Original Article

Sexual Dimorphism of Radiomorphological Features of Frontal Sinus

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ABSTRACT

Objective: Radiographs of the frontal sinus have been used in personal identification due to its uniqueness configuration. Largely there has been little agreement regarding the reliability of frontal sinus in gender determination. This study was performed to verify the dependability of radiomorphologic features of the frontal sinus in the assessment of sexual dimorphism.
Methodology: A total of 100 paranasal radiographs were evaluated for sexual dimorphic features including number of scallops on the sinuses' superior border, unilateral/bilateral presence or absence of partial septa, number of partial septa, and unilateral/bilateral presence or absence of supraorbital cells.
Results: Application of discriminative analysis to the data accurately identified the gender in merely 65.7% of cases.
Conclusion: Therefore the radiomorphologic features of frontal sinus alone have limited value in gender determination and may be used as an auxiliary method.

Key Words: *Caldwell view, frontal sinus, radiomorphological features, sexual dimorphism*

Introduction

Creating an antemortem profile of an individual from skeletal remains, which includes sex, race determination, age, and stature estimation forms an essential part of forensic anthropology. The bones that are used conventionally for sex determination are often recovered either in a fragmented or incomplete state. Therefore, it becomes necessary to use denser bones that are intact on recovery.[1,2] Many parts of the skeleton are used for identification of a person. However, the most reliable parts of the skeleton for identification are those that are anatomically variable or which do not exhibit change due to trauma, illness, or surgical intervention.[3]

Frontal sinuses are, typically, paired lobulated cavities located deep to the superciliary arches in the frontal bone.[4] Major part of sinus pneumatization happens during the puberty. A growth spurt occurs a few years after puberty, which leads to an enlargement of frontal sinus that is completed marginally earlier in girls than in boys (around 10 and 14 years, respectively). Therefore, the overall development of the frontal sinus is usually accomplished by the 20th year.[4,5] Schuller noted that the form, size, and position of the frontal sinuses do not change throughout adult life, though slight changes are possible. Variations in the appearance of frontal sinuses during lifetime are primarily due to thinning of the bone with old age and trauma, and in rare occurrences from tumors or severe infections.[4,6-10]

Due to its highly individualistic configuration, the frontal sinus patterns are considered to be unique and a potent marker for individual identification. Predictably, the frontal sinuses have been investigated in post-mortem identification over many years. The two- and three-dimensional imaging of frontal sinuses on radiographs, computed tomography (CT) scans, and cone-beam CT scans have endeavored to establish this reputed uniqueness successfully.[7] The correlation of the morphology of the frontal sinus with gender shows that sexual dimorphism of frontal sinus dimensions and morphology have been widely acknowledged, with sinuses reported to be larger in males than in females;[8,11,12] except in Canadian Eskimo populations.[13] Although individual studies display more numerous scallops (loculations) along the upper border in females,[10,14] others indicate increased loculations are more common in males.[4,15]

The previous studies have established that the radiographic pattern of the frontal sinus is distinctive to every individual even among monozygotic twins. Frontal sinuses show great differences in shape, symmetry, and degree of development. Variability was seen not only among different individuals but also within a single skull in various positions. The asymmetry of the frontal sinuses has stimulated several attempts to identify persons by analyzing measurements of the sinuses obtained from plain X-ray films.[3,13] The anatomical complexity of the facial skeleton has prompted the development of several types of radiographic techniques. Among those more commonly used is the posteroanterior (PA) view of the skull, also known as the Caldwell view. It is typically done for the radiographic

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evaluation of frontal and ethmoidal sinus morphology. With the knowledge that apart from their clinical applications, PA skull radiographs are also used for legal purposes, the aim of the present study was to demonstrate the importance of frontal sinus radiographs for gender identification in forensic investigations.[16] Hence, the present study was undertaken to assess the variability of the frontal sinus pattern in an Indian population and to evaluate the reliability of frontal sinus in gender determination.

