

Sex Determination Using Frontal Sinus Diameters on Direct Radiography

Emre Emekli ¹

1. Department of Radiology, Etimesgut Şehit Sait Ertürk State Hospital, Ankara, TUR

Corresponding author: Emre Emekli, emreemekli90@gmail.com

Review began 10/07/2023

Review ended 10/15/2023

Published 10/22/2023

© Copyright 2023

Emekli. This is an open access article distributed under the terms of the Creative Commons Attribution License CC-BY 4.0., which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Abstract

Background and aim: The shape and developmental stages of the frontal sinus (FS) differ in each individual, it can be used to determine sex and identity. This study aimed to assess the morphological structure of the FS diameters in sex determination using posteroanterior (AP) skull radiography. This data can be valuable for identifying and characterizing human features.

Methods: The study included 350 patients (171 females, 179 males) aged between 20 and 55 years who underwent AP skull radiography. FSs were classified as symmetrical, asymmetrical, unilateral, or bilateral aplasic. The right and left FS height and width measurements were made based on the largest diameters.

Results: The mean age was 32.8±11.45 years for the whole sample. The mean age of the males was 31.23±11.9 (20-51) years and that of the females was 34.45±10.75 (20-55) years. When classified anatomically, 20 patients had bilateral aplasia (12 males, eight females), 19 patients had right aplasia (10 males, nine females), and 11 patients had left aplasia (seven males, four females). FS was symmetrical in 206 (72.1%) patients while right dominance was observed in 33 (9.43%) patients and left dominance in 61 (17.43%) patients. The FS height and width values on both sides were statistically significantly higher in males than in females ($p < 0.001$ for each parameter). The females were accurately classified at a rate of 71.2% and the males at 68.2%.

Conclusion: Notably, our research has revealed that frontal sinus diameters are consistently larger in males than in females, and that direct radiography can be employed for gender determination with an accuracy rate of 69.7%. This information underscores the utility of morphometric evaluation of the frontal sinus diameters on direct radiography for gender and identity determination, potentially in conjunction with other parameters. In conclusion, our study has demonstrated the potential of the morphological structure of the frontal sinuses as a valuable tool for identifying and characterizing human individuals.

Categories: Neurosurgery, Anatomy, Radiology

Keywords: sex determination, skull radiography, direct radiography, frontal sinus, paranasal sinus

Introduction

It may be necessary to identify skeletons that cannot be recognized for any reason [1]. In this context, sex determination plays an important role as the first step [2]. In cases where descriptive characteristics, such as DNA and fingerprints cannot be used, radiological identification has an important place. Forensic anthropologists utilize various anatomical regions for sex determination in unidentified skeletons [3,4]. Paranasal sinuses are among the anatomical regions that can be used for sex determination. The frontal sinus (FS) is absent at the beginning of life, unlike other sinuses [5]. FS begins to develop as pea-shaped pockets located on both sides of the orbit. These pockets, which start to develop at the age of two, can only be detected radiologically when individuals reach the age of six [5]. FS completes its development by 20 years of age [6]. FS can sometimes be unilateral while some individuals may not have this sinus on either side. Since the shape and developmental stages of FS differ in each individual, it can be used to determine the sex and identity of individuals [7]. In 1921, Schuller evaluated the shape, complex structure, and individuality of FS for the first time and stated that it could be used for the identification of individuals in postmortem studies [8].

The aim of this study was to assess the morphological structure of the FS diameters in sex determination using posteroanterior (AP) skull radiography. This data can be valuable for identifying and characterizing human features.

This article was previously presented as a meeting abstract at the 2020 Turkey 21st National Anatomy Congress on November 29, 2020.

Materials And Methods

Patients who underwent AP cranial radiography in our hospital under outpatient conditions were included in

How to cite this article

Emekli E (October 22, 2023) Sex Determination Using Frontal Sinus Diameters on Direct Radiography. Cureus 15(10): e47476. DOI 10.7759/cureus.47476

the study. A total of 350 patients (171 females, 179 males) aged 20-55 years were included considering that FS continues to develop until the age of 20 and it can expand secondary to resorption after a certain age. Patients with developmental deficiency or pathology, craniofacial syndrome, known endocrine or metabolic disease, and known craniofacial trauma were excluded.

