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Measurement of normal maxillary sinus size using computed tomography

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Abstract

Measurement of normal maxillary sinus size using computed tomography

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1. Purpose

The purpose of this study was to evaluate the size of normal maxillary sinus by measuring the volume, width and height of sinus and analyzing their correlation and difference of the sinus respectively between sexes and on the left and right sides using computed tomography.

2. Materials and Methods

The study population comprised 60 patients (120 maxillary sinuses) who had taken CT in the Department of Dental Radiology, Seoul National University, Dental Hospital, between December 2012 and June 2013 who were no specific symptom, pathosis, surgical history.

3. Results

The mean transverse width, antero−posterior width, height and volume of the maxillary sinus were 33.44±4.55mm, 36.51±4.87mm, 45.53±5.62mm, 21.61±6.85cm^3, respectively. Differences of right and left were 2.21±1.75mm, 1.50±1.20mm, 1.65±1.36mm, 2.10±1.77cm^3, respectively. Degrees of asymmetry were 6.46±5.12%, 3.76±2.99%, 3.57±2.92%, 9.54±7.81%, respectively. There was a significant sex difference ($p<0.05$), no significant difference on both sides ($p>0.05$) in all parameters.

4. Conclusion

The outcome of the present study indicated that males have larger maxillary sinus than females, all of the measurements showed no significant difference between the right and left sides.

keywords : maxillary sinus, computed tomography, sinus volume, sinus width, sinus height, sinus asymmetry

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Introduction

In aspect of embryology, paranasal sinuses begin as derivatives in the nasal chamber[1][2][3]. The maxillary sinus is the first paranasal sinus to appear. The maxillary sinus is present at birth and developed in middle meatus with evagination[4]. The maxillary sinus has a shape of small sac at birth. When 2 years of age, the first pneumatization begins[5]. By the age of 4, the maxillary sinus enlarges laterally through infraorbital canal, and closes to the maxillae by the age of 9 years. Meanwhile, the maxillary sinus grows to downward and reaches roof of the hard plate by the age of 9 years[5]. The second pneumatization begins between 7 and 12 years of age with slow development, as the floor of the sinus extends 4 to 5 mm below the level of the floor of the nasal cavity[4][5]. 14–18 years of age, the maxillary sinus fully grows up. The maxillary sinus reaches adult dimensions at 12–15 years of age, and this value is maintained until 20 years of age[6].

There were various theories described function of the paranasal sinus. Resonance theory, proposed by Bartholinus(1660), explained sinuses had important role in phonation by reinforcing resonance[7]. Haller(1763) suggested mucus secretion theory that sinuses moistening the olfactory mucosa[8]. Olfactory theory suggested human large sinus cavities lined with olfactory epithelium proposed by Cloquet(1830)[9]. Thermal insulation theory, suggested by Proetz(1953), described paranasal sinuses helped warming nasal air by insulating thermal exchange[10]. Skillern(1920) insisted paranasal sinuses lightening skull, so neck musculature had reduced burden[11]. In 1922, Proetz first suggested facial growth theory which explained sinuses were empty space as a result of facial growth[12]. Every theory had discounted by other authors or has weak point in some viewpoint. Additional study of evolutionary biology can solve the function of paranasal sinuses[13].

Clinical major symptoms of the maxillary sinus may be due to inside disease. Generally, causes of symptoms are found in the lateral sinus wall. Anatomical variation makes spaces to recurring infections[14]. Depending on the individual anatomic variation, ventilation and secretion transport can be completely blocked, can cause retention of secretions. In this situation, superinfection or further sinus disease can occurs[14].

To analyze morphology of the maxillary sinus, various methods have been used. Schaeffer et. al.[15] measured volume of the maxillary sinus by calculating injected water in the sinus of cadaver and determined size of the maxillary sinus by direct measurement on cadaver. Uchida et. al.[16] compared volume of maxillary sinus between measured from computed tomography images and impression material. Smith et. al.[17] calculated size of the maxillary sinus using serial section of human fetus. Ariji et. al.[18] measured age-related changes in the volume of normal maxillary sinus by axial computed tomography scans. Barghouth et. al.[19] found age-related 3D size of paranasal sinuses using MRI. Jun et. al.[20] analyzed maxillary sinus aeration according to aging process using 3-dimensional reconstruction by high-resolutional computed tomography scanning. Kawarai et. al.[21]had measured the size of the paranasal cavities by reconstructing three-dimensional computed tomography images.

