Morphometric evaluation of the frontal sinus in relation to age and gender in subjects residing in Davangere, Karnataka

Introduction

Radiological identification still has a very important place in forensic medicine, particularly in the absence of comparative DNA samples and fingerprints. It involves the comparison of ante-mortem radiographs, usually performed for clinical reasons, with post-mortem radiographs taken solely for the identification of specific, individualizing structures. Morphological features depicted on the radiographs must meet the following two requirements in order to be of forensic identification value: First, the feature has to be unique to the individual; second, it has to remain stable over time despite the ongoing life processes. Both these criteria are fulfilled by the frontal sinuses. Turner and Porter were the first to study the anatomy of the frontal sinuses using radiographic methods.\(^1\)

The present study was carried out to analyze the morphometric evaluation of frontal sinus in relation to age and gender by taking posteroanterior (PA) cephalogram radiographs views of the subjects residing in Davangere, Karnataka, India visiting as outpatients in the department of oral medicine and radiology with the aim and objective to study morphometric evaluation of the frontal sinus in relation to age and sex. The aim of the study was to establish a frontal sinus pattern of a given individual and to correlate

Abstract

Objective: The main objective of the study was morphometric evaluation of the frontal sinus in relation to age and gender and to establish its forensic importance and application.

Materials and Methods: The study group consisted of 200 subjects (100 males and 100 females) in the age groups 14-20 years, 21-30 years, 31-45 years, 45 years and above. Posteroanterior (PA) cephalogram radiographs were taken using standardized technique. The processed films were traced and frontal sinus pattern was established as per Yoshino’s classification system. Results: The mean values for length, width, and area of the frontal sinus were found to be higher in males as compared to females and area of frontal sinuses increase with age except in males who were 45 years and above. The left width, left area, and bilateral asymmetry in relation to gender was found to be statistically significant. Conclusion: The morphologic evaluation of frontal sinus is a useful technique to determine gender and seems promising in personal identification.

Key words: Frontal sinus, personal identification, Yoshino’s classification
Materials and Methods

The study group consisted of 200 subjects, comprising 100 males and 100 females in the age range of 14 years and above who were randomly chosen. They were further divided into four age groups, i.e., 14–20 years, 21–30 years, 31–45 years, and 45 years onward, with an equal number of both males and females. They were included in the study after recording demographic data, brief history of the present illness, and past medical/surgical history. Apparently healthy individuals with no visible features of asymmetrical skull were included while those with hereditary facial asymmetries, history of orthodontics treatment or orthognathic surgery, history of maxillofacial trauma, and history or clinical characteristics of any type of systemic disorders like bone diseases, nutritional, and endocrinal diseases were excluded. PA cephalogram radiograph was taken with exposure parameters between 70 kVp to 75 kVp and, time being 1.60 s at 8 mA in a standardized manner depending upon the age, sex, and built of the patient. All the films were manually processed in a well-equipped, lightproof, dark room by the time-temperature method as described by Goaz, and White (1994). Only good quality radiographs were interpreted and traced using an acetate tracing paper and 0.35 mm tracing lead pencil. The following measurements were taken after reducing the magnification factor, as suggested by Camargo, Daruge, Prado, Caria, Alves, and Silva et al. [1] (Figure 1):

- Height and width of the right frontal sinus
- Height and width of the left frontal sinus
- The left, and right areas were obtained only for the portion of the frontal sinus projected above the baseline, i.e., the superior border of the orbit.

The measurements obtained from each radiograph were expressed in (centimeter).

Yoshino’s frontal sinus pattern of a given individual was established using the following parameters:

- Frontal sinus size
- Bilateral asymmetry
- Superiority of the side
- Outline of upper border (left Ou₁, right Ou₂)
- Partial septa (Ps)
- Supraorbital cells (Scs).

Each of these parameters was assigned a code number on the characteristics and the frontal sinus pattern of the individual was established. [4]

These results were expressed as mean and standard deviations (SDs) for the continuous data and as number and percentage for the categorical data. Unpaired t-test was used for the comparison between males and females. One way analysis of variance (ANOVA) was used for the comparisons between multiple groups [age-wise]. The categorical data were analyzed by Chi-square test [test of association] wherever the data were in terms of classes, analysis was done by a non-parametric test, namely the Mann-Whitney U test. For all the tests, a P value of 0.05 or less was considered for statistical significance.

