Original Research
Journal of Forensic Dental Sciences, *Vol 13(1), DOI: 10.18311/jfds/13/1/2021.622, January - April 2021, p. 10-17*
ISSN (Print) : 0975-1475
ISSN (Online) : 0975-2137

Evaluation of Frontal Sinus as an Aid in Personal Identification - A Digital Radiographic Study

A. Akanksha[1*] and Maria Priscilla David[2]

[1]Department of Oral Medicine and Radiology, Rajiv Gandhi University of Health Sciences, Bangalore, Karnataka, India; aksakku20@gmail.com
[2]Professor and Head, Department of Oral Medicine and Radiology, MR Ambedkar Dental College and Hospitals, Rajiv Gandhi University of Health Sciences, Bangalore – 560005, Karnataka, India; priscydavid@yahoo.co.in

Abstract

Background and Objectives: The cranio-facial structures have the advantage of being composed largely of hard tissue which is relatively indestructible. The frontal sinus is as unique to each individual as a fingerprint, even to monozygotic twins. The present study was conducted to evaluate frontal sinus as an aid in personal identification. **Methods:** The study was conducted among 200 subjects (100 males and 100 females). Posteroanterior radiographs were taken using KODAK 8000 C Digital Panoramic and Cephalometric system and digital measurements made using Trophy Dicom and Masterview 3.0 Software. Frontal sinuses were classified and analyzed. Total height and total width of frontal sinus was measured according to Tatlisumak and Uthman A T. Inter orbital width was measured according to Ribeiro. Total orbital width was measured as an additional parameter. **Results:** Of the total 200 (100%) subjects we observed uniqueness of frontal sinuses in all the 167 subjects with presence of frontal sinus with central septa presence with none being identical and found 16 subjects with central septa absence, where the mean total height and total width of frontal sinus was measured and 17 subjects with bilateral absence of frontal sinus, where mean inter-orbital width was measured. Total orbital width was considered for the combined 33 subjects. **Conclusion:** We conclude that frontal sinuses can be used as a potent aid in personal identification. The combined use of frontal sinus and orbital measurements can be a valuable, cost-effective adjunct to positive human identification.

Keywords: Forensic, Frontal Sinus, Orbit, Personal Identification, Uniqueness

Introduction

Human beings have come a long way from the early caveman age to the present day of covering nothing less than astronomical heights to seabed depths. His zeal to conquer new heights has created a world full of scientific advancement and technology. However, his intelligence has also led to a surge in crime rate, terrorism, wars, mass disasters, road traffic accidents and dreadful diseases. In all such incidents the identity of the deceased, assailant or the cause of death becomes important, as the core of various investigations are based on these processes[1]. The cranio-facial structures have the advantage of being composed largely of hard tissue which is relatively indestructible[2]. Radiographic examination of skeletal structures is a potentially useful procedure for identification either in human remains or in living persons. Frontal sinuses are paired lobulated cavities located posterior to the superciliary arches in the frontal bone and each frontal sinus opens into the corresponding middle meatus via the infundibulum. They are not apparent at birth. They begin to develop during the second year of life and are radiographically visible at 5 years of age. They reach their maximum size at the age of 20. The anatomy of the frontal sinus remains stable throughout the course of life until old age when gradual pneumatisation can occur from atrophic changes[3]. Frontal sinus has great variability and its structure does not change after the age of 20 years

*Author for correspondence

except very rare occurrences such as fractures, tumors or severe infections. It is well-known that the configuration of the frontal sinus is unique for each individual and even monozygotic twins differ in frontal sinus characteristics[4]. The uniqueness of the frontal sinus for each individual gives the opportunity of its use for personal identification in forensic medicine. With this background, this study was undertaken to examine, measure, classify and analyze variations of frontal sinus along with orbital width as observed on PA skull view and to assess their combined use as an aid in personal identification.

Materials and Methods

This cross-sectional study was conducted at the Department of Oral Medicine and Radiology, M. R. Ambedkar Dental College and Hospital, Bangalore. The study consisted of 200 subjects inclusive of 100 males and 100 females between the age group of 25 to 45 years. Subjects were selected randomly after obtaining an informed consent.

To ensure the selection of normal healthy individuals, a detailed case history was taken. Individuals with systemic diseases, syndromes, fractures of the skull and mid-facial region and age group below 25 years were excluded from the study. Posteroanterior skull views were taken using Kodak 8000C Digital Panoramic and Cephalometric System (82 Kv, 12 mA, 1.60 seconds) using radiation protection protocols as per the guidelines provided by the manufacturer of the X-ray unit. The resultant digital images were observed, analyzed, measured and classified as per Yoshino classification[5], Tang *et al* modifications[6], Tatlisumak[7], Uthman *et al*'s[8] consideration and Ribeiro's[9] standardization for frontal sinus measurements along with Cameriere's[10] modifications for orbital measurements. The dimensions of frontal sinus and orbit were measured on the radiographs using specially designed Windows Trophy Dicom software and analyzed. The following parameters were considered.

- Central Septa.
- The bilateral asymmetry index of height of frontal sinus.
- The bilateral asymmetry index of width of frontal sinus.
- The height superiority of left and right frontal sinus.
- The width superiority of left and right frontal sinus.
- The outline of upper borders of left frontal sinus.
- The outline of upper borders of right frontal sinus.
- The ratio of left frontal sinus width to left orbital width.
- The ratio of right frontal sinus width to right orbital width.
- Total height and total width of frontal sinuses.
- Inter-orbital width.
- Total orbital width.

