was to determine the age-related changes of upper airway morphology. ***Materials:*** The pharyngeal area of 87 patients was assessed using Cone Beam Computed Tomography (CBCT), and no artifacts were detected. The subjects were within the age range of 6-60 years, with normal body mass index (BMI) of 18-25 kg/m^2. In the CBCTs, in addition to volumetric measurements of nasopharynx, oropharynx, and hypopharynx, distances between pharyngeal wall and posterior nasal spine, uvula, or valcula in anteroposterior and horizontal planes were measured (2D measurement). In addition, the shortest distance between tongue base and posterior pharyngeal wall was calculated in the anteroposterior plane. Data were analyzed in three age groups of 6-20, 21-40, and 41-60 years old.via Spss analysis. ***Results:*** Various values of upper airway and variables which measure anteroposterior dimensions of pharynx were significantly higher in the 21-40 year-old group, compared to 6-20 year-old group. Although these variables were higher in the 21-40 year-old group, compared to the 41-60 year-old group, the difference was statistically insignificant. The transverse variables had the highest value in the 21-40 year-old group, but the difference with the other two groups was insignificant. No significant difference was observed between males and females. ***Conclusion:*** According to the results of the current study, upper airway changes in 2D and 3D models may be age-dependant and become more significant by the age of 20 years. In addition, gender has no effect on the development of upper airways.

Keywords: Nasopharynx; oropharynx; hypopharynx; upper airway; age; CBCT

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Introduction:

Upper airway, as part of the respiratory tract, begins in the posterior choana and ends in the epiglottis. It is composed of three parts: nasopharynx, oropharynx, and hypopharynx [1, 2].

Also, pharynx is a space that begins in choana and extends to esophagus[3].

Internal jugular vein, internal carotid artery and vagus nerve are adjacent to pharynx in a single sheath. Also cerebral nerve 9,10,11, and 12 and cervical sympathetic nerves are close to the pharynx[3].

In order to evaluate different parts of the upper airway, a variety of modalities can be used. Radiological procedures including lateral cephalometery, computed tomography scan, and cone beam computed tomography (CBCT) have been utilized for this purpose[4]. Lateral cephalometery is one of the most common radiologic methods in dentistry[5]. CBCT is a relatively new technology,

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introduced in 1982 for angiography, which was later used for facial and jaw imaging[6].

CBCT uses cone-shaped sources and produces images, which are analyzed by a computer in order to finalize the imaging. Speed of scanning in this method is significantly higher than the scan speed in conventional computerized tomography (CT); thus, less time is required in this method (less than 35 sec)[7]. This technology provides an opportunity for more accurate imaging, compared to standard imaging procedures. The advantages of CBCT include higher speed of scanning, higher resolution, and less x-ray absorption, compared to other methods[1, 8, 9].

This method has been utilized for diagnostic purposes in almost all areas of dentistry. CBCT should be considered as a complementary method for specific purposes, e.g., evaluation of implant site and orthodontic analysis [10,11]. In fact, with aid of CBCT, we can obtain information about anatomical changes in different parts of the upper airways [12,13]. According to previous studies, the size of airway increases until the age of 20 and then gradually decreases by the age of forty; also, the reduction rate increases after the age of 40 years[1]. Complete recognition of morphological changes and three-dimensional (3D) measurements of the upper airway could lead to more accurate evaluation of patients with obstructive sleep apnea, and help predict their clinical outcomes [8, 14].

Although a variety of studies have been conducted regarding obstructive sleep apnea, the actual relationship between upper airway anatomy and normal respiration has not been fully understood. No research has focused on the association between respiratory system and obstructive sleep apnea, or CBCT application in oral, facial, and jaw radiology. In the current study, we aimed to evaluate airway changes in different age groups (6- to 60-year-old subjects).

Since there is a correlation between facial morphology development, occlusion, and upper airway morphology, treatment of facial and jaw disorders requires a full understanding of related functional variables such as airway morphology. In different studies [10, 11], the association between airway morphology and surgical outcomes of sleep apnea patients has been studied. Therefore, it seems important to provide adequate information regarding airway development in children and airway changes in adults for different treatment methods; such information is also of high significance in the identification of airway obstruction and its site in 3D airway modeling [2, 4, 15]. The aim of this study was to evaluate age-related airway changes.