Up to now, lack of information on the influence of instrumental, physical and human limitations are main barrier which could make deviation of measurements from the true value[22]. In assessment of volumetric analysis techniques, determine experimental uncertainty is important. The use of CT compared to invasive methods has advantage which is repeated measurement can be performed without destruction of the object[22].

Calculating dimensions of the maxillary sinus is realized through lineal and volumetric analysis of images obtained from CT using specialized software. Anatomy of the maxillary sinus and exceeding irregularity influence the exactness of volumes determined by means of these instruments[23][24][25]. Perella et. al.[23] evaluated accuracy of linear measurements of the maxillary sinus made in computed tomography. They found measurements of CT based films provided adequate precision and accuracy. Deeb et. al.[25] suggested that 3D volumetric analysis combined with Hounsfield unit can help to evaluate maxillary sinus disease.

The purpose of this study was to analyze the size of maxillary sinus by measuring the volume, width and height of sinus and analyzing their correlation and difference of the sinus respectively between sexes, and on the right and left sides.

Materials and methods

1. Materials

This study was performed retrospectively, using computed tomography images selected from those of 60 patients examined in the Seoul National University Dental Hospital, Seoul, Korea between December 2012 and June 2013. Scans were selected which including both maxillary sinuses except patients who have mucosal thickening, trauma history, operation history. There were 30 males and 30 females (total 60 patients, 120 sinuses) whose ages ranged from 20 to 29 years (mean 22.90±2.56 years). The CT scans were taken by Somatom Sensation 10(Siemens AG, Forchheim., Germany) with following parameters; slice thickness 1mm; T1, 0.75s; 120kV; and 100mA/s

2. Measurements on sinus

Transverse width and antero-posterior width were defined on the axial CT image shown the widest sinus area.

1) Transverse width (T_W)

The transverse width was defined as the distance between two lines which were drawn from the most lateral point and the most medial point of the maxillary sinus parallel to the bi-auricular line.

2) Antero-posterior width (AP_W)

Antero-posterior width was defined as the distance between two lines which were drawn from the most anterior point and the most posterior point of the maxillary sinus perpendicular to the bi-auricular line.

3) Vertical height (V_H)

Vertical height was defined as the distance between the first and the last axial CT images which maxillary sinus is visible.

4) Volume (V)

Volume was calculated by the following formula.

$$\mathrm{V} = \sum_{k=1}^{n} S_k \cdot T$$

S_k is the area of the maxillary sinus in an each slice (mm^2).

T is the thickness of an each slice (1mm).

5) Degree of asymmetry

Degree of asymmetry was defined as formula below.

$$\text{Degree of asymmetry} = \frac{|Right\ side\ value - Left\ side\ value|}{Max(Right\ side\ value - Left\ side\ value)} \times 100(\%)$$

3. Statistical analysis

Student's t-test and paired t-test were used for statistical analysis: $p<0.05$ was considered to be significant. For these analyses, SPSS 18(IBM, New York, USA) was used.

Results

The overall results for measurements are summarized in Table 1.

The mean of T_W was 33.44±4.55mm (male: 34.63±4.83mm, female: 32.25±3.95mm), AP_W was 36.51±4.87mm (male: 37.58±4.96mm, female: 35.45±4.57mm), V_H was 45.53±5.62mm (male: 48.10±4.87mm, female: 42.95±5.14mm), V was 21.61±6.85cm^3 (male: 24.29±7.26 cm^3 female: 18.93±5.22 cm^3). For the sex difference, significant differences were observed in all parameters (T_W, AP_W, V_H , V) ($p<0.05$).