Results

Out of the 200 patients, 24 were not included in the study due to bilateral aplasia and rudimentary frontal sinuses. Aplasia of the frontal sinus (6.5%) was observed in 9 cases in females (9%) and 4 cases in males (4%). Unilateral aplasia was observed only in relation to the right frontal sinus in 6 cases (3%). The average right length was observed to be 1.12 cm in males and 1.19 cm in females, and the left length was 1.50 cm in males and 1.32 cm in females. The right length and left length were found to be increasing with age in males and females, except in males in the age group of 45 years and above where it was found to decrease. Difference between the right length and left length was not statistically significant. (value 0.58, P value 0.15). The average right width in males was found to be 2.36 cm and 2.24 cm females; the width increases with age in females and males and was seen to decrease in males in the age group of 45 years and above. The average left width in males was 2.92 cm and 2.61 cm in females. The left width increases with age in females and males except in males in the age group of 45 years and above. Difference in the left width in males and females was found to be statistically significant (P value 0.03) [Table 1]. The average frontal sinus area was found to be larger in males (8.63 cm²) than females (7.09 cm²). The frontal sinus area increases with age in males and was found to decrease in the age group of 45 years and above; whereas it increases in females with age. The left frontal sinus area was found to be larger in males (5.00 cm²) than females (3.89 cm²) and the difference was statistically significant (P value 0.05) [Table 2]. The bilateral asymmetry was found to be significant (P value 0.11) in males and females. Difference in relation to the superiority of side, left outline, right outline, Ps, and Scs was not found to be statistically significant age-wise and gender-wise. Scs and
Ps were found to be absent more in males than females. 14 cases shared the same frontal sinus code numbers out of the 200 cases.

**Discussion**

The results show that frontal sinus pneumatization increases with age and has a great individual variability (Rubiera et al.). This variability has also been described in the literature and is considered to be a useful tool in forensic identification as a “forensic fingerprint” (Harris et al. 1987, Nambiar et al., 1999). In this study, the average frontal sinus area in males was 8.63 cm$^2$ and in females it was 7.09 cm$^2$. The area of the frontal sinus was not found to be significant in relation to gender in our study, which was to the findings reported by Rubiera et al. The frontal sinuses of males was found to be larger than that of females; however, the statistical difference of means between them was not significant, a finding noted in various studies. (Buckland et al., Szilvassy, Yoshino, Schuller, Krogman, Menovsky et al., 1999, Prabhakaran et al., 1999, Ponde et al., Harris et al., Camargo et al., Lynnerup et al., and Ertgrul et al.)

It was found that the length and width of the frontal sinus area, increase with age (Fatu et al.) found to decrease in males in the age group of 45 years and above in accordance with the study conducted by Mc-Laughlin et al., and Ertgrul et al., who suggested that the frontal sinus continued to expand until the age of 40 years because of hormonal and mechanical stresses of mastication. However, the decrease of the frontal sinus in males in the age group of 45 year and above asobserved in our study was not reported by Saude, Fatu et al., and Ertgrul et al., who reported osseous resorption as the cause for the increase in size. The average right length and left length found were 1.12, 1.50 cm and 1.19, 1.32 cm in males and females, respectively. The average right width and left width found were 2.36, 2.92 cm and 2.24, 2.61 cm in males and females, respectively, which was different from the findings in other studies. This difference could have been due to morphological differences seen in various ethnic groups and various other radiographic techniques used for the morphological evaluation of the frontal sinuses. The measurements of length, and width were found to be higher in males than females according to the literature [Blaney, Hansen and Owsley (1980), Libersa and Faber, Ponde et al. (2003), Szilvassy, Brown et al. Ertgrul et al., and Jhonson et al.]

The length of the frontal sinus was found to be significant between genders by Farias et al., which was not found in our study but this could have been they considered a small age group of 8–16 years when the sinus was still developing. Ertgrul et al., found significant difference in the anteroposterior length and height among males and females, which was not observed in our study; this could have been due to the use of computed tomography (CT) scan in the study carried out by Ertgrul et al.

The tendency of the left side to be larger than the right was seen in agreement with the results from other studies [Gulisano, Pacini and Orlandini (1978), Ertgrul et al., and Rubiera et al.] This discrepancy in the sides can be attributed to their independent development [Nambiar, Naidu and Subramanium (1999)].