Materials and Methods:

In this study, 86 patients, referring to a private radiology clinic in Mashhad, Iran, were evaluated. Convenience sampling method was applied, and different variables related to CBCT were analyzed. In order to analyze the data, SPSS version 20 was used, and Kolmogrov-Smironov, t-test, chi-square, two-way ANOVA, and Tukey post-hoc tests were performed. Ethical approval was obtained before the start of the study.

In this study, 87 patients, aged 6-60 years old, with normal body mass index (BMI) of 18 to 25 kg/m^2, were evaluated according to their CBCT results. The pharyngeal area was fully evaluated via CBCT, and no artifacts were detected. The volumes of nasopharynx, oropharynx, and hypopharynx, along with the total volume of upper airway, were measured. Moreover, 2D evaluations, including the measurement of distance between posterior pharyngeal wall and posterior nasal spine, uvula, or vallecula, were performed.

The total volume of upper airways was also measured. In order to evaluate the upper airways, CBCT was employed; CBCT was performed by one radiologist in one unit. To perform the procedures, the subject was in natural head position and normal respiratory condition.

HP workstation xw 9400 was used for visualization tasks. CBCT images were obtained by Planmeca ProMax 3D (Planmeca, Helsinki, Finland), and the pictures were presented in 0.2mm voxel size and 15-bit gray scale. Also, 3D reconstruction of CBCT was performed by Planmeca Romexis 2.8 (11.11.2011), and all measurements were done by one radiologist. The 2D measurements of CBCT images included the following sites: posterior nasal spine (PNS), vallecula (V), upper pharyngeal wall (UPW), middle pharyngeal wall (MPW), and lower pharyngeal wall (LPW).

Results:

In this study, 86 patients were evaluated. Demographic information of the patients is summarized in Table 1-4. Based on Kolmogrov-Smironov test, all data had normal distribution ($p\text{-value} > 0.05$). As to t-test results, there was no significant difference between men's average age (30.228 ± 14.312) and women's average age (32.194 ± 16.060) ($p\text{-value} = 0.644$). Moreover, based on Chi-square test, there was no significant

Table 1. Demographic data of the patients

Group	Number	Sex		Age	
		Female	Male	SD	Average
6-20	28	11	17	3.852	13.393
21-40	31	13	18	5.395	30.613
41-60	27	12	15	5.611	49.981
Total	86	36	50	15.581	31.12

SD: Standard deviation.

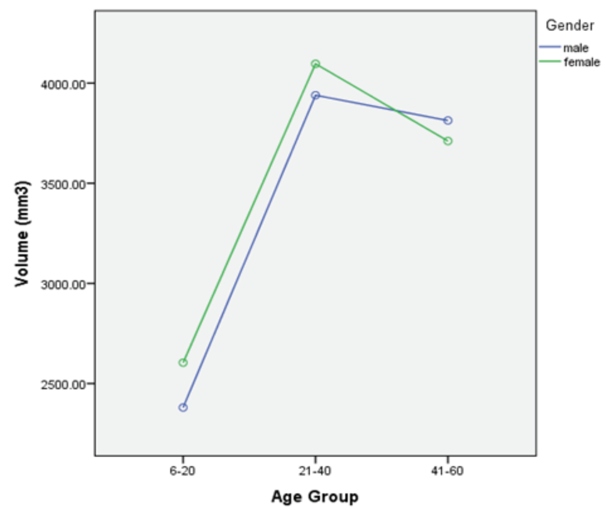
Table 2. Average and standard deviation of nasopharynx volume in different groups, based on gender

Group	Total			Male			Female		
	Number	Average	SD	Number	Average	SD	Number	Average	**SD**
6-20	28	2468.35	761.42	17	2380.29	745.26	11	2604.45	**801.96**
21-40	31	4005.19	569.51	18	3939.33	431.74	13	4069.38	**728.88**
41-60	27	3767.74	4706.83	15	3813.20	413.65	12	3710.91	**559.72**
Total	86	3430.27	910.88	50	3371.42	902.19	36	3512.02	**929.32**

SD: Standard deviation.

