Regeneration, Reconstruction & Restoration

Reconstruction

Open Access

Morphometric Evaluation of Frontal Sinus and Investigating the Role of Gender in Anatomical Variations in Cone-beam Computed Tomography Images of an Iranian Population

Anita Mahaseni Aghdam [a], Sandra Mehralizadeh [a*], Ahmadreza Talaipour [a], Amirreza Mehdizadeh[a], Niloofar Ghadimi [a]

[a] Maxillofacial Radiology Department, Dental School, Tehran Islamic Azad University of Medical Sciences, Tehran, Iran.

Corresponding authors**: Sandra Mehralizadeh, Maxillofacial Radiology Department, Dental School, Tehran Islamic Azad University of Medical Sciences, Tehran, Iran. ***E-mail: sandramehr@yahoo.com; ***Tel:*** +98-912 3195181

Submitted: 2020-12-24; **Accepted:** 2021-01-23; **Published Online**: 2021-02-09; **DOI**: *10.22037/rrr.v5i1.35535*

Introduction: The frontal sinus has been of great interest to surgical and forensic specialists for human identification due to anatomical variations. The purpose of this study was to investigate the role of gender in the dimensions and anatomical variations of frontal sinus in cone-beam computed tomography (CBCT) images. **Materials and Methods:** In this historical cohort study, CBCT images of 40 patients i.e, 20 males and 20 females, older than 18 years of age were reviewed. CBCT images with 1-mm-thick sections and NNT Viewer software for image analysis were used to measure frontal sinus height. The mean width, depth, thickness of the anterior cortex of the frontal bone, and the number of septa were measured in the axial sections, and the height was measured in the coronal sections of the CBCT images in both sexes. The data were analyzed by Student's t-test. **Results**: The mean frontal sinus height was 20.5 mm in women and 25.9 mm in men; this difference was statistically significant ($P<0.05$). The mean frontal sinus width was 48.3 mm in women and 57.1 mm in men ($P<0.002$). The mean frontal sinus depth was 16.5 mm for women and 22.1 mm for men ($P<0.05$). The mean number of frontal sinus septa was 2.1 in females and 3.1 in males ($P<0.05$). **Conclusion:** The results of this study showed the higher height, width, depth, and number of septa in males than in females, but the difference in the number of the frontal sinuses and the thickness of the anterior cortex of the frontal sinus was not sufficient to accurately determine gender.

Keywords: Anatomical Variation; Cone-Beam Computed Tomography; Forensic Identification; Frontal Sinus

Introduction

Understanding the dimensions and anatomical variations of the frontal sinus in cone-beam computed tomography (CBCT) images can be helpful for surgical treatment, as well as gender determination (1). One of the most common problems in forensic medicine is the identification of individual identity, which is sometimes related to the gender determination of the sample. CBCT imaging provides the highest resolution and visualizes facial bones and nowadays considered to what extent analysis of frontal sinus information helps identify an individual in forensic cases. Some specific views of the frontal sinus morphology make it reliable for identification through the bone system (2).

The frontal sinus is an anatomical structure that begins to develop at the age of 2 to 3 years and is visible in radiography at the age of 5 to 6 years, with the final development taking place at the age of 20 years (3). The radiographic view of frontal sinuses is unique to each individual, and even in identical twins, different radiographic views are observed (4). This uniqueness of frontal sinus characteristics has led to special attention in forensic medicine (5). On the other hand, for surgery in the anterior region of the frontal bone, knowledge of the anatomy of the frontal sinus is necessary to optimally perform surgery and to prevent complications during surgery (6, 7).

Because frontal sinuses usually do not reach the frontal bone before the age of six, they are essentially the only paranasal sinuses missing at birth. The development of frontal sinus is quite variable; in 4% of otherwise normal people, both frontal

sinuses may not be present. The average frontal sinuses are 28 mm high, 24 mm wide, and 20 mm deep. Frontal sinuses are of different sizes, and sinus pneumatization may include the vertical plate of the frontal bone (squamous section), the horizontal plate of the frontal bone (orbital roof), or both of these areas (8).

Identification seeks information about race, sex, height, age, occupation, and even the cause of death (9). In this regard, gender is very important because it can play a positive role in rejecting a percentage of probabilities. The skull, pelvis, and thigh are most useful for radiologic sex determination (10). Radiology can be used to determine sex by providing accurate dimensions. Size and dimension of the frontal sinus can be used to determine age and sex when other methods are inconclusive (11).