FS was anatomically classified as symmetrical, asymmetrical (right or left dominance), and unilateral or bilateral aplasic. The longest dimensions on both sides were divided into each other to evaluate the right and left asymmetry, and the result was multiplied by 100. FS was evaluated as asymmetric if the result was greater than 20% and symmetric if less than 20% (Figure 1) [9,10].

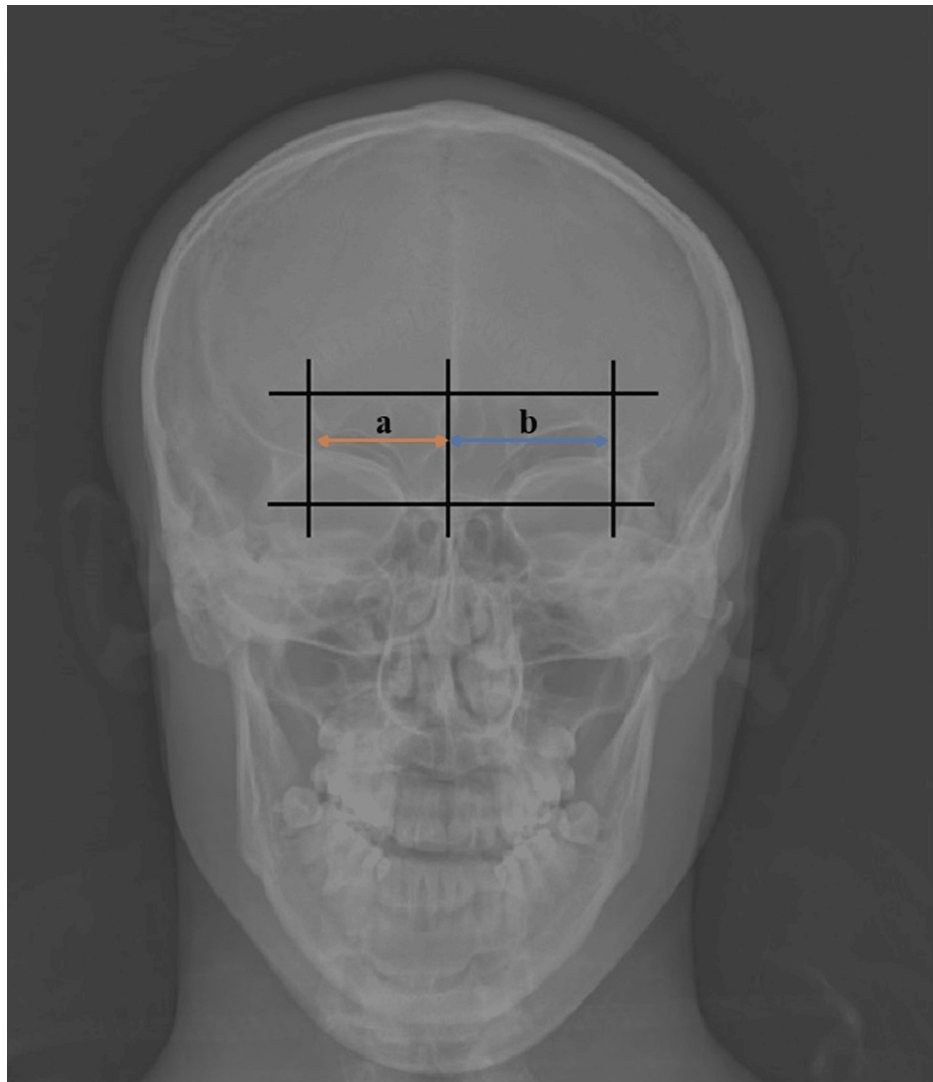


FIGURE 1: Method used to determine the symmetry and asymmetry of the frontal sinus. If $\left\{\frac{a}{b}\right\} \times 100 > 20$, the frontal sinus was evaluated to be asymmetric.

The frame shows the largest diameters of the frontal sinuses. (a) Right frontal sinus width and (b) left frontal sinus width.

The right and left FS height and width measurements were made based on the largest diameters. For both sides, the width was evaluated as the largest diameter from the central septum, and the height as the upper limit of FS from the frontonasal suture. Patients with bilateral or unilateral aplasia were not included in these measurements.

