ORIGINAL ARTICLE

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

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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

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 radiograph 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

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the size of frontal sinus with age and sex of the individual as an aid in identification in forensic studies.

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 4 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).[2] 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*.[3] [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 Ou_1, right Ou_2)
- Partial septa (Ps)
- Supraorbital cells (Scs).

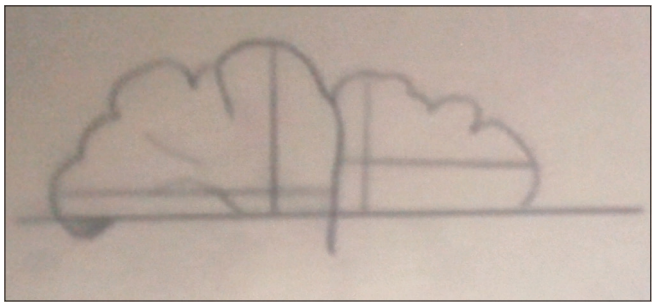

Figure 1: Traced outline of the frontal sinus

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 comparisions 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 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 cm^2) than females (7.09 cm^2). 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 cm^2) than females (3.89 cm^2) 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 agewise and genderwise. 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)*.[5] 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*.[5] 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*.[6] Szilvassy,[7] Yoshino,[8] Schuller, Krogman, Menovsky *et al.* 1999, Prabhakaran *et al.* 1999, Ponde *et al*.[9] Harris *et al*.[1] Camargo *et al*.[3] Lynnerup *et al*.,[10] and Ertgrul *et al*).[11]

It was found that the length and width of the frontal sinus area, increase with age (Fatu *et al*.)[12] 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 Ertugrul *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.[11,13] 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,[14] and Fatu *et al*.,[12] 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.* Ertugrul *et al*., and Jhonson *et al*].[9,11,15]

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

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. Ertugrul *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 Ertugrul *et al*.[16]

The tendency of the left side to be larger than the right was seen in agreement with the results from other studies [Gulisno, Pacini and Orlandini (1978), Ertugrul *et al*., and Rubiera *et al.*][5,9,11] This discrepancy in the sides can be attributed to their independent development [Nambiar, Naidu and Subramanium (1999)].[17]

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*.,[3] and Uthman *et al*.[18]

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, Sapanet *et al*. (1996), Patil and Mody (2005)].[8] 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.* Aydilioglu *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

Porbonikova *et al*.(1974), Adinligou *et al*., and Cakur *et al*.[9] It has been reported that the presence of metopic suture is associated with aplasia of the sinus.[18] 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.[15]

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 sinus 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-four 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 the 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.[4] Various studies have reported the successful use of the frontal sinuses in personal identification (Yoshino *et al*.[4] Cameriere *et al*.[21] Kirk *et al*.[22] Christensen *et al*.[23] Kullman *et al*.[24] Marlin[25] Quaterhomme *et al*.[8] Nambiar *et al*.[17] Tang *et al*.[26] Silva[27] David and Runjhun[28] and Victoria *et al*.)[29] 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 the150 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*.,[30] and Rossouw *et al*.,[31] 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.[18]

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.

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Conflicts of interest
There are no conflicts of interest.

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