In recent years, one of the most controversial discussions about paranasal sinuses has been the anatomical variation of the frontal sinuses (12). One important factor that has an influential role in the variations and details of the anatomical structure of the frontal sinus is gender (13). Several studies showed sexual dimorphism in the frontal sinus in different radiographic modalities, especially using CBCT as an imaging technique (14, 15).

In this study, we aimed to investigate the role of gender in the dimensions and anatomical variations of the frontal sinus in CBCT images of patients who were referred to a private imaging center in Tehran.

Materials and Methods

Study population

Individuals over 18 years of age referring to a private oral and maxillofacial radiology center in Tehran, who agreed to cooperate, were included in the study. The participants were matched according to age, and those with an obvious facial deformity, frontal sinus inflammation, trauma, frontal sinus disease, and a history of sinus surgery were excluded.

The number of samples and sampling method

In a similar study published in 2015, the sample size was considered to be 30 samples distributed in two equal groups (n=15) (16). We examined 20 individuals in each group and 40 in total. The sampling method was purposive sampling and was performed by selecting the case (male) and the control group (female).

Data collection technique

Interview and observation techniques were used to complete the datasheets. This was a historical cohort study performed on CBCT images of the frontal sinus of patients (20 females and 20 males) over 18 years of age, who were referred to a private oral and maxillofacial radiology center in Tehran in 2017-18.

Exclusion criteria included previous sinus surgery, trauma, sinusitis, and congenital malformations. The images were taken using NewTom VGi (QR s.r.l., Verona, Italy) CBCT unit with a high resolution and 0.3-mm voxel size with exposure settings of 110 kilovoltage peak (kVp) and 9 to 29 milliamperes (mA; depending on the patient's size). The images were evaluated using NNT Viewer software (Quantitative Radiology, Verona, Italy). The images were taken with a field of view (FOV) of 12×15 cm. To obtain the images, the patient's head position was adjusted in the standard position by aligning the occlusal plane with the horizontal plane and by adjusting the sagittal plane to be vertical.

High-quality images were selected. The areas adjacent to the frontal sinus (nasion, the nasal spine of the frontal bone, crista Galli, and the cribriform plate of the ethmoid) were well identified in the images. One-mm-thick CBCT sections were used to study the frontal sinus.

In this study, the presence or absence of frontal sinus in each image was investigated. We considered any visible pneumatization as the presence of the sinus, and if there was a frontal sinus, the height, width, and depth were measured separately for each sinus aligned by the Frankfurt line.

In the observed coronal sections, the maximum frontal sinus height, by definition from the highest point of the frontal sinus to the lowest frontal sinus point, was measured (Figure 1-2). When the inferior part of the frontal sinus was adjacent to the ethmoid sinus, and the border was not detectable for measurement, the nasofrontal junction was considered as the inferior border of the frontal sinus.

In the axial sections, the maximum width of the frontal sinus was measured (Figure 3-4). In the axial sections, the maximum depth of the frontal sinus was measured as the distance from the most anterior area of the frontal sinus to the most posterior part of the frontal sinus (Figure 5-6).