The Statistical Package for the Social Sciences (SPSS) version 20.0 (Armonk, NY: IBM Corp.) was used for statistical analysis. The independent samples t-test was used to compare the differences in the mean dimensions measured between the males and females. For the use of frontal sinus parameters in sex determination, discriminate analysis, which is one of the multivariate statistical analysis methods, was used

to determine whether the units were correctly assigned to their own groups. The linear discriminant function was used for the two groups.

Results

The mean age of all patients included in the study was 32.8 ± 11.45 (20-55) years. The mean age of the males was 31.23 ± 11.9 (20-51) years and that of the females was 34.45 ± 10.75 (20-55) years. When classified anatomically, 20 patients had bilateral aplasia (12 males, eight females), 19 patients had right aplasia (10 males, nine females), and 11 patients had left aplasia (seven males, four females) (Figure 2).

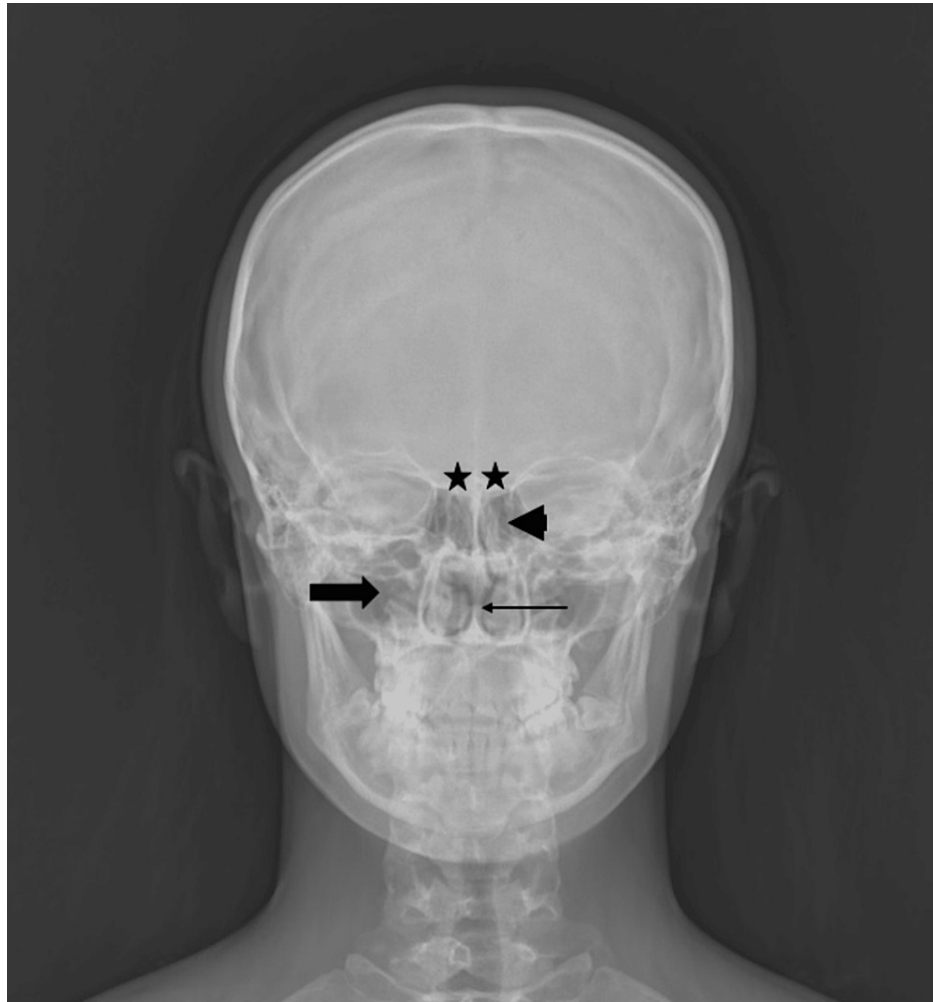


FIGURE 2: Radiography image of a 20-year-old woman with bilateral frontal aplasia.

The image shows bilateral frontal aplasia (star), maxillary sinus (bold arrow), ethmoidal cells (arrowhead), and nasal septum (arrow).

Excluding 50 (14.29%) patients with aplasia, FS was symmetrical in 206 (72.1%) of the remaining 300 patients while right dominance was observed in 33 (9.43%) patients and left dominance in 61 (17.43%) patients. The distribution of findings according to sex is summarized in Table 1. After excluding the patients with aplasia, the measurements were performed in the remaining 300 patients (154 male, 146 female) and the results are presented in Table 2.

