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Original research

ARE MAXILLARY AND SPHENOID SINUS VOLUMES PREDICTORS OF GENDER AND AGE? A CONE BEAM COMPUTED TOMOGRAPHY STUDY

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ABSTRACT

Objectives: This study aimed to analyze the applicability of maxillary sinus (MS) and sphenoid sinus (SS) volumes in determining gender and age.

Materials and Methods: This retrospective study included cone beam computed tomography images of 164 MSs and 164 SSs of 82 patients (40 females and 42 males). Right, left, and total MS and SS volumes were estimated. The independent samples t-test, logistic regression, and Pearson correlation coefficient were used to explore their accuracy in determining age and gender.

Results: Males had greater right SS, average, and total SS volumes than females (p=0.007, p=0.013, and p=0.013, respectively). The right SS volume had the best predictive power (65.9%) for gender. A regression formula using this parameter alone showed satisfactory accuracy. No significant correlations were found between age and MS or SS volumes (p>0.05).

Conclusions: The SS volume is a valuable tool in determining gender, whereas neither MS nor SS are reliable predictors of age. A simple gender determination is possible with our regression formula using the right SS volume. Further studies are needed to investigate the role of paranasal sinus volumes with a view to develop formulations in determining age and gender in different populations.

Keywords: Maxillary sinus, sphenoid sinus, cone beam computed tomography, forensic sciences, forensic dentistry.

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INTRODUCTION

Genderual dimorphism can exist in nearly all skeletal parts of adults. It may be determined by environmental factors such as genetic factors, nutritional status, and lifestyle, but ethnic background may also play a role. Thanks to morphological and metric properties of cranial structures, a person's gender can be determined with an accuracy rate of over 60%.[1]

Prior to the advent of computed tomography (CT), cadaveric studies and two-dimensional radiographs were used to measure paranasal sinus size. The use of CT has greatly contributed to the diagnosis of paranasal sinus diseases. For instance, studying the variations of certain anatomical structures, such as the sinus septa, pneumatization, and ostia, has now made it possible to perform detailed analyses of those structures.[2]

Age determination is often of critical importance.[3] For example, determination of legal or illegal immigrants may directly affect the legal procedures followed. In autopsies, the paranasal sinuses can be used to determine a person's gender. Even if body parts lose their anatomical properties in an accident or disaster, the paranasal sinuses may remain intact by virtue of their sheltered position within the cranium, where anthropometric measurements play an important role.[4]

The genderual uniqueness of anatomic structures can be clearly viewed on tomographic images. Several studies have reported the usefulness of the paranasal sinuses in gender determination, particularly in postmortem examinations.[3,5,6] Other studies, however, have argued that the paranasal sinuses do not possess a dimorphic character.[7-9] Thus, no clear consensus exists in this regard.

The sphenoid bone, which neighbors the optic nerve, cavernous sinus, and pituitary gland, is a unique and strategically located cranial bone. The sphenoid sinuses (SS) are located inside that bone. The development of the SSs begins in intrauterine life and is completed by the age of 14 years. Their size may vary according to age, gender, and ethnicity.[10] The development of the maxillary sinus (MS), on the other hand, begins in the prenatal period and continues until the age of 18 years.[8]

In this study, we investigated the applicability of SS and MS volumes in determining gender and age using cone beam CT (CBCT) images of an Eastern Turkish population.

MATERIALS AND METHODS

Study Sample

This retrospective study used CBCT images of SSs and MSs of female and male residents of Eastern Turkey. A power analysis was conducted using G*power version 3.1.9.2 (Franz Faul, University of Kiel, Germany). The analysis showed that a minimum sample size of 68 patients would be required to determine statistical significance with 95% confidence, 95% test power, and an effect size of $d = 0.88$.

According to the power analysis results, the study included 82 patients, 40 females and 42 males, and examined the CBCT images of 164 SSs and 164 MSs. The mean age of the patients was 37.3 years (range: 14–71 years). The patients had undergone tomography imaging for dental implant planning, impacted teeth, dental anomalies, odontogenic or non-odontogenic lesions, and root fractures. The inclusion criteria were a patient age of 14 years or older, adequate image quality, and absence of craniofacial abnormalities. Patients who had a history of trauma to or any lesions in the sinus region and patients whose CBCT images were of poor quality were excluded. This study was approved by the Ethics Committee of Van Yüzüncü Yıl University (approval no. YYU-2018/12/07-10).

CBCT Scanning

The CBCT images were acquired using a 3D eXam device (KaVo, Biberach, Germany). The scan parameters were as follows: 18.54 mAs, 120 kVp, 8.9 s scan time, 160 × 130 field of view (FOV), and 0.3 mm voxel size.