Table 2. shows the mean differences in parameters between the right and left maxillary sinus and degree of asymmetry were summarized. There were no significant differences in all parameters between the values on the both sides ($p>0.05$). High correlation coefficients between the right and left sinus were observed. The values of correlation coefficient(γ) of all parameters between both sides were 0.811, 0.832, 0.928, 0.921 respectively. The mean differences of all parameters between two sides were 2.21±1.75mm, 1.50±1.20mm, 1.65±1.36mm and 2.10±1.77cm^3 respectively. The mean degree of asymmetry between two sides were 6.46±5.12%(T_W), 3.76±2.99%(AP_W), 3.57±2.92%(V_H) and 9.54±7.81%(V)

respectively.

Discussion

Standard values for the changes in the maxillary sinus in accordance with the age and size of the maxillary sinus help to evaluate the abnormal state of the maxillary sinus[26]. For maxillary fracture that contains the maxillary sinus, in order to repair the maxillae in exact location and evaluate the results of the surgery, it has clinical importance[15]. If there is a traumatic disease, or suspected to one side of the maxillary sinus, with a comparison with the opposite side of the normal, in consideration of the standard value according to the age, evaluation and more accurate diagnosis is possible[26].

Exact measurement of the maxillary sinus volume is essential for procedures of sinus floor elevation. Kühl el. al.[27] found computed tomography is promising method to evaluate for graft materials in sinus elevation. It is useful for establish the optimal volume of implant. Gray et. al.[28] calculated that amount of graft material for sinus lift by 3D-MRI. Park et. al.[29] investigated the prevalence, location, height, morphology, and orientation of maxillary sinus septa by use of computed tomography (CT) and 3-dimensional imaging. The results of these studies will help the clinicians to understand the clinical and radiographic findings of sinus and to evaluate disease of sinus and possibility of surgical intervention[14].

Studies similar to the current study were done in the past in a variety of ways. Wolf et. al.[30] used dried skulls and cadaver heads to measure the maxillary sinus. Weiglein et. al.[31] found radiological anatomy of maxillary sinus by human skull using plain radiograph. Spaeth et. al.[32] measured pneumatization and development of paranasal sinuses in children using computed tomography scans. Lee et. al.[33] evaluated normal development of paranasal sinuses in Korean children with magnetic resonance imaging. Duerinckx et. al.[34] described normal paranasal sinus development and provided preliminary criteria for clinical sinus disease using medium field strength magnetic resonance imaging.

Since the introduction of the computed tomography in biological measurement by Koehler et. al.[35], measurement of the volume using a computer tomography, have been actively studied in the field of medicine[16][26][36]. Furthermore, development of technology in computed tomography equipment allows drawing boundary of region of interest shown on monitor. This made it easier measurement process. It can be calculated automatically by the computer on the cross-sectional area of the site, also it is possible to automatically calculate the volume of a special software program. Automatic boundary selection software allows to computer draw boundary of region of interest, reduced the error caused by the user to recognize the eyes, to draw the boundaries of their own, it became possible to run more quickly and accurately the work[37] [38].

Kirmeier et. al.[39] found that there were very small inaccuracy in volume analysis using computed tomography scans of maxillary sinus-like phantoms. They recommended computed tomography as a clinical diagnostic tool to gain dependable results on volume of the maxillary sinus. In the case of research methods using cadavers, there were inaccuracies in the measurement of age and risks of incorrectness in size of the maxillary sinus caused by loss soft tissue[36]. Calculating sinus size by 2-dimentional radiography has difficulties in distinguishing anatomical structures and overlapping the adjacent sturctures[40].

Coronado et. al.[41] found that it is possible without any special equipment or additional software, reliable estimates of the maxillary sinus volume number of slices is limited. In current study, using 1mm thickness of computed tomography images promise more accuracy in value of measurement. Robert Deeb et. al.[25] used Eigentool which helps to select region of interest by Hounsfield unit. The boundary between air cavity and maxillary bone was divided easily in radiographic images. These findings are maintaining exactitude of current study.

Previous studies on the maxillary sinus volume are summarized on table 4. The value of this study was greater than some of the previous studies. But the results are mainly in line with those of previous studies. This difference seems to result from race, age distribution and measuring method disagreement. In cases of Ariji et. al.[18][42], Park et. al.[43] (2010), Barghouth et. al.[19], they included less than 20 years old in subjects. These methods result in a decrease in the mean size of the maxillary sinus compared to current study. Also Barghouth et. al.[19] calculated sinus volume using sinus volume index by MRIs. Fernandes et. al.[44], Coronadoby et. al.[41], Gosau et. al[45]. used cadavers for measuring volume of the maxillary sinus. These differences in research methods lead to difference between the values of the results.

