ORIGINAL ARTICLE

Morphometric analyses of maxillary sinus anatomy in dentate patients using cone beam computed tomography: a gender assessment study

Konik ışınlı bilgisayarlı tomografi kullanarak dişli hastalarda maksiller sinüs anatomisinin morfometrik analizi: bir cinsiyet değerlendirme çalışması

Assoc. Prof. Guldane Magat
Necmettin Erbakan University, Faculty of Dentistry, Oral Radiology Department, Konya/TURKEY
Orcid ID: 0000-0003-4418-174X

Oral & Maxillofacial Radiologist Selcuk Hakbilen
Konya Oral and Dental Health Hospital, Sanliurfa/TURKEY
Orcid ID: 0000-0002-5235-0964

Prof. Sevgi Ozcan
Necmettin Erbakan University, Faculty of Dentistry, Oral Radiology Department, Konya/TURKEY
Orcid ID: 0000-0002-2349-9292

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Corresponding author:
Assoc. Prof. Güldane Mağat
Necmettin Erbakan University, Faculty of Dentistry, Oral Radiology Department,
Karaciğan Mah. Ankara Cad. No: 74/A PK: 42050
Karatay/KONYA.
Tel: 090 505 945 61 57
E-mail: gul_dent@hotmail.com

SUMMARY

Aim: Gender identification is a classical judicial procedure, and an important step in creating a post-mortem profile. The purpose of this study was to determine the gender of the individuals using maxillary sinus (MS) measurements obtained with cone beam computed tomography (CBCT) scans and to investigate the accuracy of these measurements.

Materials and Methods: In this study, a total of 414 MSs of 207 individuals (81 males and 126 females aged between 20 and 41 years) with a complete dentition were evaluated. The length (internal wall), width and height of the MS were measured using CBCT. Descriptive statistics, Mann Whitney-U test and discriminant function tests were used. In all analyses, values less than $p<0.05$ were considered statistically significant.

Results: A statistically significant difference was found between males and females only in the left MS height ($p<0.05$). However, no significant difference was found between genders with respect to other measurements of MSs on both sides ($p>0.05$). In addition, discriminant function analysis showed that MS height was the most significant variable in the differentiation of sex groups. The accuracy rate of gender assessment was 53.8% for females and 65.5% for males with a mean of 58.8%.

Conclusion: The results of the present study showed that the left MS height showed anatomical variability between genders. CBCT scanning is a useful tool for evaluating MS.

Key words: Sex determination, cone-beam computed tomography, maxillary sinus, identification.

ÖZET

Amaç: Cinsiyet tanımlaması klasik bir adli prosedürdür ve ölüm sonrası profil oluşturulmasında önemli bir adımdır. Bu çalışmanın amacı konik ışınlı bilgisayarlı tomografi (KIBT) taramaları ile elde edilen maksiller sinüs (MS) ölçümlerini kullanarak bireylerin cinsiyetini belirlemek ve bu ölçümlerin doğruluğunu araştırmaktır.

Gereç ve Yöntemler: Bu çalışmada 20 ila 41 yaşları arasında tam dişli 207 bireyin (81 erkek ve 126 kadın) toplam 414 MS'si değerlendirildi. KIBT kullanılarak MS'nin uzunluğu (iç duvar), genişliği ve yüksekliği ölçüldü. Tanımlayıcı istatistikler, Mann Whitney-U testi ve diskriminant fonksiyon analizi kullanıldı. Tüm analizlerde, $p<0.05$'ten küçük değerler istatistiksel olarak anlamlı kabul edildi.

Bulgular: Sol üst MS yüksekliğinde erkekler ve kadınlar arasında istatistiksel olarak anlamlı bir fark bulundu ($p<0.05$). Ancak, her iki taraftaki diğer MS ölçümlerinde erkekler ve kadınlar arasında anlamlı bir fark bulunmadı ($p>0.05$). Ek olarak, diskriminant fonksiyon analizi, MS yüksekliğinin cinsiyet gruplarının farklılaşmasındaki en önemli değişken olduğunu gösterdi. Cinsiyet değerlendirmesinin doğruluk oranı kadınlarda %53,8, erkeklerde %65,5 olarak bulundu.