Classification	Number of individuals		Total (percentage)
	Males	Females	
Symmetry	93 (26.57%)	113 (32.29%)	206 (58.85%)
Left-dominant asymmetry	36 (10.29%)	25 (7.14%)	61 (17.42%)
Right-dominant asymmetry	21 (6%)	12 (3.43%)	33 (9.42%)
Left unilateral aplasia	7 (2%)	4 (1.14%)	11 (3.14%)
Right unilateral aplasia	10 (2.86%)	9 (2.57%)	19 (5.42%)
Bilateral aplasia	12 (3.43%)	8 (2.29%)	20 (5.71 %)

TABLE 1: Distribution of frontal sinus patterns.

Frontal sinus parameters (mm)	Data	Minimum	Maximum	Mean	SD	p-Value (sex)
Right side width	Female	8	47.5	25.52	8.26	<0.001
	Male	18.5	57.8	32.92	7.68	
	Total	8	57.8	29.32	8.78	
Right side height	Female	7.77	50	22.66	8.57	<0.001
	Male	12	64	30.4	10.1	
	Total	7.77	64	26.63	10.14	
Left side width	Female	8.1	51.7	25.79	8.07	<0.001
	Male	11.3	60.1	33.62	8.21	
	Total	8.1	60.1	29.81	9.02	
Left side height	Female	9.37	50.3	23.61	8.77	<0.001
	Male	11.3	61.9	30.93	9.61	
	Total	9.37	61.9	27.37	9.9	

TABLE 2: Descriptive statistics and independent samples t-test parameters studied.

SD: standard deviation

The bilateral mean width values were higher than the height values in both sexes (right $p=0.014$, left $p=0.012$ for males; right $p=0.004$, left $p=0.020$ for females). The FS height and width values on both sides were all statistically significantly higher in males than in females ($p<0.001$ for each parameter). However, there was no significant difference between the right and left FS values (width $p=0.534$, height $p=0.676$ for males; width $p=0.663$, height $p=0.318$ for females).

In the analysis conducted for sex determination, it was determined that the females were accurately classified at a rate of 71.2% and the females at a rate of 68.2%. The accurate classification rate for each sex was calculated as 69.7%.

Discussion

In the realm of forensic medicine and dentistry, craniometric parameters also play a vital role in both postmortem and antemortem evaluations of individuals. Cranial dimensions can differ among different populations, and measuring the cranium aids in determining racial distinctions and sexes [11]. When we evaluated FS anatomically, we detected the presence of bilateral or unilateral aplasia in 50 patients. FS was symmetrical in 206 of the remaining cases while it was asymmetric in 94 with right or left dominance. We found that the height and width measurements (mm) on both sides were statistically significantly larger in

the males compared to the females. All these findings support the thesis that the development of FS is unique and can be used in the identification of individuals, as stated in the literature. In addition, our findings show that FS diameters can also be useful in sex determination.

In our study, we included patients over 20 years of age since it is reported in the literature that FS development can continue up to this age [6]. In addition, we chose to exclude elderly patients from our study considering that after a certain age, FS dimensions are reported to increase secondary to bone resorption [12]. We did not attempt to include an equal number of male and female patients in contrast to some studies in the literature [9,13]. Rather, consistent with some other researchers, we included all patients who met our criteria within a certain time interval [10,14].

Patients with bilateral aplasia constituted 5.71% of our study population. In studies conducted in the literature, this rate varies between 2% and 10% [13-17]. In some studies, no bilateral aplasia was reported [16]. We detected unilateral aplasia in 8.56% of our patients, right aplasia in 5.42% and left aplasia in 3.14%. In the literature, unilateral aplasia has been reported at rates varying between 2.5% and 13.75% [9,13-16]. Our findings are mostly consistent with the previously reported data [11,13-17]. However, the wide range of these rates can be explained by the different genetic, environmental, and ethnic origins of the samples evaluated [18]. For example, a previous study suggested that the absence of FS was very common in the Inuit, which may be a result of adaptation to cold climate [19].

Symmetry was observed in 58.85% of our patients and asymmetry in 26.84% (left dominance in 17.42% and right dominance in 9.42%). In the literature, the FS symmetry and asymmetry have been reported as 55.14-78% and 11.4-23.7%, respectively, which is similar to the values we obtained [9,14,15]. However, there is also a study that found 43.1% symmetrical and 56.6% asymmetrical FS rates, unlike other studies in the literature [20].