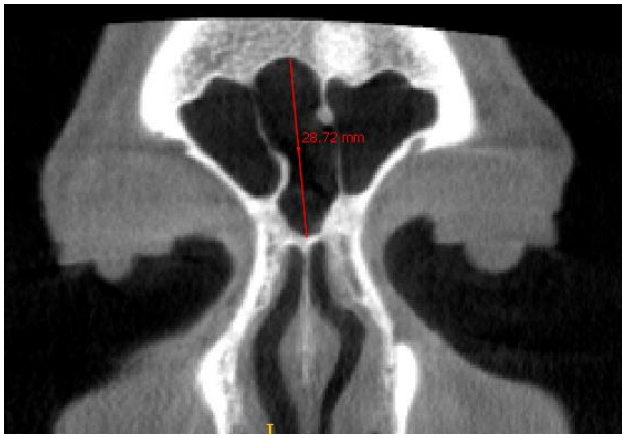

Figure 1. Maximum frontal sinus height in the male

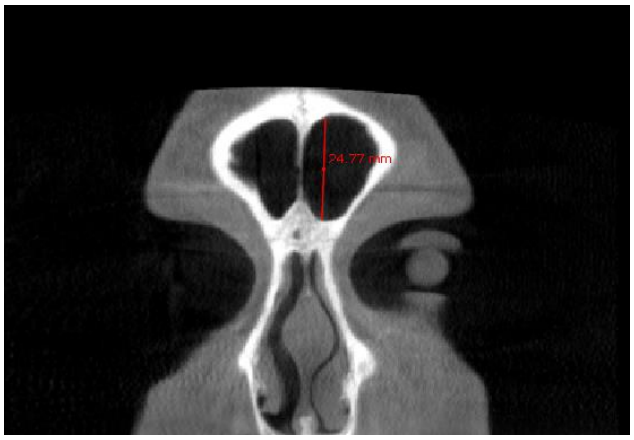

Figure 2. Maximum frontal sinus height in the female group

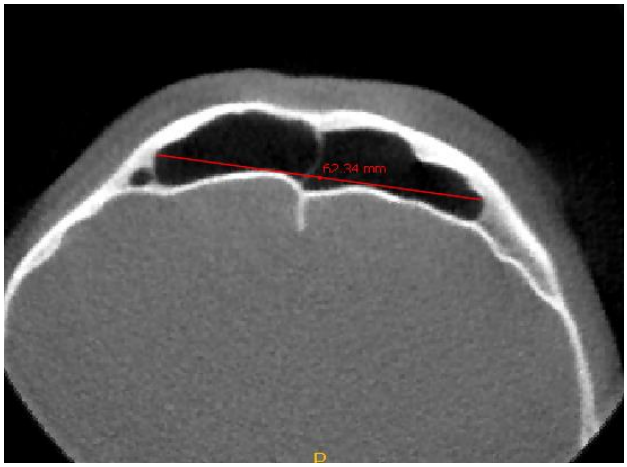

Figure 3. Maximum frontal sinus width in the male group

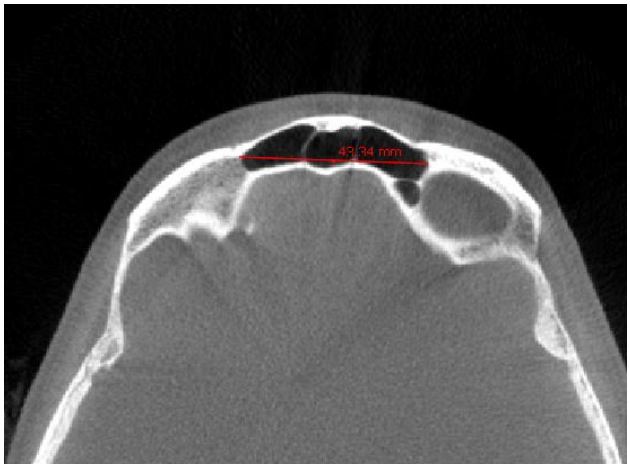

Figure 4. Maximum frontal sinus width in the female group

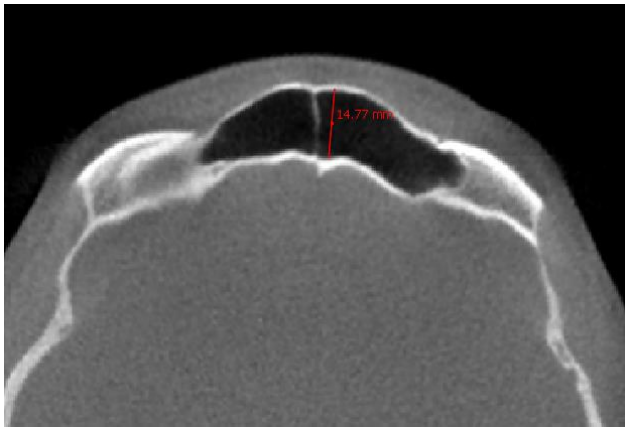

Figure 5. Maximum frontal sinus depth in the male group

Figure 6. The maximum frontal depth in the female group

In the axial sections, at the point where we obtained the greatest width, the thickness of the anterior cortex of the frontal sinus was defined as the distance from the outer edge of the frontal sinus to the inner edge of the frontal sinus (Figure 7).

We considered any bony extension that was drawn into the sinus as a septum (17).