In our study, it was found that the left width and the left area are most suitable for gender determination in accordance with the study conducted by Camargo et al., and Uthman et al.

The morphological differences in the cranium between the two genders are determined mainly by the genetic factors, more so than nutritional, hormonal, or muscular factors. [Quatrehomme, Fronty, Sapan et al. (1996), Patil and Mody (2005)]. Such aspects can explain why the frontal sinus of men is on an average larger than that of women.

Bilateral aplasia was seen in 6.5% of cases in total; it was more frequent in females (9%) than males (4%), and was more in the age group of 14–20 years that was in accordance with the results of studies conducted by Fatu et al., Krogman et al., Gulisano et al., Aydilloglu et al., and Spaeth et al. The frequency of bilateral absence of the sinus in the data was reported to be between 5% and 20%, except in the Eskimo population, as per the findings in our study. Unilateral aplasia was noted in 3% of the cases only in the right frontal sinus, suggesting larger growth of the left sinus compared to the right one that is similar to the finding reported by

---

**Table 1: Gender-wise comparison of the frontal sinus in all age groups together**

| Variable  | Gender | Mean  | SD   | t    | P   |
|-----------|--------|-------|------|------|-----|
| Right width | M      | 2.36  | 1.29 | 0.66 | 0.51|
|           | F      | 2.24  | 1.04 |      |     |
| Left width | M      | 2.92  | 1.04 | 2.19 | 0.03|
|           | F      | 2.61  | 0.82 |      |     |
| Right length | M     | 1.12  | 0.93 | 0.56 | 0.58|
|           | F      | 1.19  | 0.77 |      |     |
| Left length | M     | 1.50  | 0.89 | 1.45 | 0.15|
|           | F      | 1.32  | 0.75 |      |     |
| Right area  | M      | 3.63  | 4.20 | 0.84 | 0.41|
|           | F      | 3.20  | 2.54 |      |     |
| Left area   | M      | 5.00  | 4.32 | 2.01 | 0.05|
|           | F      | 3.89  | 2.90 |      |     |

**Table 2: Frontal sinus area in relation to age and gender**

| Age group (years) | Males (R+L) | Females (R+L) |
|-------------------|-------------|---------------|
| 14-20             | 7.27 cm$^2$ | 5.03 cm$^2$   |
| 21-30             | 8.49 cm$^2$ | 7.55 cm$^2$   |
| 31-45             | 11.80 cm$^2$| 7.62 cm$^2$   |
| 45 and above      | 6.84 cm$^2$ | 8.03 cm$^2$   |
Porbonikova et al. (1974), Adinligou et al., and Cakur et al. [8] It has been reported that the presence of metopic suture is associated with aplasia of the sinus. [10] Sanchez et al. [19] reported aplasia of 3.9%. Unilateral absence and bilateral absence of the frontal sinus reported by Fatu et al., were 1.6% and 1.5%, respectively, which was different from that of our study. [9] Similarly, Danesh et al. reported 8.32% bilateral absence and 5.66% unilateral absence, which was different from our study; this difference can be attributed to geographic and racial features and the different methodologies used for each study. [13]

The frequency of bilateral and unilateral agenesis of the frontal sinus is known to differ in most ethnic populations, with the highest being in the Eskimo population where it is considered to be an adaptation to the cold climatic conditions. [20] This low percentage of the frontal agenesis must be taken into consideration during presurgical planning related to the sinus.

The frontal sinuses of both sides are asymmetrical in configuration as a rule because of unequal reabsorption of the diploe during the development of the sinuses. In our study, all the samples examined were bilaterally asymmetrical as reported by Yoshino et al. [4] and Szilvassy et al. [7] The degree of bilateral asymmetry was classified into five categories based on the asymmetry index. It was seen that males had more bilateral asymmetry than females and the difference was statistically significant, as reported by Szilvassy et al. [7] Szilvassy also suggested that bilateral asymmetry differs from one race to another.