Materials and Methods

Subjects

A retrospective, cross-sectional study was carried out after being approved by the Committee on Ethics in Research. Radiographs of 99 participants of Indian origin, taken by the Caldwell technique with frontonasal support, were evaluated [Figure 1]. The sample comprised 49 females and 50 males, whose ages ranged between 21 and 54 years. This age range limit was preferred as sinus development is completed by around 20 years and in older age group atrophic changes may lead to progressive pneumatization, possibly precluding results of sexual dimorphism. Individuals in perfect health were selected to participate in the present study. Those with a history of orthodontic treatment or orthognathic surgery, or any surgery of the skull, or trauma, history or clinical characteristics of endocrine disturbances, nutritional diseases, or hereditary facial asymmetries were excluded from the study.[17]

Methods

The same radiologist took the radiographs, and the frontal sinuses patterns were graded by slight modification of the methods given by Yoshino *et al*., Tang *et al*., and Goyal *et al*.[7,13,18] and were evaluated regarding:

1. Number of scallops on the sinuses' superior border (right, left, and total),
2. Unilateral/bilateral presence or absence of partial septa
3. Number of partial septa (right, left, and total), and
4. The unilateral/bilateral presence or absence of supraorbital cells (the latter two features graded as "0" for bilateral absence, "1" for the unilateral presence, and "2" for bilateral presence).

The scores obtained were tabulated and subjected to statistical analysis using the Statistical Package for the Social Sciences version 20.0. (SPSS Inc., Chicago, USA; IBM Corp., Armonk, USA).

Mann–Whitney U-test was applied for evaluating variation in two independent samples, whereas interobserver agreement was assessed using the Cohen's Kappa coefficient, a nonparametric test for determining differences in two related samples. Discriminant functional analysis, an advanced statistical method that allows the establishment of a relationship between two or more groups based on different variables simultaneously, by deriving a discriminant equation was also obtained. Here, using gender as a classifying variable and ratio as an independent variable the discriminant equation was derived.

Results

A total of 99 individuals were studied (49 females and 50 males) with an age range of between 21 and 54 years. The measurements were made by two radiologists. To evaluate intraobserver differences and assess the reproducibility of our analysis a subset of 30 radiographs (15 females and 15 males) were randomly chosen, and the features of the sinuses were reviewed by the same observers after 2 months.

Bilateral absence of frontal sinus was seen in 6 (6%) cases (3 females and 3 males). Unilateral absence was seen with 8% of cases, that is, in 5 females and 3 males. Of the three males, one showed the absence of left and 2 showed the absence of right frontal sinus. Moreover, among all the 5 females, the right frontal sinus was found to be missing.

The Cohen's Kappa coefficient was determined. Interobserver analysis [Table 1] revealed Kappa values of >0.75 for all the variables, which shows good agreement between the observers. Intraobserver findings showed that Kappa values were between 0.6 and 0.8 for all the variables, which shows substantial agreement within the examiner 1 and examiner 2.

Application of Mann–Whitney U-test in Table 2 showed highly significant difference in the presence of right partial septa ($P < 0.001$), whereas significant difference in number of left scallops ($P = 0.04$) and the total number of partial septa ($P = 0.007$) between males and females.

Based on the discriminant function coefficients [Table 3], an equation was constructed which can be executed for sex determination when number of right scallops (RS), number of left scallops (LS), presence of right partial septa (RPS), presence of left partial septa (LPS), total number of partial septa (TPS), unilateral left supraorbital cells (LSO), and bilateral supraorbital cells (BSO) is considered. The resultant formula of the discriminant functional analysis is as follows:

$$\text{Gender} = ([0.681 \times \text{RS}] - [0.579 \times \text{LS}] + [1.342 \times \text{RPS}] + [3.344 \times \text{LPS}] - [4.857 \times \text{TPS}] + [0.418 \times \text{LSO}] + [0.415 \times \text{BSO}])$$

After executing the above equation with the data, sex determination could be made with the help of canonical centroids of 0.481-0.491, that is, if the product obtained is close to 0.481 then the proposed gender of the patient is male and if close to 0.491 then the proposed gender of the patient is female.