Table 3: V-LPW analysis in different groups, based on gender

	Total			**Male**			**Female**		
Group	**Number**	**Average**	**SD**	**Number**	**Average**	**SD**	**Number**	**Average**	**SD**
6-20	28	12.32	2.14	17	12.05	1.91	11	12.72	**2.49**
21-40	31	15.80	1.76	18	16.11	1.45	13	15.53	**2.14**
41-60	27	15.18	1.49	15	15.06	1.43	12	15.33	**1.61**
Total	86	14.50	2.37	50	14.42	2.37	36	14.61	**2.40**
Two-way ANOVA test results									
Group	**Type 3 Sum of Squares**	**df**	**F**	**Sig.**					
36 female, 50 male	184.582	2	27.373	0.000					
	0.304	1	0.090	0.765					
	5.757	2	0.854	0.430					
Error	269.732	80							
Total	18561.000	86							
Tukey post-hoc test results									
Group (I)	**Group(J)**	**Average (I-J)**	**Standard Error**	**Sig.**					
6-20 years old	21-40 41-60	-3.5495 -2.8638	0.47873 0.49527	0.000 0.000					
21-40 years old	6-20 41-60	3.5495 0.6858	0.47873 0.48336	0.000 0.336					
41-60 years old	6-20 21-40	2.8638 -0.6858	0.49527 0.48336	0.000 0.336					



Graph 1. Nasopharynx volume in different age groups, according to gender

difference in gender distribution among the groups (p-value=0.918).

In the evaluation of nasopharynx volume via Levene's test, the homogeneity of variance was approved in different groups (p-value=0.369); based on two-way ANOVA analysis, there was a significant difference between the three groups. On the other hand, considering gender differences, there was no significant difference in the average nasopharynx volume between men and women. According to Tukey post-hoc test, there was a significant difference between the 6-20 year-old group and the other two groups.

In uvula to the middle pharyngeal wall [U-MPW (T)] evaluation, homogeneity of data was approved by Levene's test in different groups (p-value=0.193). Based on two-way ANOVA test and after the comparison of U-MPW (T) in different age groups and genders, there was no significant difference between these groups.

Moreover, in vallecula epiglottic-lateral pharyngeal wall (V-LPW) evaluation, homogeneity of data was approved by Levene's test (P-value=0.664). As to two-way ANOVA test results, a significant difference was observed between the three groups, regardless of gender; on the other hand, in terms of gender, there was no significant difference in average V-LPW between men and women. The results of Tukey post-hoc test suggested that the difference between 6-20 year-old group and the other two groups was significant.

Discussion

Upper airway is of paramount importance in developmental defects of vocal tract, considering its correlation with maxillofacial development. It has been revealed that upper airway obstruction can change the normal pattern of respiration, and has a noticeable effect on the normal development of respiratory tract [16, 17]. Since early detection of these defects can help prevent the progress of many defects, reliable and safe diagnostic procedures should be followed [18, 19].

Ghoneima and colleagues in their study, by constructing an acrylic airway model and attaching it to a human skull, showed that CBCT is a practical and useful method in upper airway evaluation [20]. Cheung et al (2012). Studied cases with cleft palate