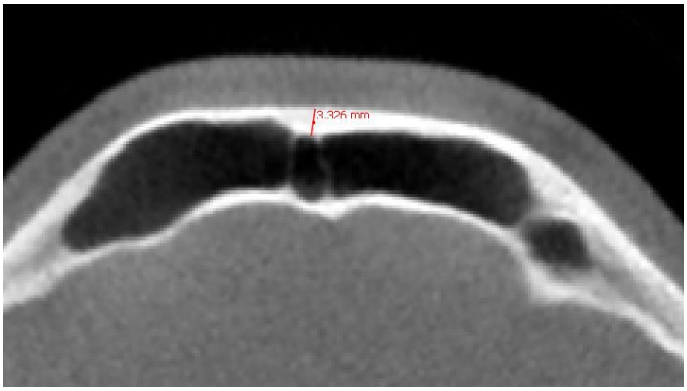

Figure 7. The maximum anterior cortical thickness of frontal sinus

Data analysis methods and tools

The student's t-test was used to compare the quantitative variables on the right and left sides. The Chi-square test was used to determine the relationship of the variables with gender. Paired t-test was used to measure the mean of the variables.

Results

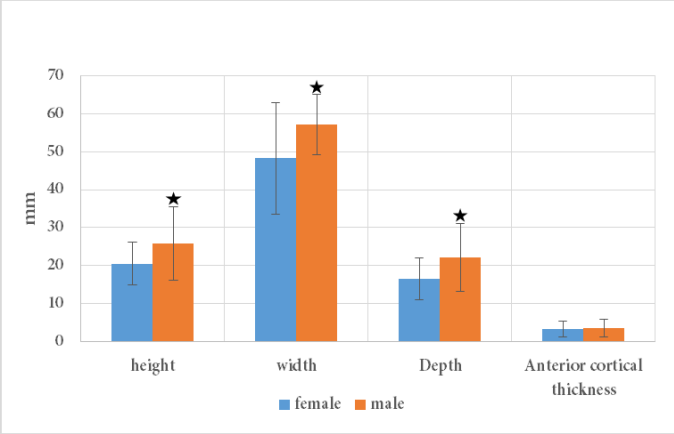

Figure 8. Frontal sinus dimension in both groups

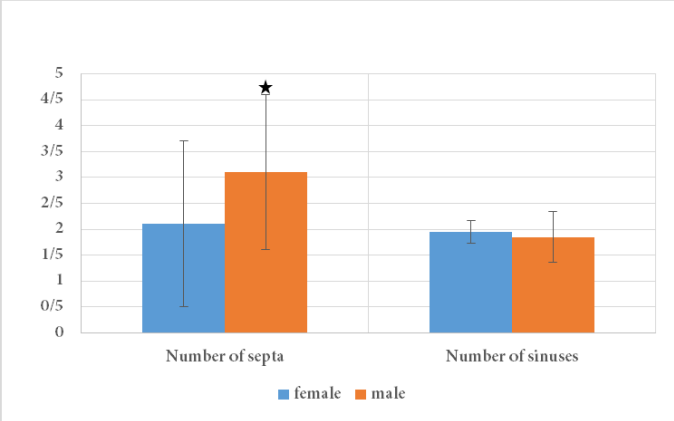

Figure 9. Number of septa and sinuses in both groups

This study was performed on CBCT images taken for various general and specialized dental examinations in a private radiology clinic.

In this study, 40 subjects, including 20 samples in each sex group, were studied. The age range of the participants was 20-70 years. The mean age was 38.8±14.4 years for females and 37.7±13.81 years for males. The student t-test showed no significant difference between the mean age of males and females. The subjects lacked the exclusion criteria i.e. obvious facial deformity, frontal sinusitis, trauma, and any frontal sinus disease and surgery. The files of these scans were examined by two oral and maxillofacial radiologists.

The values of the six evaluated indices are presented in Figure 8 and 9 according to gender.

In the coronal sections, the frontal sinus height, as defined by the highest point of the frontal sinus to the lowest frontal sinus point, averaged 20.5 mm in females and 25.9 mm in males, calculated with a difference of 5.4 mm or 36%, which was greater in males. The difference was statistically significant ($P<0.05$).

In the observed axial sections, the frontal sinus width averaged 48.3 mm for women and 57.1 mm for men, which was 8.8 mm or 42.9% larger in men ($P<0.002$), and the depth of the frontal sinus, defined by the most anterior region of the frontal sinus to the most posterior part of the frontal sinus, was 16.5 mm for females and 22.1 mm for males, which was 5.6 mm or 35% greater in males ($P<0.05$).