Table 1: Interobserver agreement

Frontal sinus variables	Kappa values
Number of right scallops	0.82
Number of left scallops	0.83
Total number of scallops	0.77
Presence of right partial septa	0.87
Presence of left partial septa	0.94
Total number of partial septa	0.85
Presence of unilateral right supraorbital cells	0.80
Presence of unilateral left supraorbital cells	0.78
Presence of bilateral supraorbital cells	0.79

Table 2: Comparison of frontal sinus variables between male and female

Variable	Sex	Median	*Z*	*P*
Number of right scallops	Male	3	0.99	0.32
	Female	2		
Number of left scallops	Male	3	2.01	0.04*
	Female	2		
Total number of scallops	Male	6	1.51	0.13
	Female	5		
Presence of right partial septa	Male	1	3.66	<0.001**
	Female	0		
Presence of left partial septa	Male	1	1.01	0.30
	Female	1		
Total number of partial septa	Male	2	2.69	0.007*
	Female	1		
Presence of unilateral right supraorbital cells	Male	0	1.01	0.31
	Female	0		
Presence of unilateral left supraorbital cells	Male	0	1.39	0.16
	Female	0		
Presence of bilateral supraorbital cells	Male	1	1.07	0.28
	Female	1		

Mann–Whitney U-test, ***P*<0.001 highly significant, **P*<0.05 significant

Table 3: Discriminant analysis of variables involved in frontal sinus

Variables	Discriminant function coefficient	Canonical centroids	
		Male	Female
Number of right scallops (RS)	0.681	−0.481	0.491
Number of left scallops (LS)	−0.579		
Presence of right partial septa (RPS)	1.342		
Presence of left partial septa (LPS)	3.344		
Total number of partial septa (TPS)	−4.857		
Presence of unilateral left supraorbital cells (LSO)	0.418		
Presence of bilateral supraorbital cells (BSO)	0.415		

RS: Right scallops, LS: Left scallops, RPS: Right partial septa, LPS: Left partial septa, TPS: Total number of partial septa, LSO: left supraorbital, BSO: Bilateral supraorbital

After applying the obtained determinant equation to the study sample sex identification using the frontal sinus [Table 4] showed an accuracy of 65.7% with a higher confidence in female diagnosis (67.3%) than male diagnosis (64.0%) [Table 5].

Discussion

Sexing of the skull is of pivotal importance in the forensic investigation. The skull is usually resistant to damage through inhumation. Therefore, the skull is used for sex determination either through the assessment of morphological or osteometric measurement with an accuracy ranging from 77 to 92%.[19] But in certain circumstances, there may be partial recoveries of the skull which may necessitate the evaluation of alternate robust structures like that of the frontal sinus.[7,20] This is especially useful in individuals who are edentulous.[21]

Table 4: Classification results

	Gender	Predicted group membership		Total
		Female	Male	
Original				
Count	Female	33	16	49
	Male	18	32	50
Percentage	Female	67.3	32.7	100.0
	Male	36.0	64.0	100.0

65.7% of original grouped cases correctly classified

Table 5: Sex identification accuracy

Females, *n* (%)	Males, *n* (%)	Total percentage correct
33.49 (67.3)	32.50 (64.0)	65.99 (65.7)

Females were correctly identified more often than males

The morphology of the frontal sinus is said to be unique in each individual even among monozygotic twins akin to individual fingerprints.[22,23] Owing to its highly variable but relatively stable structure, the morphological configuration of the frontal sinus helps in positive identification in cases of unknown human remains, especially when they are highly immolated or decomposed.[23-25] Moreover, the frontal sinus is not affected by the time elapsed till autopsy.[4,10,22,23]

Forensic anthropological examination relies heavily on radiographs, particularly when skeletal remnants are not properly documented. The dimensions, shape, and situation of the frontal sinus give its morphology a diversity that can be detected in all radiographs of frontal sinuses. Scheier in 1896 was the first to report the use of radiographs to determine and delineate the anatomical configuration of paranasal sinuses.[26]