In this study, there was no significant difference between left and right sides in transverse width, antero−posterior width, height and volume of the maxillary sinus. Also the mean differences of all parameters between two sides were 2.21±1.75mm, 1.50±1.20mm, 1.65±1.36mm and 2.10±1.77cm^3

respectively. The mean degrees of asymmetry between two sides were 6.46±5.12%, 3.76±2.99%, 3.57±2.92% and 9.54±7.81% respectively. These results support there were similarity in the maxillary sinus between left and right sides. Ariji et. al.[18][42], Uchida et. al[16]. found no significant difference of T_W, AP_W, V between both sides. Park et. al.[43] found no significant difference of AP_W, V_H, V between both sides. Barghouth et. al.[19], Deeb et. al.[25], Coronado et. al.[41], found no significant difference of V between two sides. Current study coincides with most of the studies previously conducted. The maxillary sinuses have anatomical variations and age-related morphological changes. But, like symmetries present in the other body structures, the maxillary sinus on both sides resemble each other.

Correlation coefficients of the maxillary sinus between both sides were summarized on Table 3. In all parameters, there were high correlation coefficient, The values of correlation coefficient of transverse width, antero-posterior width, height and volume of the maxillary sinus were between both sides were 0.811, 0.832, 0.928, 0.921 respectively. Ariji et. al.[18][42] found correlation coefficient of transverse width, antero-posterior width, height and volume of the maxillary sinus were 0.67, 0.79, 0.73, 0.95 respectively. Park et. al.[43] found correlation coefficient of transverse width, antero-posterior width, height and volume of the maxillary sinus were 0.87, 0.89, 0.86, 0.94 respectively. According to studies of Shumacher et. al.[46], correlation coefficient of between the left and right sinus was 0.49. Sum up the results of the correlation coefficient of the maxillary sinus between left and right side, volume of the maxillary sinus has higher correlation coefficient than others.

All measurements in this study show gender differences were statistically significant. According to Gosau et. al.[44], Fernandes et. al.[45], Barghouth et. al.[19], Park et. al.[43], males have larger maxillary sinus than females. By contrast, Shatz CJ et. al.[47], Bite U et.al.[26] found no size difference between sexes. The studies which suggest sex difference in maxillary sinus reflect the relation of maxillary sinus volume to facial bone and body size and similarity between size of maxillary sinus and facial sized and form[36].

Measurement on the normal maxillary sinus had done by computed tomography is known for non-invasive and high accuracy. But using reconstructed 1mm thickness images have slight more inaccuracies compared to original computed tomography data. Through additional research, more accuracy can be accomplished by using specific software which realizes direct measurement on original computed tomography images. Also studies on the effects of the presence or absence of dental disease on the size and shape of the maxillary sinus will conducted in hereafter studies.

Conclusions

In this study, we found that the mean size of normal maxillary sinuses by measuring transverse width, antero-posterior width, height and volume using computed tomography. There was a significant sex difference, but no significant difference between the right and left sides in all parameters. The outcomes of the present study indicate that males have larger maxillary sinus than females and there is no differences of size between the right and left sides.

Table 1. Mean values of transverse and antero−posterior widths, vertical height and volume of maxillary sinus and statistical significance according to sex.

	Male (n=60)	Female (n=60)	Total (n=120)	Significance
	ME±SD	ME±SD	ME±SD	
T_w(mm)	34.63±4.83	32.25±3.95	33.44±4.55	*
AP_w(mm)	37.58±4.96	35.45±4.57	36.51±4.87	*
V_H(mm)	48.10±4.87	42.95±5.14	45.53±5.62	*
V(cm^3)	24.29±7.26	18.93±5.22	21.61±6.85	*

n : number of maxillary sinuses, ME : mean value, SD : standard deviation, * : statistically significant difference ($p<0.05$)

Table 2. Mean differences in measurements between both sides and degree of asymmetry.