In the axial sections, the thickness of the anterior cortex of the frontal sinus, as defined by the distance from the outer edge of the frontal sinus to the inner edge of the frontal sinus, averaged 3.3 mm in women and 3.5 mm in men, which was 0.2 mm or 6% greater in men than in women; this difference was not statistically significant ($P<0.8$). In the axial sections, the

number of frontal sinus septa averaged 2.1 in women and 3.1 in men, which was 47.6% more in men than in women (*P<0.05*).

In the axial and coronal sections, bilateral agenesis was not observed, and unilateral agenesis was seen in 7.5% of the cases (two men and one woman). The average number of frontal sinuses was 1.95 in females and 1.85 in males, which was 5% lower in women; this difference was not statistically significant (*P<0.6*).

Discussion

Identification of the identity of human remnants using the frontal sinus is highly accurate and has been estimated as equivalent to fingerprints in some articles (17). In the present study evaluation of the scans showed no statistically significant difference in the number of frontal sinuses and the thickness of the anterior cortex of the frontal bone in men and women in relation with gender, but there was a significant relationship between the number of septa, height, width, and the anteroposterior size of the frontal sinus with gender.

In a study by Benghiac *et al.,* on 30 CBCT scans of Romanian adults aged 18-65 years, radiographic images were evaluated regarding frontal sinus volume, the thickness of the anterior cortex of the frontal sinus, and anatomical variations such as the number of septa, hyper pneumatization, and hypo pneumatization (16). In this study, bilateral frontal sinus agenesis was not observed in the radiographs, and unilateral agenesis was observed in 2.13% of the patients i.e., one male and two females (16). In the present study, bilateral agenesis was not observed either, consistent with the results reported by Benghiac *et al.,* and unilateral agenesis was observed in 7.5% of the cases (two men and one woman, however the difference was not significant. In addition, the presence of septa in the right frontal sinus in men based on Kappa agreement=0.16 and in the left frontal sinus in women based on Kappa agreement=0.59 indicates the ability of this test to determine sex based on the number of septa in the frontal sinus (16).

In our study, the average number of septa was 1.6±2.1 in women and 1.5±3.1 in men; this difference was statistically significant and denotes the correlation between the number of septa and gender. The results of the cited study were in agreement with the results of the current research (*P<0.05*) (16).

In the above-mentioned study, the anterior cortex thickness on the right side was 2.01±0.63 mm in men and 2.22±0.87 mm in women (*P<0.2*). The anterior cortex thickness on the left side was 2.91±1.03 mm in men and 2.0±0.6 mm in women (*P=0.9*) (16).So the results are in line with the results calculated in the present study.

Benghiac *et al.,* performed another study on the relationship between the frontal sinus index and gender on CBCT images using the below formula (18):

Frontal sinus index=Maximum high/Maximum Depth

There were no statistically significant results in the studies of the relationship between maximal frontal sinus height and gender (*P=0.31*).However there was a significant difference in the maximum frontal sinus width between men and women (*P<0.0001*) (18). From the calculations, it was concluded that the frontal sinus index cannot be invoked alone, and to obtain the relation of gender with frontal sinus, in addition to the frontal sinus index, other calculable indices of the frontal sinus must also be considered (16, 18).

Taking into account all the calculations made in that studies as well as the results obtained in the present study, we can conclude that the relationship of frontal sinus width with gender is consistent with the results of our study, but there is inconsistency concerning the maximum frontal sinus height, which may be due to racial, genetic, and geographical differences of the regions under study.

Luo et al., conducted a study on cephalometric images of 299 women and 246 men to investigate the relationship between sex and frontal sinus using the below formula (19):

Frontal sinus index=Maximum high/Maximum Depth

And significant correlation was found between gender and this index (*P<0.001*) (19), which is consistent with the results of the present study.

Tatlisumak *et al.,* evaluated the CT scans of 180 women and 180 men in Turkey concerning the size of the frontal sinus (20). The measurements included the frontal sinus width, height, depth, and volume. The study was performed on adults of different ages. They concluded that in the age range of 40-49 years, the size of the frontal sinus was greater in women. This size was greater in men over the age of 70 years. In the age range of 60-69 years, the dimensions were smaller compared to over 70 years of age. It was concluded that the average size varies with age; they did not provide a clear explanation for this matter. By measuring the height of the left and right frontal sinuses, it was concluded that there was no significant difference in the height of the right frontal sinus between men and women (20).