Sonuç: Bu çalışmanın sonucunda, sol MS yüksekliğinin cinsiyetler arasında anatomik olarak değişkenlik gösterdiği bulunmuştur. KIBT taraması MS'nin değerlendirilmesinde yararlı bir

araçtır.

Anahtar kelimeler: Cinsiyet tayini, konik ışınlı bilgisayarlı tomografi, maksiller sinüs, kimlik.

INTRODUCTION

Examination of anthropometric properties is of great importance for solving the problems related to identification. Craniometric features are among those features closely related to forensic dentistry because they can be used to help identify a person from a skull separated from his skeleton.[1]

Gender identification is a classic judicial procedure, and an important step in creating a post-mortem profile.[2] Recently, due to the increase in criminal cases involving youth, irregular migration and modern crime, judicial demand for gender definition has increased.[3] Traditionally, the use of radiological methods in forensic medicine applications is limited. When it is necessary to define skeletal remains, visual examination, anatomical measurement and precise measurement of bone dimensions are in radiological contributions. The most useful area of the body for comparison radiography is cranium. Radiography is used to identify a person in forensic pathology, especially when the body is disassembled, disintegrated or burned.[4,5] The skull, pelvis, and long bones are the most useful for the determination of gender radiologically.[2] Thus, the use of thicker and heavier bones that mostly remain intact will give reliable results in predicting gender. Although the skull and other bones may deteriorate poorly in the burning victims, the zygomatic bones and maxillary sinus (MS) remain intact.[6,7]

The first developing paranasal sinuses are MSs. They are located in the right and left maxillary bones. They consist of air-filled space covered with mucosa. They develop at the end of the second embryonic month, and development usually occurs between the ages of 18 and 20.8,9 The shape and size of MS differ according to individuals, genders and various populations. They stabilize after the second decade of life, and therefore reliable measurements can be obtained on radiographic images.10 MS has a complex structure. Therefore, three-dimensional imaging systems such as magnetic resonance imaging (MRI) and computed tomography (CT) are accepted as the gold standard for evaluating the anatomy of the sinuses.[3] However, their use is limited by their high dose, cost, or restricted accessibility.[11] With cone beam computed tomography (CBCT) technology, three dimensional (3D) measurements of MSs can be done reliably with high resolution. In addition, it has lower radiation dose compared to CT scans, as well as lower costs compared to MRI. Thanks to these advantages, CBCT technology has become an effective tool for gender determination.[12] However, the morphometric methods used for gender determination have certain limitations because of their specificity to the population. Moreover, properties that are sexually dimorphic in a population may not be in another.[13]

To the best of our knowledge, even though in the literature there are few studies on sexual dimorphism of MS performed using CT scan images [7,14,] and there are no studies using CBCT imaging modality have been reported in a Turkish population till date. In this regard, the purpose of this study was to determine the gender of the individuals using MS measurements obtained with CBCT scans and to investigate the accuracy of these measurements in a Turkish population.

MATERIALS AND METHODS

This study was approved by the Local Ethics Committee under protocol number 2018.06. For this retrospective study, 207 CBCT images of the MS of individuals (81 males and 126 females aged between 20 and 41 years) with a complete dentition (excluded third molars) were selected from the archive of Oral and Maxillofacial Radiology Department, Faculty of Dentistry, Necmettin Erbakan University. The original sample size of 207 subjects was determined by power software based on the assumption of a 43.3 ± 4.8 mm based upon a previous study[5] for MS volume, with a 90% power and a two-sided alpha of 0.05. The estimated sample size was 115 subjects. Considering possible loss to follow-up, 207 subjects were decided to recruit for sample size. CBCT images of subjects with a history of facial trauma and fracture, congenital developmental abnormalities, and pathology associated with MSs were excluded from the study.