Sinus Volume Measurements

The CBCT images were converted to DICOM format and transferred to 3D-DOCTOR (Able Software Corp., Lexington, MA, USA) to estimate the right, left, and total SS and MS

volumes. The program's segmentation function allows the coloring of sinuses according to their density in axial sections. Manual correction was performed when the color-tagged areas did not accurately match the borders of the sinuses. After the sinus borders were drawn, the software combined the segmented areas in each section to obtain a three-dimensional (3D) model (Figure 1).

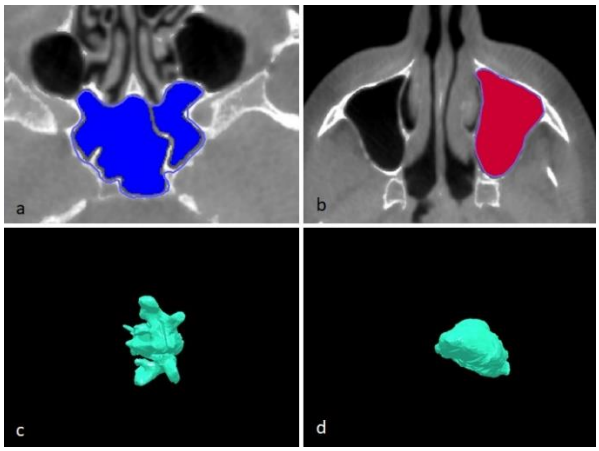

Fig. 1. Segmentation of maxillary and sphenoid sinuses on sectional cone-beam computed tomography images (a, b). Three-dimensional model of maxillary and sphenoid sinuses after volume estimation using semiautomatic segmentation (c, d).

The volumes were then estimated automatically. All measurements were performed by a single oral and maxillofacial radiologist with five years' experience in CBCT and volumetric measurements. Repeated measurements on the images of 20 patients were performed to estimate intra-reader reliability.

Statistical Analysis

Statistical analyses were performed using NCSS (Number Cruncher Statistical System) 2007 (NCSS, LLC., Kaysville, UT, USA). Descriptive statistics (means and standard deviations, medians, frequencies, and ranges) were used to analyze the study data. The normality of the distribution of quantitative variables was evaluated with the Shapiro-Wilk test and graphical analyses. The independent samples t-test was used to compare normally distributed variables between males and females. Logistic regression analysis was used to determine the patients' gender using the volume variables. Correlations between age and volumes were assessed using Pearson's correlation analysis. The level of statistical significance was set to $p < 0.05$. The intraclass correlation coefficient (ICC) was used to evaluate intra-examiner reliability.

RESULTS

Males had greater right, mean, and total SS volumes than females ($p = 0.007$, $p = 0.013$, and $p = 0.013$, respectively). No significant differences between males and females were found with respect to right, left, and mean MS and left SS volumes (Table 1).

Table 1. Gender-based comparison of paranasal sinus volumes (mm^3)

	Male		Female		p
	Mean±SD	Min-Max	Mean±SD	Min-Max	
Right MS	13248.08±5747.61	2341.78-24711.99	12063.93±4608.12	4270.37-22847.94	0.308
Left MS	14059.72±5494.37	3076.72-23975.23	12228.41±4633.38	3415.72-21165.49	0.108
MS average	13653.9±5387.16	2709.25-23227.47	12146.17±4500.29	3943.43-20310.36	0.174
Right SS	5160.94±2603.3	953.39-12319.08	3727.46±2037.65	483.91-8464.45	0.007*
Left SS	4555.36±2867.1	602.98-13109.32	4129.63±1977.14	537.81-9839.21	0.438
SS average	4858.15±1801.13	1367.98-9409.9	3928.55±1481.49	1218.89-7257.99	0.013*
Total SS	9859.26±3655.25	2776.22-19096.69	7972.7±3006.57	2473.64-14729.56	0.013*

SD standard deviation, Min minimum, Max maximum

A logistic regression model using the right MS volume accurately predicted 66.7% of males, 42.5% of females, and 54.9% of total patients. A model using the left MS volume accurately predicted 64.3% of males, 50% of females, and 57.3% of total patients. A model using the mean MS volume accurately predicted 64.3% of males, 45% of females, and 54.9% of total patients. A model using the right SS volume accurately predicted 64.3% of males, 67.5% of females, and 65.9% of total patients. A model using the left SS volume accurately predicted 54.8% of males, 37.5% of females, and 46.3% of total patients. A model using the mean SS volume accurately predicted 61.9% of males, 62.5% of females, and 62.2% of total patients. A model using the total SS volume accurately predicted 61.9% of

males, 62.5% of females, and 62.2% of total patients. A model using all sinus volumes accurately predicted 64.3% of males, 65% of females, and 64.6% of total patients (Table 2).