The Caldwell projection especially is considered as the best for examining frontal sinuses and is a standard in modern sinus surveys.[27] Although CT scan technology affords greater precision, currently antemortem records of CT scans are not yet routine. Furthermore, two-dimensional radiographs are more easily reproduced, often performed, easily available, and in continuous use in many geographic regions.[7,21]

Several investigators have recognized that the various parameters of the frontal sinus provide for classifications and methods for comparing. As a result of this, many classifications systems of frontal sinuses have been developed along with methods to describe their anthropomorphology to aid in the study of frontal sinuses.[4,18] Nevertheless, these classification systems have not been standardized, and there is a suspected lack of reproducibility.[4] If standardized, the parameters and the classifications can be used as a database for comparison of frontal sinus morphology patterns between different clinics. Most of the studies done to establish the dimorphism of frontal sinus have utilized the morphometric method. The studies/papers assessing the morphological patterns of frontal sinus for gender determination are very

Figure 1: Caldwell view showing radiographic features of frontal sinus: Scalloping of the superior border, septa, and supraorbital cells

few.[3,7,13,18] In our study, the morphology of the frontal sinus was assessed using parameters suggested by Yoshino *et al*., Tang *et al*., and Goyal *et al*.[3,7,18]

Number of scallops on the sinuses' superior border (right, left, and total), unilateral/bilateral presence or absence of partial septa, number of partial septa (right, left, and total), and unilateral/bilateral presence or absence of supraorbital cells were assessed in our study.

Among the features of frontal sinuses, bilateral absence of frontal sinus was seen in 6 (3 females and 3 males) cases, whereas the unilateral absence was seen with 8% of cases, that is, in 5 females and 3 males. Of the three males, one showed the absence of the left and 2 showed the absence of right frontal sinus. Moreover, among all the 5 females, the right frontal sinus was found to be missing. Complete aplasia of frontal sinus is uncommon, but the occurrence of unilateral hypoplasia in plain radiographic studies is 7.2% which is similar to that of our study.[28]

Yoshino *et al*. was among the first to propose a classification system for frontal sinuses but found no significant sexual dimorphism for the numbers of scallops on the superior border, numbers of partial septa and number of supraorbital cells.[13] On the contrary, our study showed highly significant difference in the presence of right partial septa ($P < 0.001$), significant difference in number of left scallops ($P = 0.04$), and total number of partial septa ($P = 0.007$) between males and females. This difference could be due to ethnicity of the populations being studied. Furthermore, in the study by Yoshino *et al*., post-mortem radiographs were analyzed, and the morphological features were given codes to form a seven-digit code number. As stated by Krus from the arrangement of numbers, frontal sinus patterns were divided into more than 20,000 probable combinations of class numbers. Although the chance of two people having identical codes in a small random sample is higher than 1:20,000, the possibility of two people having identical codes in a large sample cannot be denied.[13,23]

Tatlisumak *et al*. and Tang *et al*. assessed the patterns of frontal sinus for personal identification through similar variables as in our study using CT and plain radiographs, respectively. In the study by Tatlisumak *et al*. the presence or absence of supraorbital cells was not considered as a variable. Using their system, they could eliminate 93% of formulas for a case, which increased to 98% on addition of measurements. Meanwhile, Tang *et al*. found statistical sex differences for three out of eight variables ($P < 0.05$). Both the studies do not comment on the differences in the variables among males and females.[29,18]

Later Uthman *et al*. studied three features of the frontal sinus including the presence or absence of frontal sinus, septum, and scalloping along with two groups of measurements of the frontal sinus and three skull dimensions obtained from CT images. After discriminative analysis, they found the overall accuracy of the frontal sinus in identifying gender was 76.9%, and further increased to 85.9% on adding the skull measurements to the frontal sinus measurements, whereas in our study, the discriminant function's accuracy in sex identification using morphological patterns of the frontal sinus was 65.7%. This difference could be in part due to the consideration of solely the morphological features in our study rather than morphometric assessment as in the study done by Uthman *et al*.[3]