CBCT images were obtained in sitting position with Morita 3D Accuitomo 170 (J Morita MFG Corp., Kyoto, Japan) according to manufacturer's recommendations. The exposure parameters were 90 kVp and 5 mA, 17.5-second rotation time, voxel 0.25 mm, 100 mm field of view (FOV). The morphometric analysis was performed with the CBCT imaging software (i-Dixel, J Morita MFG Corp., Kyoto, Japan). The measurements were performed from the reconstructed CBCT images that were perpendicular to the hard palate by going through the scenes interactively. Six measurements were taken in the MS on CBCT images according to Urooge and Patil[12]: length, width, height, area, perimeter, and volume. The first two measurements were obtained from axial images of CBCT (Figure 1), and while the third measurement was obtained from the coronal images (Figure 2).

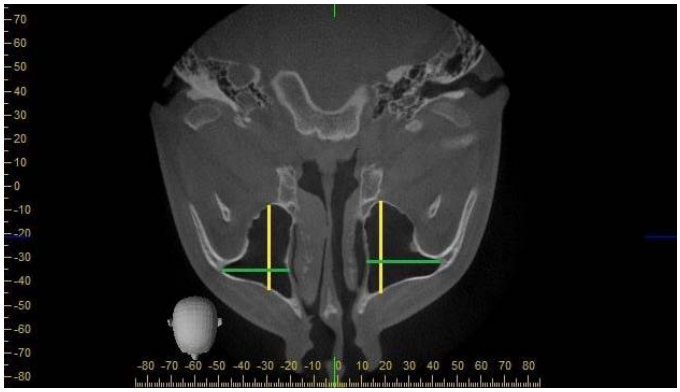

Figure 1. Axial view of cone beam computed tomography (CBCT) images of width (green line) (the largest distance from the most medial point of the sinus to the most lateral point of the sinus) and the length (yellow line) (the largest distance from the most anterior to the most posterior sinus point) of the left and right maxillary sinuses.

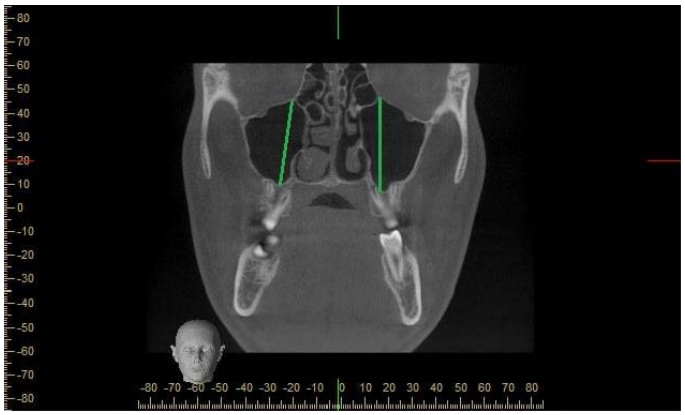

Figure 2. Coronal view of cone beam computed tomography (CBCT) images of the height of left and right maxillary sinuses (green line) (the maximum distance from the lowest point ofthe maxillary sinus floor to the upper most point of the roof).

The last three measurements were performed manually (Table 1).

Table 1. The definitions of the maxillary sinus parameters according to units and reference points.

Measurements	Parameter	Units	Reference points
1	Width	mm	Outer most point of the lateral wall to the medial wall.
2	Length	mm	Longest anterior to posterior measurement of the cavity.
3	Height	mm	Superior wall to lower most point of the inferior wall of the sinus.
4	Area	mm^2	Area = Length × width
5	Perimeter	mm	Perimeter = 2 x length + 2 x width
6	Volume	mm^3	Volume = length x width x height x1/2

The width of MS was determined as the largest distance from the most medial point of the sinus to the most lateral point of the sinus. The largest distance from the most anterior to the most posterior sinus point of the left and right MS was stated as the length. The height was measured as the maximum distance from the lowest point of the MS floor to the uppermost point of the roof. The morphometric analyses of right and left MS were made separately for each individual by an oral radiologist with four years of experience (S.H.). Fifty images were randomly selected and re-evaluated by the same investigator after three weeks for intra-observer reliability. In addition, inter-observer agreement was also evaluated.