In our study, FS diameters on both sides were larger in the males compared to the females. Our results showed that sex determination using FS diameters was successful for 68.2% of the males and 71.2% of the females, while the accuracy rate for both sexes was 69.7%. The literature contains studies using different imaging techniques for sex determination based on FS [21-28]. In a study conducted in India with computed tomography (CT), it was reported that sex determination had an accuracy rate of 61.4% [21], and in a direct radiography study, the accuracy of sex determination was determined as 59% [22]. In the literature using direct skull radiography as in our study, Verma et al. noted that sex determination was undertaken at 61% accuracy [10], while a study conducted in India reported 59.4-64.4% accuracy rates after evaluating the FS diameters on the two sides separately [23], and researchers from Nigeria showed that the accuracy of this method was 60% among patients aged 20-91 years [24].

The highest accuracy rate for sex determination was reported as 80% in a study [4]. However, in contrast to all these studies, there are also a few researchers concluding that FS cannot be used in sex determination. For example, in an Indian study, Goyal et al. found no significant sex difference [17]. Similarly, in a study using conical CT, the accurate sex determination rate was found to be non-significant, being determined as 92% for females and 50% for males [25]. The rates reported in studies conducted in Turkey are similar to those we obtained. Ekizoğlu et al. stated that accurate sex determination was made in 77.5% of females and 70.5% of males. In a study performed with direct skull radiography, it was reported that sex discrimination was successful at a rate of 68.1% [27], while a conical CT study showed a 79% accuracy rate in sex determination [28]. In many studies comparing FS diameters, it has been reported that they are larger in males, which is consistent with our results [23,24,29]. In summary, the frontal sinus is a unique anatomical feature that displays variations in both size and shape across individuals. Our study supports earlier findings, demonstrating that males generally possess larger frontal sinuses than females. These disparities may be linked to distinct developmental patterns and the influence of handedness or footedness, which might potentially affect cerebral dominance [11]. In all these studies, it was found that FS diameters could be used at 59.4-80% accuracy in sex determination. The differences in these percentages may be due to the effects of geographical and environmental factors. It has been reported in the literature that FS diameters have a linear relationship with ambient air temperature and pneumatization. In addition, a relationship between pneumatization and FS diameters and shapes has been reported [19,30].

Our study had certain limitations. First, the number of cases was relatively small. Second, it is known that the morphological characteristics of FS are affected by genetic and environmental factors, and therefore it may not be possible to generalize our data to all populations. Lastly, we were able to evaluate only the parameters of height and width for FS on direct radiography. More parameters can be evaluated with further studies using cross-sectional imaging methods.

Conclusions

Notably, our research has revealed that frontal sinus diameters are consistently larger in males than in females, and that direct radiography can be employed for gender determination with an accuracy rate of 69.7%. This information underscores the utility of morphometric evaluation of the frontal sinus diameters on direct radiography for gender and identity determination, potentially in conjunction with other parameters. In conclusion, our study has demonstrated the potential of the morphological structure of the

frontal sinuses as a valuable tool for identifying and characterizing human individuals. Furthermore, our findings provide clues for medical experts and researchers in the field of craniofacial medicine regarding the complex relationship between frontal sinuses and craniofacial parameters that can be explored in the future, utilizing advanced imaging technology and a specific population focus.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Emre Emekli

Acquisition, analysis, or interpretation of data: Emre Emekli

Drafting of the manuscript: Emre Emekli

Critical review of the manuscript for important intellectual content: Emre Emekli

Disclosures

Human subjects: Consent was obtained or waived by all participants in this study. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