In the study above, on the left side, the mean of all measurements was greater in men than in women, and the difference was significant (*P<0.05*) (9). Therefore, the mean values obtained in the left frontal sinus correspond to the values found in the present study.

In the above study, the mean frontal sinus width was 26.85 mm on the right side and 27.37 mm on the left side for women and 27.65 mm on the right side, and 28.11 mm on the left side for men, respectively. In the cited study, the relationship between left frontal sinus width and gender was significant but the correlation was not significant for the right frontal sinus (20). The correlation between the mean left frontal sinus width and gender in the mentioned study agrees with the results of the present study.

Lee et al., examined 150 CT scans concerning frontal sinus anatomy and gender diversity (21). One hundred images belonged to men, and 50 images belonged to women with a mean age of 40 years. The dimensions of the frontal sinus and the thickness of the anterior frontal cortex were taken in axial and sagittal images. The average thickness of the anterior frontal cortex was 2.6 mm to 4.1 mm, and the average sinus depth was 8 mm to 9.3 mm, with no statistically significant differences. The maximum frontal sinus height was 24.5 mm. The mean width above the supraorbital ridge reached 52.5 mm (21). In the mentioned study, no significant differences were observed between the right and left frontal sinuses. In comparing the relation between gender and average frontal sinus dimensions, all the numbers were greater in men. The results obtained in the study by Lee *et al.,* were consistent with the findings of the present study except for the thickness of the anterior frontal cortex, which was 3.9±1.9 mm in men and 2.9±1.1 mm in women (*P<0.05*) (21).

The difference observed in the above study with the present study may be due to the difference in making the measurements as Lee *et al.,* measured the supraorbital ridge in the glabella, while in the present study, the measurements were taken in the axial view in the section where we observed the largest frontal sinus width.

In recent years, three-dimensional (3D) radiographic techniques, such as CT, magnetic resonance imaging, and CBCT, have made great progress; these modalities provide us with much information and are very useful for human identification. Compared to 2D techniques, 3D images provide more information. CBCT devices have reduced radiation levels compared to medical CT; therefore, a lot of information is gained at a low cost. Although CBCT use is not yet fully accepted by identification authorities, in the USA, Sarment and Christensen have suggested the use of CBCT in forensic medicine (22).

Choi et al., conducted a study on the relationship between frontal sinus volume and gender and recommended the use of CBCT in forensic medicine (23). Forensic researchers expect that many future identifications will be based on CBCT scans.

It is suggested to examine the relationship of the frontal sinus volume index with gender. It is also suggested to examine the frontal sinus indices separately in the right and left frontal sinuses and to examine frontal sinus indices at different ages in future studies.

Conclusion

The results of this study showed that the height, width, depth, and the number of septa of frontal sinuses are greater in men, but the difference in the number of frontal sinuses and the thickness of the anterior cortex of the frontal sinuses was not sufficient to accurately distinguish between males and females.

Conflict of Interest: 'None declared'.

References

1. Štoković N, Trkulja V, Čuković-Bagić I, Lauc T, Grgurević LJCA. Anatomical variations of the frontal sinus and its relationship with the orbital cavity. 2018;31(4):576-82.
2. Wanzeler AMV, Alves-Júnior SM, Ayres L, da Costa Prestes MC, Gomes JT, Tuji FMJIjolm. Sex estimation using paranasal sinus discriminant analysis: a new approach via cone beam computerized tomography volume analysis. 2019;133(6):1977-84.
3. Yun IS, Kim YO, Lee S-K, Rah DKJJoCS. Three-dimensional computed tomographic analysis of frontal sinus in Asians. 2011;22(2):462-7.
4. PS AP, Adams K, Fernandes L, Kranioti EJMBdLadA. Frontal sinus as an identity and sex indicator. 2021.
5. Gadekar NB, Kotrashetti VS, Hosmani J, R N. Forensic application of frontal sinus measurement among the Indian population. J Oral Maxillofac Pathol. 2019;21(1):147-51.
6. Sommer F, Hoffmann TK, Harter L, Döscher J, Kleiner S, Lindemann J, *et al.,* Incidence of anatomical variations according to the International Frontal Sinus Anatomy Classification (IFAC) and their coincidence with radiological sings of opacification. 2019;276(11):3139-46.