It is well known that the frontal sinus varies in configurations. The upper border, superiority of the side, Ps, and Scs were taken as the available parameters in our study for expressing the morphological characteristic of the frontal sinuses. The upper borders of the frontal sinuses were classified into six categories based on their outlines. Schuller mentioned that the arcades of the scalloped upper border of the frontal sinuses were smaller and more numerous in females skulls than in male skulls. In our study, however, morphological characteristics of the upper border of the sinuses showed no significant difference between both genders; this trend was also observed by Yoshino et al. [4] The presence or absence of Ps and of the Scs were classified into 4 categories. In our study, no statistical significance was noted gender-wise and age-wise, reported by Yoshino et al. [4] In all the classification items, no sex differences were noted. Thus, the system of classification of the frontal sinus patterns might be applicable to the samples of both sexes.

The frontal sinus patterns can be divided into approximately 20,000 possible combinations by combining the class numbers in each classification item of Yoshino’s classification system and accordingly, the chances of two people having similar patterns of the frontal sinus are so remote that this method of identification can be safely relied upon. [14] Various studies have reported the successful use of the frontal sinuses in personal identification (Yoshino et al., Cameriere et al., Kullman et al., Marlin, Quaterhomme et al., Nambiar et al., Tang et al., Silva, David and Runjhun, and Victoria et al.) with 100% accuracy. Kirk et al., also reported that the duration between ante- and post-mortem radiographic examinations, age, gender, and cause of death did not affect the ability to obtain a match. [22]

In our study, Yoshino’s code number was used to identify the frontal sinuses in 176 individuals. However, those in the age group of 14–20 years were excluded as complete frontal sinus growth is completed by 20 years. It was noted that 14 cases (seven males and seven females) shared the same code numbers out of the 150 cases. Thus, the frontal sinus can be used in the personal identification of individuals by comparing the pre- and post-mortem radiographs. Like fingerprints, sinus patterns are unique for a person. Identification by comparison of radiographs of the pre- and post-mortem frontal sinuses is scientifically valid because the frontal sinus configurations of no two persons are alike. However, unlike fingerprints they are affected by pathology such as acute or chronic inflammations, some endocrine dysplasias, osteitis, and trauma. We had ruled out this possibilities in case history taking for subjects included in the study.

Farias et al., and Rossouw et al., reported that the frontal sinus is a reliable structure when related to maturation and prediction of mandibular growth but not a substitution for hand wrist radiographs by lateral cephalometric study that was not evaluated in our study.

There are, however, limitations in the use of the frontal sinus in personal identification and also, its size varies with the role of genetic and environmental factors. They may be affected by the pathology, craniofacial configuration, and thickness of the frontal bone and, even hormonal levels are known to influence the frontal sinus. [18]

However, there is no doubt that interpopulation variation seriously affects the frontal sinus morphological features. The results reported in this study indicate that it is possible to achieve accuracy and precision using a discrete number of morphological features of the frontal sinus to determine the sex and for the personal identification of unknown skeletal remains. It has been suggested that the frontal sinus has the potential to be used for personal identification, age estimation, and sexual dimorphism. [19]

The application of this technique on different populations is tested and reliable, though it has its own limitations. Good and accurate radiographs, correct identification of the landmarks, minimizing the intraobserver variation(s), and
large sample sizes might give better results. The method of frontal sinus morphologic evaluation used was simple and not time-consuming and it can be easily employed by a general dentist and was covered in one radiograph, which is most commonly taken in clinical examinations.

Furthermore, from a review of the literature it was seen that very few studies on the Indian population have been conducted in relation to morphological evaluation of the frontal sinus and the forensic applications of all morphological parameters; thus, the study marked a good attempt at gender and personal identification based on the frontal sinuses, along with their morphometric evaluation.

However, to establish the same we suggest further studies with implementation of newer parameters for the determination of gender, age, personal identification, and the consideration of various ethnic groups and the undertaking of a larger samples size that will enable making a meaningful interpretation at the community level.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