Recently, Goyal *et al*. examined the number of scallops on the sinuses' superior border (right, left, and total), the number of partial septa (right, left, and total), unilateral/bilateral presence or absence of partial septa, and unilateral/bilateral presence or absence of supraorbital cells on 100 paranasal sinus radiographs. The accuracy for gender allocation using multivariate logistic regression equations yielded a 60% rate. They suggested the exclusion of supraorbital cells for differentiating gender as its exclusion marginally increased the sex prediction accuracy to 61%. They also concluded that the frontal sinuses may be of little value as the sole indicator of gender. Our study showed agreement with most of the previous studies regarding a low sexual dimorphism for the frontal sinus. As observed earlier, the unique morphology of the frontal sinus can be positively utilized for human identification but less so for gender determination. The probable reasons for reduced sexual dimorphism as suggested in earlier studies include a high inter-individual variability, studies with small sample sizes, and involvement of specific populations.[7,13,23,24]

According to Christensen Angi and Cox *et al*. many of the studies using classifications or coding of frontal sinus features permit a quick, objective, and accurate assessment, but do not disclose what part of the population exhibits a particular configuration as there may be variations, wherein not all traits exist concurrently. Despite the application of advanced analytic techniques, these studies have shown moderate accuracy for gender determination.[3,4,7,24]

Conclusion

In the present study, frontal sinuses were assessed based on the morphological parameters. The sexual discriminative power of these parameters was low at 65.7% accuracy rate. The reduced accuracy of the sexual dimorphism of frontal sinus could be due to smaller sample size and the consideration of only morphological rather than morphometric methods. Therefore, forensic application of morphology of frontal sinus can be recommended as an adjunctive tool rather than sole indicator for gender determination.

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Conflicts of interest

There are no conflicts of interest.