7. Dassi CS, Demarco FR, Mangussi-Gomes J, Weber R, Balsalobre L, AC S. The Frontal Sinus and Frontal Recess: Anatomical, Radiological and Surgical Concepts. Int Arch Otorhinolaryngol. 2020;24(3):e364-e75.
8. Eksi MS, Güdük M, Usseli MIJJoCS. Frontal Bone is Thicker in Women and Frontal Sinus is Larger in Men: A Morphometric Analysis. 2021;32(5):1683-4.
9. Nagare SP, Chaudhari RS, Birangane RS, PC P. ex determination in forensic identification, a review. J Forensic Dent Sci. 2018;10(2):61-6.
10. Ekizoglu O, Hocaoglu E, Inci E, Can IO, Solmaz D, Aksoy S *et al.,* Assessment of sex in a modern Turkish population using cranial anthropometric parameters. 2016;21:45-52.
11. Wu W, Li Y, Fan F, Zhang K, Deng ZJFyxzz. Research Progress on Individual Identification by Frontal Sinus Imaging. 2021;37(1):81-6.
12. Nautiyal A, Narayanan A, Mitra D, Honnegowda TM, Sivakumar. Computed Tomographic Study of Remarkable Anatomic Variations in Paranasal Sinus Region and their Clinical Importance - A Retrospective Study. Ann Maxillofac Surg. 2020;10(2):422-8.
13. Akhlaghi M, Bakhtavar K, Moarefdoost J, Kamali A, Rafeifar SJLM. Frontal sinus parameters in computed tomography and sex determination. 2016;19:22-7.
14. Cossellu G, De Luca S, Biagi R, Farronato G, Cingolani M, Ferrante L, *et al.,* Reliability of frontal sinus by cone beam-computed tomography (CBCT) for individual identification. 2015;120(12):1130-6.
15. Zhao H, Li Y, Xue H, Deng ZH, Liang WB, Zhang LJIJoLM. Morphological analysis of three-dimensionally reconstructed frontal sinuses from Chinese Han population using computed tomography. 2021;135(3):1015-23.
16. Benghiac AG, Thiel BA, D H. Reliability of the frontal sinus index for sex determination using CBCT. Rom J Leg Med. 2015;23(4):275-8.
17. Scendoni R, Kelmendi J, Cossellu G, Canturk N, Arslan BC, Peker E, *et al.,* Comparison of Frontal Sinuses for Personal Identification in 3 Populations Using Cameriere's Code Number. 2021;42(1):42-5.
18. Benghiac AG, Constantin Budacu C, Moscalu M, Ioan B, Moldovanu A, D H. CBCT assessment of the frontal sinus volume and anatomical variations for sex determination. Rom J Leg Med. 2017;25(2):174-9.
19. Luo H, Wang J, Zhang S, Mi CJJof, medicine l. The application of frontal sinus index and frontal sinus area in sex estimation based on lateral cephalograms among Han nationality adults in Xinjiang. 2018;56:1-4.
20. Tatlisumak E, Asirdizer M, Bora A, Hekimoglu Y, Etli Y, Gumus O, *et al.,* The effects of gender and age on forensic personal identification from frontal sinus in a Turkish population. Saudi Med J. 2017;38(1):41-7.
21. Lee MK, Sakai O, JH S. CT measurement of the frontal sinus - gender differences and implications for frontal cranioplasty. J Craniomaxillofac Surg. 2010;38(7):494-500.
22. Sarment DP, Christensen AMJJoFR, imaging. The use of cone beam computed tomography in forensic radiology. 2014;2(4):173-81.
23. Choi IG, Duailibi-Neto EF, Beaini TL, da Silva RL, Chilvarquer IJJofs. The frontal sinus cavity exhibits sexual dimorphism in 3D cone-beam CT images and can be used for sex determination. 2018;63(3):692-8.

Please cite this paper as: Mahaseni Aghdam A, Mehralizadeh S, Talaipour A, Mehdizadeh A, Ghadimi N. Morphometric Evaluation of Frontal Sinus and Investigating the Role of Gender in Anatomical Variations in Cone-beam Computed Tomography Images of an Iranian Population. Regen Reconstr Restor. 2021;6 (1): e6. Doi: 10.22037/rrr.v5i1.35535.