References

1. Austin D, King RE: The biological profile of unidentified human remains in a forensic context . *Acad Forensic Pathol.* 2016, 6:370-90. [10.23907/2016.039](https://doi.org/10.23907/2016.039)
2. Albalawi AS, Alam MK, Vundavalli S, Ganji KK, Patil S: Mandible: an indicator for sex determination - a three-dimensional cone-beam computed tomography study. *Contemp Clin Dent.* 2019, 10:69-73. [10.4103/ccd.ccd_313_18](https://doi.org/10.4103/ccd.ccd_313_18)
3. Soman BA, Sujatha GP, Lingappa A: Morphometric evaluation of the frontal sinus in relation to age and gender in subjects residing in Davangere, Karnataka. *J Forensic Dent Sci.* 2016, 8: [10.4103/0975-1475.176945](https://doi.org/10.4103/0975-1475.176945)
4. Şimşek HA, Gültekin T, Bilecenoglu B, Kolsuz ME, Atakan C: Konik ışınli bilgisayarli tomografi ile frontal sinüsten morfolojik cinsiyet tayini. *Turkiye Klinikleri J Foren Sci Leg Med.* 2020, 17:117-21. [10.5356/forensic.2019-73247](https://doi.org/10.5356/forensic.2019-73247)
5. Coemert S, Veith L, Strauss G, Schmitz PM, Lueth TC: Anatomical characterization of frontal sinus and development of representative models. *Annu Int Conf IEEE Eng Med Biol Soc.* 2019, 2019:6113-7. [10.1109/EMBC.2019.8856327](https://doi.org/10.1109/EMBC.2019.8856327)
6. Moore K, Ross A: Frontal sinus development and juvenile age estimation . *Anat Rec (Hoboken).* 2017, 300:1609-17. [10.1002/ar.23614](https://doi.org/10.1002/ar.23614)
7. Watelet JB, Van Cauwenberge P: Applied anatomy and physiology of the nose and paranasal sinuses . *Allergy.* 1999, 54:14-25. [10.1111/j.1398-9995.1999.tb04402.x](https://doi.org/10.1111/j.1398-9995.1999.tb04402.x)
8. Schuller A: A note on the identification of skulls by X-ray pictures of the frontal sinuses . *Med J Aust.* 1945, 1:554-6. [10.5694/j.1326-5377.1945.tb44655.x](https://doi.org/10.5694/j.1326-5377.1945.tb44655.x)
9. Verma K, Nahar P, Singh MP, Mathur H, Bhuvaneshwari S: Use of frontal sinus and nasal septum pattern as an aid in personal identification and determination of gender: a radiographic study. *J Clin Diagn Res.* 2017, 11:71-4. [10.7860/JCDR/2017/22037.9201](https://doi.org/10.7860/JCDR/2017/22037.9201)
10. Verma S, Mahima VG, Patil K: Radiomorphometric analysis of frontal sinus for sex determination . *J Forensic Dent Sci.* 2014, 6:177-82. [10.4103/0975-1475.137052](https://doi.org/10.4103/0975-1475.137052)
11. Denny C, Bhoraskar M, Abdul Aziz Shaikh S, T S B, Sujir N, Natarajan S: Investigating the link between frontal sinus morphology and craniofacial characteristics with sex: a 3D CBCT study on the South Indian population. *F1000Res.* 2023, 12: [10.12688/f1000research.137008.2](https://doi.org/10.12688/f1000research.137008.2)
12. Quatrehomme G, Fronty P, Sapanet M, Grévin G, Baillet P, Ollier A: Identification by frontal sinus pattern in forensic anthropology. *Forensic Sci Int.* 1996, 83:147-53. [10.1016/s0379-0738\(96\)02033-6](https://doi.org/10.1016/s0379-0738(96)02033-6)
13. Pereira JG, Sa Santos JB, de Sousa SP, Franco A, Silva RH: Frontal sinuses as tools for human identification: a systematic review of imaging methods. *Dentomaxillofac Radiol.* 2021, 50: [10.1259/dmfr.20200599](https://doi.org/10.1259/dmfr.20200599)
14. Nagaraj T, Nigam H, Santosh H, Sumana C, Gogula S, Sahu P: Personal identification using frontal sinus and nasal septum patterns in forensic medicine: a retrospective digital radiographic study. *J Med Radiol Pathol Surg.* 2017, 4:5-8. [10.15713/ins.jmrps.105](https://doi.org/10.15713/ins.jmrps.105)
15. David MP, Saxena R: Use of frontal sinus and nasal septum patterns as an aid in personal identification: a digital radiographic pilot study. *J Forensic Dent Sci.* 2010, 2:77-80. [10.4103/0975-1475.81286](https://doi.org/10.4103/0975-1475.81286)
16. Shamlou AA, Tallman SD: Frontal sinus morphological and dimensional variation as seen on computed tomography scans. *Biology (Basel).* 2022, 11: [10.3390/biology11081145](https://doi.org/10.3390/biology11081145)
17. Goyal M, Acharya AB, Sattur AP, Naikmasur VG: Are frontal sinuses useful indicators of sex? . *J Forensic Leg*