Table 2. Results of the logistic regression analysis of the studied volumes to predict gender

Correctly classified; n (%)

	Male	Female	Total
Right MS	28 (66.7)	17 (42.5)	45 (54.9)
Left MS	27 (64.3)	20 (50)	47 (57.3)
MS average	27 (64.3)	18 (45)	45 (54.9)
Right SS	27 (64.3)	27 (67.5)	54 (65.9)
Left SS	23 (54.8)	15 (37.5)	38 (46.3)
SS average	26 (61.9)	25 (62.5)	51 (62.2)
Total SS	26 (61.9)	25 (62.5)	51 (62.2)
All sinuses	27 (64.3)	26 (65)	53 (64.6)

n number

All variables were included as independent variables, and logistic regression analysis with the backward elimination method was performed. The resulting model identified only the right SS volume as an independent predictor. In a regression model using the right SS, no improvement in accuracy was observed when any other variable was included. In the regression formula (Eq. 1), male = 0 and female = 1. Values of 0.5 or greater were considered as indicating females, and those below 0.5 were considered as indicating males.

$$Gender = 1.142 - 2.71 \times 10^{-4} \times right\ SS\ volume\ (\mathrm{mm}^3)\ (1)$$

No significant correlation was found between age and any sinus volume (Table 3). Thus, no reliable age-based model could be designed. Excellent intra-examiner reliability (ICC=0.988) was estimated for repeated measurements.

Table 3. Coefficients of the correlations between age and paranasal sinus volumes

	Age	
	r	p
Right MS	-0.018	0.870
Left MS	-0.091	0.417
MS average	-0.057	0.615
Right SS	-0.115	0.305
Left SS	0.053	0.639
SS average	-0.043	0.702
Total SS	-0.043	0.702

DISCUSSION

In this study, we investigated the applicability of MS and SS volumes to determine age and gender in an Eastern Turkish population, aiming to develop predictive models. Of all the MS parameters, the left MS volume had the highest prediction accuracy. The SS parameters had a higher prediction accuracy; among them, the right SS volume showed the highest accuracy. The model using all sinus volumes was less accurate than the model using the right SS alone. These results suggest that the right SS volume alone can accurately predict gender, obviating the need for including all sinus volumes.

Technological advances have made CBCT imaging a more accessible technique. Besides its clinical applications, it has now become a tool of forensic medicine. For instance, if previously acquired CBCT images of a person are available, they can be used to identify that person in cases of mass deaths, such as those occurring during wars, natural disasters, or airplane crashes. Registries of postmortem personal identification show that the frontal bone and sinus remain unaffected in only one-tenth of the cases, whereas the cranial region involving the SS is nine times less affected.[5] This suggests that it is reasonable to use more sheltered anatomic structures, such as the SS, for postmortem personal identification instead of

anatomical structures like the frontal sinus and MS, which are close to the body surface and thus more susceptible to trauma. Furthermore, the greater degree of anatomical variation compared to the MS, such as asymmetric right and left SSs, and the absence of a septum dividing the two sides or accessory septa in some individuals, make the SS unique among anatomical structures. Both SS morphological examinations and dimensional measurements enable prompt personal identification.

Several studies have attempted to predict age and gender using MS and SS volumes of patients of various populations.[1-6,9] Previous studies have utilized two-dimensional imaging techniques to determine the applicability of paranasal sinuses to determine gender and age. Luo *et al*.[11] explored gender determination by estimating the area of the frontal sinus on lateral cephalograms of 475 patients and found that, when combined, the parameters of the frontal sinus index and area predicted gender in 76.6% of the cases. Sidhu *et al*.[12] measured the area of the MS and its perimeter using lateral cephalograms of 50 patients, reporting a predictive accuracy of 76%.

Other studies have attempted to predict age and gender based on linear measurements using 3D techniques. Rani *et al*.[3] reported that MS length, width, and height on MR images can be used to determine age and gender. Uthman *et al*.[4] analyzed the helical CT images of 88 patients to determine gender. They found that MS length was the best parameter and reported an accuracy rate of 73.9% when all MS parameters were combined. Bangi *et al*.[13] performed linear measurements on CT images of 100 patients' MSs to determine gender, reporting an average accuracy rate of 88%. Conversely, in our study, the MS volume was not a reliable predictor of gender. In line with our results, Barghouth *et al*.[7], Degirmenci *et al*.[8], Ariji *et al*.[14], and Koppe *et al*.[15] found that the MS volume did not show dimorphism. Kajoak *et al*.[16] performed linear measurements on CT images of SSs in a Sudanese population and reported that the studied parameters showed significant differences not only between genders but also from other populations. Other studies, in line with our findings, have reported significantly greater SS volumes in males.[2,17] Previous studies have reported conflicting results regarding the applicability of SS volumes to gender predictions. Some studies found that SS volumes did not show genderual dimorphism.[9,18,19]

The development of 3D modeling software for 3D imaging techniques has enabled gender predictions based not only on linear measurements but also on volume estimations of paranasal sinuses. Farias Gomes *et al*.[20] performed linear measurements and volumetric estimations of MSs in 60 patients. They found that MS length was the most dimorphic parameter (77.7% accuracy) and reported that their regression model accurately predicted the gender of 84% of the patients. Oliveira *et al*.[9], on the other hand, measured SS volumes on the CT images of 47 patients and found no significant differences according to gender. Similarly, measuring SS volumes on the CBCT images of 172 patients, Nejaim *et al*.[18] failed to detect a significant correlation between gender and SS volume.