Statistical Analysis

Statistical analyses were assessed using the SPSS program (version 21; SPSS Inc., Chicago, IL). Descriptive statistics, Mann Whitney-U test and discriminated function tests were used. In all analyses, values less than $p<0.05$ were considered to be statistically significant.

RESULTS

The study evaluated the MS of 207 subjects (81 male, 126 female) on CBCT images. The mean age was 25.69±6.61 (aged ranging from 20 to 41). Intra-class and inter-class correlation coefficient indicates a high level of compatibility between measurements (r-value ranged between 0.87-0.93).

The mean sinus measurements and p values according to gender are presented in Table 2. A statistically significant difference was found between males and females only in the left MS height ($p<0.05$) (Table 2). There was no significant difference between males and females with respect to other measurements of maxillary sinuses on both sides ($p>0.05$) (Table 2).

Table 2. The comparison of the right maxillary sinus measurements according to gender.

Parameter	Gender	n	Mean	Std. Dev.	p - value
Right Maxillary Sinus Length (mm)	Male	81	35.594	3.959	0.845
	Female	126	35.259	4.310	
Right Maxillary Sinus Width (mm)	Male	81	25.294	3.963	0.214
	Female	126	24.294	3.950	
Right Maxillary Sinus Height (mm)	Male	81	31.760	4.567	0.11
	Female	126	30.380	4.854	
Right Maxillary Sinus Area (mm^2)	Male	81	911.357	879.321	0.319
	Female	126	866.515	205.495	
Right Maxillary Sinus Perimeter (mm)	Male	81	3645.427	821.982	0.411
	Female	126	3466.060	821.982	
Right Maxillary Sinus Volume (mm^3)	Male	81	14758.251	4951.787	0.174
	Female	126	13473.199	4451.331	

In addition, discriminant function analysis showed that left MS height was the most important variable in the differentiation of genders. The accuracy rate of gender assessment was 53.8% for females and 65.5% for males with a mean of 58.8%.

DISCUSSION

One of the most important tasks of forensic procedures is the identification of the remains of human skeletons. Determination of age and gender are important steps for identification. Reliable results were obtained by using pelvis and long bones in gender determination. There is no doubt that analysis is more reliable when more bones are obtained. If a complete skeleton is found, the gender identity rate is 100%. This rate falls to 95% if the cranium and pelvis are present and falls to 80% - 90% if pelvis and long bones are present.[15] Gender prediction can be performed using morphological or metric methodologies. The statistical evaluation of morphometric measurements obtained from bones by linear discriminant function method has been very popular in gender determination recently.[16] For this reason, we also used discriminant function analysis in this study.

This study was designed to determine the reliability of the MS measurements and their accuracy as a sex identification method using CBCT over 207 subjects (81 males and

126 females). After birth, the MS continues pneumatically into the developing alveolar ridge because permanent teeth are erupting. At age 20, with the eruption of the third molar teeth, the sinus pneumatization ends. That is why the number of individuals over the age of 20 was included in this study. It has been reported that genetic diseases, infections, and environmental factors can affect the MS dimensions.[5] Considering this factor, patients with these disease conditions were excluded from the study.

In previous studies, different imaging modalities were used for measurements of the MS dimensions. Sahlstrand-Johnson et al.[17]reported that CT has a higher accuracy than other imaging modalities. However, recently, CBCT has become popular today because of lower cost and radiation dose than CT.[18] Hence, we used CBCT for the measurement of MS.

In this study, there was no statistical difference between the male and female groups in terms of the MS parameters both on the right and left sides, except the left MS height (Table 2). Males had statistically higher left MS height than females (p<0.023, Table 2).

Table 3. The comparison of the left maxillary sinus measurements according to gender.