- Med. 2013, 20:91-4. [10.1016/j.jflm.2012.04.028](https://doi.org/10.1016/j.jflm.2012.04.028)
18. Danesh-Sani SA, Bavandi R, Esmaili M: Frontal sinus agenesis using computed tomography . J Craniofac Surg. 2011, 22:48-51. [10.1097/SCS.0b013e318231e26c](https://doi.org/10.1097/SCS.0b013e318231e26c)
 19. Koertvelyessy T: Relationships between the frontal sinus and climatic conditions: a skeletal approach to cold adaptation. Am J Phys Anthropol. 1972, 37:161-72. [10.1002/ajpa.1330370202](https://doi.org/10.1002/ajpa.1330370202)
 20. Taniguchi M, Sakoda S, Kano T, Zhu B, Kamikodai Y, Fujita MQ, Maeda H: Possible use of nasal septum and frontal sinus patterns to radiographic identification of unknown human remains. Osaka City Med J. 2003, 49:31-8.
 21. Baglivo M, Winkhofer S, Hatch GM, Ampanozi G, Thali MJ, Ruder TD: The rise of forensic and post-mortem radiology - analysis of the literature between the year 2000 and 2011. J Forensic Radiol Imaging. 2013, 1:3-9. [10.1016/j.jofri.2012.10.003](https://doi.org/10.1016/j.jofri.2012.10.003)
 22. Sheikh NN, Ashwinirani S, Suragimath G, Kumar KS: Evaluation of gender based on the size of maxillary sinus and frontal sinus using paranasal sinus view radiographs in Maharashtra population, India. J Oral Res Rev. 2018, 10:
 23. Belaldavar C, Kotrashetti VS, Hallikerimath SR, Kale AD: Assessment of frontal sinus dimensions to determine sexual dimorphism among Indian adults. J Forensic Dent Sci. 2014, 6:25-30. [10.4103/0975-1475.127766](https://doi.org/10.4103/0975-1475.127766)
 24. Eboh DE, Ogbeide OU, Ivwighren T: Radiographic anthropometric study of frontal sinus for sex determination in Benin city, South-South Nigeria. J Forensic Dent Sci. 2017, 9:31-5. [10.4103/jfo.jfds.40_16](https://doi.org/10.4103/jfo.jfds.40_16)
 25. Benghiac AG, Thiel BA, Haba D: Reliability of the frontal sinus index for sex determination using CBCT . Rom J Leg Med. 2015, 23:275-8.
 26. Ekizoğlu O, Hocaoğlu E, İnci E: Bilgisayarlı tomografi ile frontal sinüs morfometrik analizinin cinsiyet belirlenmesinde kullanımı. Bull Leg Med. 2017, 22:91-6. [10.17986/blm.2017227229](https://doi.org/10.17986/blm.2017227229)
 27. Teke HY, Duran S, Canturk N, Canturk G: Determination of gender by measuring the size of the maxillary sinuses in computerized tomography scans. Surg Radiol Anat. 2007, 29:9-13. [10.1007/s00276-006-0157-1](https://doi.org/10.1007/s00276-006-0157-1)
 28. Dağistan S, Miloğlu Ö, Altun O, Umar EK, Ezmeçi T: Konik ışınli bilgisayarlı tomografi kullanılarak infraorbital foramen, infraorbital sulkus ve çevre yapıların anatomik olarak retrospektif incelenmesi. J Dent Fac Atatürk Uni. 2019, 29:1-6. [10.17567/ataunidfd.522559](https://doi.org/10.17567/ataunidfd.522559)
 29. Chalkoo AH, Sharma P, Nazir N, Tariq S: Evaluation of the frontal sinuses dimensions in sex estimation among a sample of adult Kashmiri population using multidetector computed tomography. Int J Maxillofac Imaging. 2018, 4:122-5. [10.18231/2581-3838.2018.0031](https://doi.org/10.18231/2581-3838.2018.0031)
 30. Amusa Y, Eziyi J, Akinlade O, Famurewa OC, Adewole SA, Nwoha PU, Ameye SA: Volumetric measurements and anatomical variants of paranasal sinuses of Africans using dry crania. Int J Med Med Sci. 2011, 3:299-303.