Regarding age prediction based on paranasal sinus volumes, the results reported in the literature are also contradictory. Yonetsu *et al*.[19] found no correlation between age and SS size calculated on CT images. Similarly, Radulesco *et al*.[21] and Jun *et al*.[22] found no correlations between age and MS volumes on CT images. Likewise, Oliveira *et al*.[9] reported that SS volume did not significantly correlate with age. In line with these findings, we found no correlations between age and SS or MS volumes. Conversely, Cohen *et al*.[2] reported a significant age-dependent volume reduction in MS and SS, although they found no correlation between the frontal sinus volume and age.

As can be seen, previous studies have reported varying predictive accuracies of paranasal sinus measurements in determining gender and age. These inconsistencies are possibly due to differences in patient populations, sample sizes, radiographic techniques, and data analyses. It is also possible that the volume measurement method and the software used may affect the results. For

instance, Möhlhenrich *et al*.[23] suggested that paranasal sinus volume estimation using formulas obtained from linear measurements does not provide accurate results. Moreover, whereas some studies used stereological methods applied to tomographic sections to estimate the volumes of sinuses and various organs, others have used 3D models to estimate the volumes of certain anatomical structures.[2,24] It has been reported that semiautomatic segmentation, by which three-dimensional modeling can be performed, is superior to stereological methods for volume estimation on CBCT images and can provide up to three times more practical volumetric estimations.[25]

CONCLUSIONS

This study found no correlations between age and MS or SS volumes. Conversely, MS and SS volumes were more reliable predictors of gender. However, it is reasonable to use SS rather than MS parameters, as they show higher accuracy in gender predictions. The right SS volume can be used alone. Our regression model shows acceptable accuracy in predicting gender. Thus, CBCT with a relatively lower dose, a smaller FOV, and high precision is preferable for performing all measurements and evaluations.

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CONFLICT OF INTEREST STATEMENT

The author declare no conflict of interest.

Maksiller ve Sfenoid Sinüs Hacimleri Cinsiyet ve Yaş Hesaplamada Belirleyici midir? Bir Konik Işınlı Bilgisayarlı Tomografi Çalışması

ÖZ

Amaç: *Bu çalışmanın amacı; maksiller sinüs (MS) ve sfenoid sinüs (SS) hacimlerinin cinsiyet ve yaş tahminindeki rolünü analiz etmektir.* ***Gereç ve Yöntemler:*** *Bu retrospektif çalışmada 82 hastaya (40 kadın, 42 erkek) ait 164 MS ve 164 SS'ün konik ışınlı bilgisayarlı tomografi (KIBT) görüntüleri kullanılmıştır. Sağ MS, sol MS, sağ SS, sol SS, total SS ve total MS hacimleri hesaplanmıştır. Hacimlerin cinsiyet ve yaş tayinindedi rolünü analiz etmek için bağımsız örneklem testi, lojistik regresyon analizi ve Pearson korelasyon analizi kullanılmıştır.* ***Bulgular:*** *Erkekler daha büyük sag SS, ortalama SS, ve total SS hacimlerine sahiptir (p=0,007, p=0,013, p=0,013, sırasıyla). Sağ SS hacmi, cinsiyeti belirlemede en yüksek tahmin gücüne (%65,9) sahiptir. Tek başına bu parametrenin kullanıldığı regresyon modelinde, tatmin edici doğruluk elde edilmiştir. Yaş ve herhangi bir hacim değeri arasında korelasyon bulunmamıştır (p>0,05).* ***Sonuçlar:*** *SS hacminin cinsiyet belirlemede değerli bir araç olduğu sonucuna varılmıştır, buna rağmen, ne MS ne de SS yaş tayininde belirleyici değildir. Daha basit bir cinsiyet tayini, bizim regresyon formülünde sağ SS boyutları kullanılarak yapılabilir. Farklı hasta populasyonlarındaki hastaların paranazal sinüs hacimlerini kullanarak, yaş ve cinsiyet tayinini formüllerle belirleyecek ileri çalışmalara ihtiyaç duyulmaktadır.* ***Anahtar Kelimeler:*** *maksiller sinüs, sfenoid sinüs, konik ışınlı bilgisayarlı tomografi, adli bilimler, adli diş hekimliği.*

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