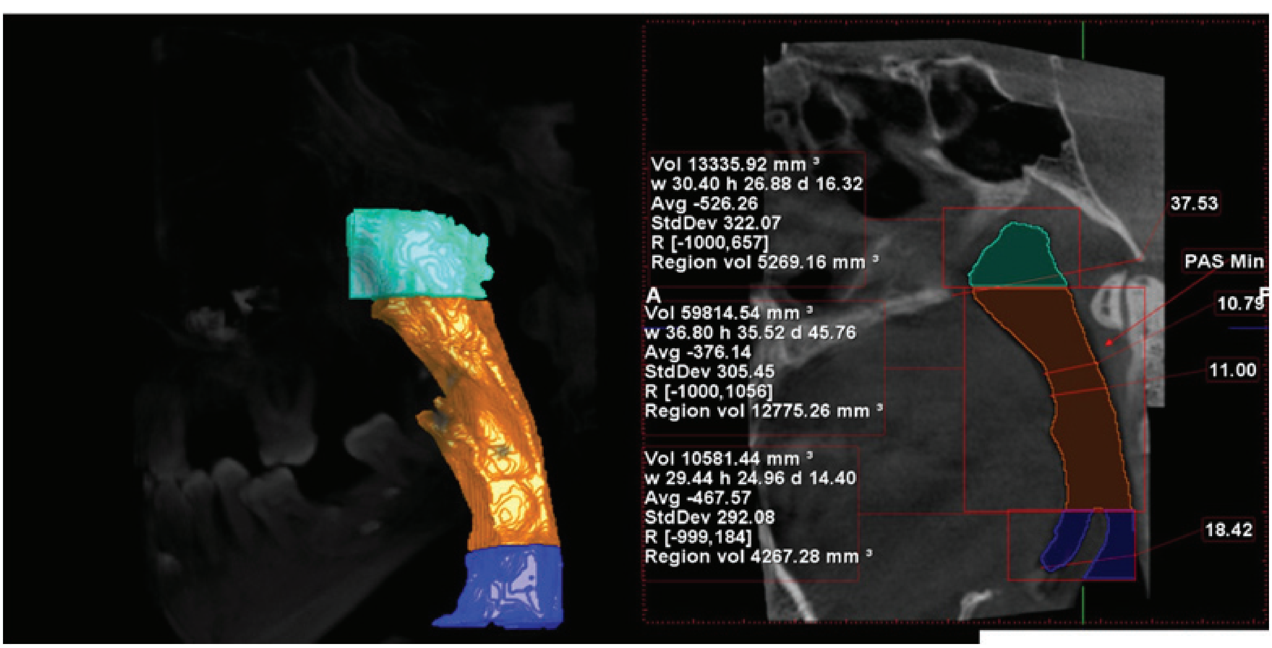


Figure 1. Evaluation of different parts of upper airway in Planmeca Romexis

and lip, and suggested that upper airway volume does not decrease in patients with non-syndromic cleft palate and lip [21]. Abramson et al. showed that airway size in adults is larger than children and is oval in shape [8]. Moreover, Schendel and colleagues (2012) suggested that the total volume of upper airway increases until the age of 20 and remains the same until the age of 40; also, they showed a slight decreasing trend from 40 to 60 years of age [1]. Fagala and colleagues (2011) demonstrated that the total volume of airway increases from 5 to 20 years of age [24]; this finding was in consistence with our results. In fact, after CBCT evaluation of upper airway in our study, it was revealed that the total airway volume was much higher in the 21-40 year-old group, compared to the 6-20 year-old group. In line with our research, the results of other studies indicated that there was no significant difference between males and females in terms of the studied factors. This can be due to the similarity of growth pattern in males and females. In fact, despite some differences in some particular periods, the growth pattern was the same between males and females.

In the evaluation of axial sections, PNS-UPW (T), U-MPW(T), and V-LPW(T) measurements were not significantly different between the age groups; although they increased in 21-40 year-old subjects, they followed a decreasing trend afterwards. In addition, there was no relation between gender and these factors. This can be related to differences in parts of the airway; actually, transverse growth of the airway completes before anteroposterior growth.

In this study, not only the total volume of the upper airway was measured, but also the volumes of different parts of the airway were evaluated. Schendel et al (2012) and Fagala et al (2011). used CBCT for 3D evaluation of airways in different ages and genders. On the other hand, Abramson and colleagues (2009), used CT scan to evaluate the effect of age on different parameters of airways [7,15].

Figure 1. Evaluation of different parts of upper airway in Planmeca Romexis

Abramson [5], Chiang, and their colleagues found no significant difference in airway parameters between male and female subjects [22]. In fact, in the study by Alvez et al (2011), there was no significant difference in total airway volume and minimum axial area between males and females [23]. Contrarily, Fagal and colleagues (2011) concluded that airway volume in 5- to 20-year-old males was greater than that of females of the same age [24].

Based on the results of our study, it could be suggested that airway changes in 2D and 3D models are age-dependent, and become more significant by the age of twenty. Also, gender had no significant effect on airway development.

The low number of cases was one of the limitations of the current study. Also, the study would have been more reliable if airway changes had been evaluated in only one person after certain periods; in this way, interpersonal differences would have been excluded and the results would have been more accurate. Moreover, since there were significant changes in airway measurements of the group under the age of 20, classification of this group into smaller groups could lead to a more accurate evaluation of airway changes. In fact, lack of such classification was another limitation of our study. Moreover,our limited sample size and lack of control group are another limitations of our studies.

Conclusion:

According to the results of our study, it can be suggested that airway changes in 2D and 3D models may be age-dependent and become more significant by the age of twenty. In addition, as the results indicated, gender has no significant effect on airway development.

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