	Right and left difference		Degree of asymmetry (%)
	ME±SD	Significance	ME±SD
T_w(mm)	2.21±1.75	NS	6.46±5.12
AP_w(mm)	1.50±1.20	NS	3.76±2.99
V_H(mm)	1.65±1.36	NS	3.57±2.92
V(cm^3)	2.10±1.77	NS	9.54±7.81

NS : statistically no significant difference ($p>0.05$)

Table 3. Correlation coefficients of the maxillary sinus between both sides.

	T_w	AP_w	V_H	V
γ	0.811	0.832	0.928	0.921

Table 4. Previous studies on measuring sinus size using variety of methods.

Reference	Subjects	Method	Measurements
Ariji et. al. (1993,1996)	230 sinuses 4~94 years Japanese	CT	T_W : 27.0mm AP_W : 35.6mm V : 14.7 cm^3
Park et. al. (2000)	95 sinuses 20~48 years Korean	CT	T_W : 28.33mm AP_W : 39.69mm V_H : 46.60mm V : 21.90 cm^3
Uchida et. al. (1998)	38 sinuses 25~87 years Japanese	CT	V : 13.6 cm^3
Deeb et. al. (2011)	50 sinuses Amearican	CT	V : 24.4 cm^3
Park et. al. (2010)	520 sinuses Under 25years Korean	CT	V : 14.83 cm^3
Cho et. al. (2010)	104 sinuses 18~60 years Korean	CT	V : 20.78 cm^3
Barghouth et. al. (2002)	358 sinuses Under 17years Switzerland	MRI	V : 18.3 cm^3
Fernandes et. al. (2004)	106 sinuses Zulu and European adult cadavers	Cadaver (CT)	T_W:20.57~25.27mm AP_W:34.47~40.54mm V_H:30.96~37.89mm V:10.76~18.40cm^3
Coronadoby et. al. (2011)	10 adult dried skulls	Cadaver (CT)	V : 13.95 cm^3
Gosau et. al. (2009)	130 sinuses Caucasian 50~97 years	Cadaver (Material −water)	V : 12.5 cm^3

Figure 1. Computed tomography with the measuring method used for the transverse width and antero−posterior width.