References

1. Harris AM, Wood RE, Nortje CJ, Thomas CJ. The frontal sinus: Forensic fingerprint? - A pilot study. J Forensic Odontostomatol 1987;5:9-15.
2. White SC, Pharaoh MJ. Oral Radiology Principles and Interpretation. 4th ed. Philadelphia: The C.V. Mosby Company; 2000. p. 205-16.
3. 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.
4. 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.
5. Rubira-Bullen IR, Rubira CM, Sarmento VA, Azevedo RA. Frontal sinus size on facial plain radiographs. J Morphol Sci 2010;27:77-81.
6. Buckland-Wright JC. A radiographic examination of frontal sinuses in early British populations. Man 1970;5:512-7.
7. Szilvássy J. Development of the frontal sinuses. Anthropol Anz 1981;39:138-49.
8. Quatrehomme G, Fronty P, Sapanet M, Grévin G, Baille P, Ollier A. Identification by frontal sinus pattern in forensic anthropology. Forensic Sci Int 1996;83:147-53.
9. Pondé JM, Metzger P, Amaral G, Machado M, Prandini M. Anatomic variations of the frontal sinus. Minim Invasive Neurosurg 2003;46:29-32.
10. Lynnerup N, Homæ P, Skogaard LT. The frontal sinus in ancient and modern Greenlandic Inuit. Int J Anthropol 1999;14:47-54.
11. Tatlisumak E, Ovali GY, Asirdizer M, Aslan A, Ozyurt B, Bayindir P, et al. CT study on morphometry of frontal sinus. Clin Anat 2008;21:287-93.
12. Fatu C, Puisoru M, Rotaru M, Truta AM. Morphometric evaluation of the frontal sinus in relation to age. Ann Anat 2006;188:275-80.
13. McLaughlin RB Jr, Rehl RM, Lanza DC. Clinically relevant frontal sinus anatomy and physiology. Otolaryngol Clin North Am 2001;34:1-22.
14. Karakas S, Kavakli A. Morphometric examination of the paranasal sinuses and mastoid air cells using computed tomography. Ann Saudi Med 2005;25:41-5.
15. Danesh-Sani SA, Bavandi R, Esmaili M. Frontal sinus agenesis using computed tomography. J Craniof Surg 2011;22:e48-51.
16. Tatlisumak E, Yilmaz Ovali G, Aslan A, Asirdizer M, Zeytcoğlu Y, Tarhan S. Identification of unknown bodies by using CT images of frontal sinus. Forensic Sci Int 2007;166:42-8.
17. Namibiar P, Naidu MD, Subramaniam K. Anatomical variability of the frontal sinuses and their application in forensic identification. Clin Anat 1999;12:16-9.
18. 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.
19. Sánchez Fernández JM, Anta Esucchini JA, Santaullalla Montoya F. Morphometric study of the paranasal sinuses in normal and pathological conditions. Acta Otolaryngol 2000;120:273-8.
20. Koertvelyesy T. Relationships between the frontal sinus and climatic conditions: A skeletal approach to cold adaptation. Am J Phys Anthropol 1972;37:161-72.
21. Cameriere R, Ferrante L, Molleson T, Brown B. Frontal sinus accuracy in identification as measured by false positives in kin groups. J Forensic Sci 2008;53:1280-2.
22. Kirk NJ, Wood RE, Goldstein M. Skeletal identification using the frontal sinus region: A retrospective study of 39 cases. J Forensic Sci 2002;47:318-23.
23. Christensen AM. Testing the reliability of frontal sinuses in positive identification. J Forensic Sci 2005;50:18-22.
24. Kullman L, Eklund B, Grundin R. Value of the frontal sinus in identification of unknown persons. J Forensic Odontostomatol 1990;8:3-10.
25. Marlin DC, Clark MA, Standish SM. Identification of human remains by comparison of frontal sinus radiographs: A series of four cases. J Forensic Sci 1991;36:1765-72.
26. 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.
27. da Silva RF, Prado FB, Caputo IG, Devito KL, Botelho Tde L, Daruge Júnior E. The forensic importance of frontal sinus radiographs. J Forensic Leg Med 2009;16:18-23.
28. David MP, Saxena R. Use of frontal sinus and nasal septum patterns as an aid in personal identification: A digital radiographic study. J Forensic Dent Sci 2010;2:77-80.
29. Smith VA, Christensen AM, Myers SW. The reliability of visually comparing small frontal sinuses. J Forensic Sci 2010;55:1413-5.
30. Farias PJ, Gonzalez VA, Christensen AM. The reliability of visually comparing small frontal sinuses. J Forensic Sci 2010;55:1413-5.
31. Rossouw PE, Lombard CJ, Harris AM. The frontal sinus and mandibular growth prediction. Am J Orthod Dentofacial Orthop 1991;100:542-6.