References

1. Abdel Moneim WM, Abdel Hady RH, Abdel Maaboud RM, Fathy HM, Hamed AM. Identification of sex depending on radiological examination of foot and patella. Am J Forensic Med Pathol 2008;29:136-40.
2. Amin MF, Hassan EI. Sex identification in Egyptian population using multidetector computed tomography of the maxillary sinus. J Forensic Leg Med 2012;19:65-9.
3. Uthman AT, Al-Rawi NH, Al-Naaimi AS, Tawfeeq AS, Suhail EH. Evaluation of frontal sinus and skull measurements using spiral CT scanning: An aid in unknown person identification. Forensic Sci Int 2010;197:124.e1-7.
4. Christensen, Angi M, An Empirical Examination of Frontal Sinus Outline Variability Using Elliptic Fourier Analysis: Implications for Identification, Standardization, and Legal Admissibility. PhD diss. University of Tennessee, 2003. Available from: http://trace.tennessee.edu/utk_graddiss/1981. [Last accessed on 2016 Jan 28].
5. Prossinger H, Bookstein FL. Statistical estimators of frontal sinus cross section ontogeny from very noisy data. J Morphol 2003;257:1-8.
6. Schuller A. Das roentgenogramm der stirnhöle: Ein hilfsmittel für die identi tätsbestimmung von schadlen. Monatsschrift Für Ohrenheilkunde Und Laryngo-Rhinologie Monatsschrift für ohrenheilkunde und laryngo-rhinologie. German 1921;55: 1617-20.
7. Goyal M, Acharya AB, Sattur AP, Naikmasur VG. Are frontal sinuses useful indicators of sex? J Forensic Leg Med 2013;20:91-4.
8. Buckland-Wright JC. A Radiograhic examination of frontal sinuses in early British populations. Man 1970;5:512-7.
9. Dolan KD. Paranasal sinus radiology, part 1B: The frontal sinuses. Head Neck Surg 1982;4:385-400.
10. Schuller A. A note on the identification of skulls by X-ray pictures of the frontal sinuses. Med J Aust 1943;1:554-7.
11. Hajek M. Normal anatomy of the frontal sinuses. In: Hajek M, Heitger JD, editors. Pathology and Treatment of the Inflammatory Diseases of the Nasal Accessory Sinuses. 5th ed. St. Louis: The C.V. Mosby Company; 1926. p. 35-43.
12. Harris AM, Wood RE, Nortjé CJ, Thomas CJ. The frontal sinus: Forensic fingerprint? A pilot study. J Forensic Odontostomatol 1987;5:9-15.
13. Yoshino M, Miyasaka S, Sato H, Seta S. Classification system of frontal sinus patterns by radiography. Its application to identification of unknown skeletal remains. Forensic Sci Int 1987;34:289-99.
14. Krogman WM, Iscan MY. The Human Skeleton in Forensic Medicine. 2nd ed. Springfield: C.C. Thomas; 1986.
15. Harris AM, Wood RE, Nortjé CJ, Thomas CJ. Gender and ethnic differences of the radiographic image of the frontal region. J Forensic Odontostomatol 1987;5:51-7.
16. da Silva RF, Prado FB, Caputo IG, Devito KL, Botelho Tde L, Daruge Júnior E, *et al.* The forensic importance of frontal sinus radiographs. J Forensic Leg Med 2009;16:18-23.
17. Camargo JR, Daruge E, Prado FB, Caria PH, Alves MC, Silva RF, *et al.* The frontal sinus morphology in radiographs of Brazilian subjects: Its forensic importance. Braz J Morphol Sci 2007;24:239-43.
18. Tang JP, Hu DY, Jiang FH, Yu XJ. Assessing forensic applications of the frontal sinus in a Chinese han population. Forensic Sci Int 2009;183:104.e1-3.
19. Devang Divakar D, John J, Al Kheraif AA, Mavinapalla S, Ramakrishnaiah R, Vellappally S, *et al.* Sex determination using discriminant function analysis in indigenous (Kurubas) children and adolescents of Coorg, Karnataka, India: A lateral cephalometric study. Saudi J Biol Sci 2016;23:782-8.
20. Dawson C, Ross D, Mallett X. Sex determination. In: Black S, Ferguson E. Forensic anthropology 2000-2010. CRC press Taylor & Francis group, LLC; 2011:61-94.
21. Quatrehomme G, Fronty P, Sapanet M, Grévin G, Bailet P, Ollier A, *et al.* Identification by frontal sinus pattern in forensic anthropology. Forensic Sci Int 1996;83:147-53.
22. Jablonski NG, Shum BS. Identification of unknown human remains by comparison of antemortem and postmortem radiographs. Forensic Sci Int 1989;42:221-30.
23. Krus BS. 3D CBCT Analysis of the Frontal Sinus and its Relationship to Forensic Identification. Doctoral Dissertation, Faculty of the University Graduate School in Partial Fulfillment of Requirements for the Degree Master of Arts in the Department of Anthropology, Indiana University.
24. Cox M, Malcolm M, Fairgrieve SI. A new digital method for the objective comparison of frontal sinuses for identification. J Forensic Sci 2009;54:761-72.
25. Steadman DW, Adams BJ, Konigsberg LW. Statistical basis for positive identification in Forensic anthropology. Am J Phys Anthropol 2006;131:15-26.
26. Maresh MM. Paranasal sinuses from birth to late adolescence. Am J Dis Child 1940;60:55-78.
27. Dolan KD. Paranasal sinus radiology part 1A: Introduction and the frontal sinuses. Head Neck Surg 1982;4:301-11.
28. Bassiouny A, Newlands WJ, Ali H, Zaki Y. Maxillary sinus hypoplasia and superior orbital fissure asymmetry. Laryngoscope 1982;92:441-8.
29. Tatlisumak E, Yilmaz Ovali G, Aslan A, Asirdizer M, Zeyfeoglu Y, Tarhan S, *et al.* Identification of unknown bodies by using CT images of frontal sinus. Forensic Sci Int 2007;166:42-8.