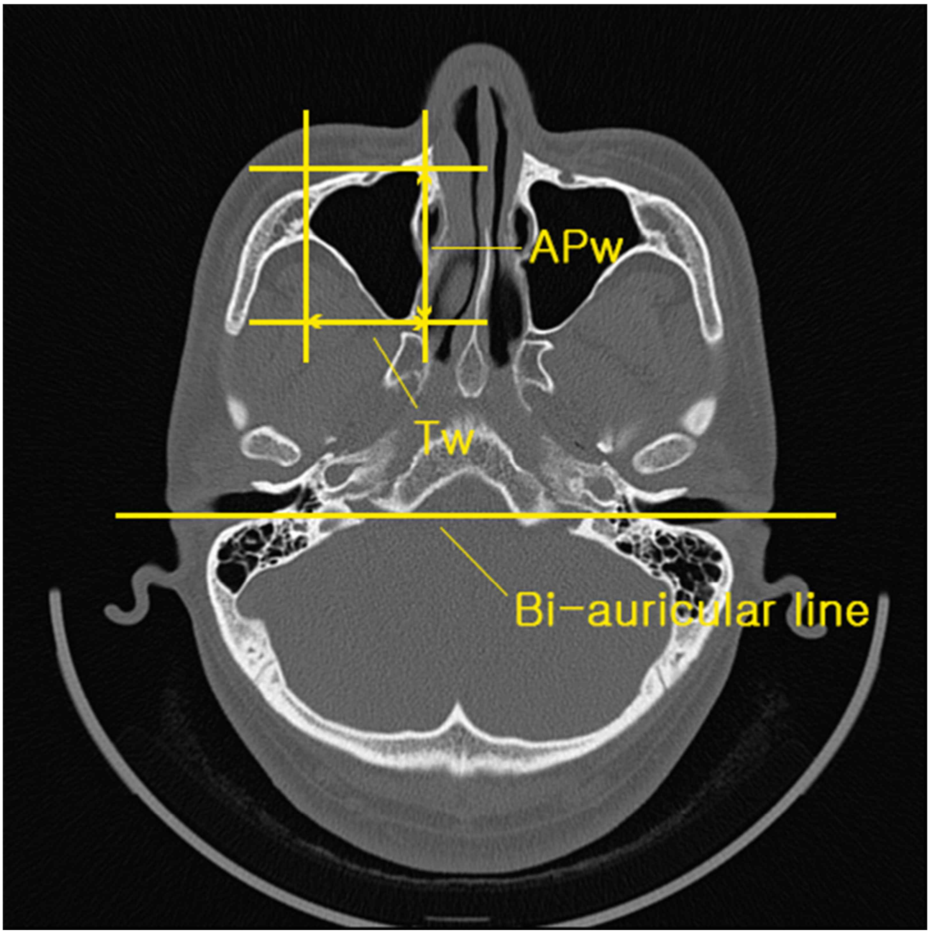
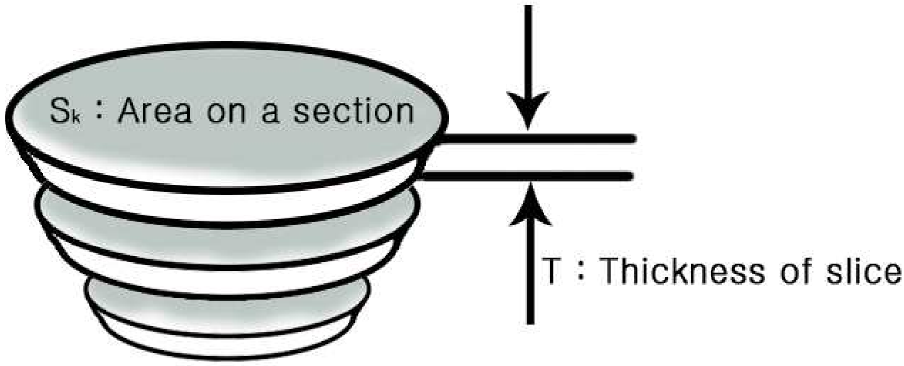


Figure 2. Diagram with the measuring method used for volume of maxillary sinus.



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초　　록

1. 목 적

컴퓨터단층촬영을 이용하여 정상인 상악동의 체적, 폭경, 고경을 측정하고 각각의 상관관계를 분석하며, 성별, 좌우별에 따른 차이를 조사하는 것이 이번 연구의 목적이다.

2. 방 법

2012년 12월부터 2013년 6월까지 서울대학교 치과병원에서 상악동 부위를 포함한 컴퓨터단층촬영을 한 사람 중에서 상악동 병소, 증상, 수술경력 등이 있는 사람은 제외한 정상인 60명을 대상자(120개의 상악동)로 선정하였다. 대상자는 남자 30명, 여자 30명으로 구성되었다.

3. 결 과

전체 대상자의 횡단폭경, 전후폭경, 고경, 체적의 평균값은 각각 33.44±4.55mm, 36.51±4.87mm, 45.53±5.62mm, 21.61±6.85cm^3 이었다. 횡단폭경, 전후폭경, 고경, 체적의 좌우간 차이는 평균적으로 각각 2.21±1.75mm, 1.50±1.20mm, 1.65±1.36mm, 2.10±1.77cm^3 이었으며 비대칭도는 각각 6.46±5.12%, 3.76±2.99%, 3.57±2.92%, 9.54±7.81% 로 나타났다. 모든 계측치에서 통계학적으로 유의미하게 남자가 여자보다 큰 값을 나타냈다($p<0.05$). 좌우별 검증에서는 모든 계측치에서 좌우간에 통계학적으로 유의미한 차이가 없었다($p>0.05$).

4. 결 론

이번 연구결과에 따르면 남자가 여자보다 상악동의 크기가 크게 나

타났다. 좌우에 따른 상악동 크기에는 차이가 없었다.

주요어 : 상악동, 컴퓨터단층촬영, 상악동체적, 상악동폭경, 상악동고경, 상악동비대칭도

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