Parameter	Gender	n	Mean	Std. Dev.	p - value
Left Maxillary Sinus Length (mm)	Male	81	35.771	4.133	0.699
	Female	126	35.305	4.338	
Left Maxillary Sinus Width (mm)	Male	81	25.546	4.666	0.071
	Female	126	23.895	4.981	
Left Maxillary Sinus Height (mm)	Male	81	32.186	4.815	**0.023***
	Female	126	29.940	5.649	
Left Maxillary Sinus Area (mm^2)	Male	81	911.357	230.054	0.164
	Female	126	866.515	245.147	
Left Maxillary Sinus Perimeter (mm)	Male	81	3702.588	920.214	0.164
	Female	126	3434.286	980.588	
Left Maxillary Sinus Volume (mm^3)	Male	81	15232.996	5077.157	0.063
	Female	126	13338.945	5242.602	

In our study, the accuracy level for each parameter was determined and the best discriminant parameter that can be used to study gender determination was found as the left MS height with a general accuracy of 58.8%.

Uthmanet al.[5] found that MS width and height was statistically significantly different between the left and right sides. Therefore, racial differences should be considered in gender evaluations. Fernandes[19] stated that European sinuses were significantly larger than the Zulu sinuses.

In the literature, it is stated that the MS shows anatomical variability between genders. In the current study, only one measurement (left MS height) was significantly different between genders. These results were in accordance with the results reported by Fernandes[19] and Paknahadet al.[18] Consistent with our study, Attia et al.[20] also reported that no statistically significant difference was found for MS width between males and females. However, in some previous studies, it was found that males had significantly larger MSs than females.[5,7,14,17] Ariji et al.[21] noted that the difference between these genders may be due to the greater body height and weight of males.

Discrimination analysis is an effective method for morphometric analysis. In the current study, we found that the most pronounced variable in the differentiation of genders was the MS height. Gender assessment was established correctly with an accuracy of 53.8% for females and 65.5% for males with a mean of 58.8%. Similar to our result, Uthman et al.[5] reported that the left MS height was the best discriminate variable between genders. Teke et al.7 found that the overall accuracy rate for left MS height measurement was only 63.8%. Attia et al.[20]concluded that the height of the MS is valuable in studying the sexual dimorphism with an overall accuracy of 69.9%. Kiruba et al.[22] recorded that the accuracy of maxillary sinus measurements to identify gender was 55% in females and 69.5% in males. In a recent study, the maximum accuracy for sex determination was indicated by the maximum distance between the sinuses and the maximum width of the right sinus.[23] With age, the difference between the two sexes decreased in terms of anthropometric indicators of the MSs. Ekizoglu et al.[14] reported that the female and male genders could be estimated at 80% and 74.3%, respectively. These differences in outcomes may depend on numerous global influences among various ethnic and racial groups; such as the skeletal dimension, the size and body of the individual, environmental conditions of sinus and pneumatization process in changing age and sex groups.[24]

The limitation of this study included the small sample size due to the stringent inclusive and exclusive criteria of the study. Although the statistical formula was used to determine the sample size of the study, further studies are needed to conduct these analyses on a larger population. For volume measurement, a 3-dimensional software program can be used. Also, gender determination based on anthropometric methods has some limitations. Gender determination based on anthropometric methods has some limitations. It is population-specific because it depends on various factors such as genetics, maternal health, culture, environmental quality conditions during prenatal development, and race.[25] Therefore, the distinctive functions presented in this study are best suited for a Turkish population, and the degree of sexual dimorphism needs to be questioned for another population, and therefore specific discriminatory functions need to be developed and regularly updated for each population.

CONCLUSION

The results of the present study revealed that the maxillary sinus showed anatomical variability between genders, as statistically significantly high values for MS height were observed on the left side in males. However, other parameters did not show a significant difference between the genders. For this reason, the height of the left MS can be used as an adjunct to forensic anthropology for gender determination. In our study, CBCT images may provi-

de adequate measurements for MS with exposure to low radiation, thus suggesting the use of CBCT to assess MS dimensions in the forensic area.

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