Each classification of the parameter was given a class number according to its variation and frontal sinus patterns were described by the combined code numbers. Total height and total width of frontal sinus was measured according to Tatlisumak *et al.* According to Ribeiro inter-orbital width was measured. Total orbital width was measured as an additional parameter.

Results

- Of 200 (100%) subjects, bilateral absence of frontal sinus was observed in 17 (8.50%) subjects, bilateral presence of frontal sinus was observed in 153 (76.50%) subjects and unilateral presence of frontal sinus was observed in 30 (15.00%) subjects. Bilateral absence of frontal sinus was observed more in females [12 (12%) subjects] than males [5 (5%) subjects].
- Of 200 (100%) subjects, bilateral presence of frontal sinus was observed in 153 (76.50%) subjects. Among them, bilateral presence of frontal sinus was observed slightly more in males 80 (80%) than females 73 (73%).
- Of 200 (100%) subjects, unilateral presence of frontal sinus was observed in 30 (15.00%) subjects. Of 30 (100%) subjects with unilateral presence of frontal sinus, more subjects [21(70%)] had unilateral presence of frontal sinus on left side than 9 (30%) subjects who had unilateral presence of frontal sinus on right side.
- Of 153 (100%) subjects with bilateral presence of frontal sinus, central septa was present in 137 (89.55%) subjects, while 16 (10.46%) subjects showed absence of central septa.
- Of the total 200 subjects, we also found 16 subjects with central septa absence, where the mean total height and total width of frontal sinus was 24.46mm and 58.89mm respectively. Of the total 200 subjects, we also found 17 subjects with bilateral absence of frontal sinus, where mean inter-orbital width was 28.66mm. Total orbital width was considered for the combined 33 subjects that is 16 subjects with absence

of central septa and 17 subjects with bilateral absence of frontal sinus, the mean being 114.78mm. Results are explained in Tables (1-15).

Table 1. Frontal sinus presence and absence

Frontal Sinus	Number	Percentage
Bilateral Absence	17	8.50%
Bilateral Presence	153	76.50%
Unilateral Presence	30	15.00%
Total	**200**	**100%**

Table 2. Unilateral presence of frontal sinus

Side of Frontal Sinus	Number	Percentage
Left	21	70%
Right	9	30%
Total	**30**	**100%**

Table 3. Unilateral absence of frontal sinus

Side of Frontal Sinus	Number	Percentage
Left	9	30%
Right	21	70%
Total	**30**	**100%**

Table 4. Frontal sinus in males

Frontal Sinus	Male	
	Number	Percentage
Bilateral Absence	5	5%
Bilateral Presence	80	80%
Unilateral Presence	15	15%
Total	**100**	**100%**

Table 5. Frontal sinus in females

Frontal Sinus	Female	
	Number	Percentage
Bilateral Absence	12	12%
Bilateral Presence	73	73%
Unilateral Presence	15	15%
Total	**100**	**100%**

Table 6. Presence and absence of central septa

Central Septa	Number	Percentage
Presence	137	89.55%
Absence	16	10.46%
Total	153	100%

Table 7. Central septa classification

Central Septa-Classification	Classification	Number	Percentage
Absent	0	16	10.46%
Present in midline	1	37	24.18%
Sloping to left side of midline	2	19	12.42%
Sloping to right side of midline	3	29	18.95%
Located in left side of midline	4	10	6.54%
Located in right side of midline	5	22	14.38%
Crossing midline from upper left to lower right	6	10	6.54%
Crossing midline from upper right to lower left	7	10	6.54%
Total		**153**	**100%**

Table 8. Asymmetry index of height of frontal sinus

Degree	Classification	Class Number	Number	Percentage
Symmetry and Almost symmetry	100-80	1	59	43.07%
Slight asymmetry	80-60	2	42	30.66%
Moderate asymmetry	60-40	3	24	17.52%
Strong asymmetry	40-20	4	12	8.76%
Extreme asymmetry	<20	5	0	0%
		Total	**137**	**100%**

Table 9. Asymmetry index of width of frontal sinus

Degree	Classification	Class Number	Number	Percentage
Symmetry and almost symmetry	100-80	1	58	42.34%
Slight asymmetry	80-60	2	54	39.42%
Moderate asymmetry	60-40	3	18	13.14%

Strong asymmetry	40-20	4	7	5.11%
Extreme asymmetry	<20	5	0	0%
		Total	**137**	**100%**

Table 10. Height superiority of left and right frontal sinus

Classification	ClassNo	Number	Percentage
The left frontal sinus superiority over the Right one	Class1	78	56.93%
The right frontal sinus superiority Over the left one	Class2	55	40.15%
The equivalent between bilateral frontal sinuses	Class3	4	2.92%
	Total	**137**	**100%**

Table 11. Width superiority of left and right frontal sinus

Classification	Class Number	Number	Percentage
The left frontal sinus superiority Over the right one	Class1	89	64.96%
The right frontal sinus superiority over the left one	Class2	42	30.66%
The equivalent between bilateral Frontal sinuses	Class3	6	4.38%
	Total	**137**	**100%**

Table 12. Outline of upper border of left frontal sinus

Classification	Class No	Number	Percentage
Smooth	1	30	18.99%
Scalloped with 2 arcades	2	37	23.42%
Scalloped with 3 arcades	3	44	27.85%
Scalloped with 4 arcades	4	29	18.35%
Scalloped with 5 arcades	5	14	8.86%
Scalloped with 6 arcades	6	4	2.53%
Scalloped with 7 arcades	7	0	0%
	Total	**158**	**100%**

Table 13. Outline of upper border of right frontal sinus

Classification	Class Number	Number	Percentage
Smooth	Class 1	36	24.66%
Scalloped With 2 arcades	Class 2	39	26.71%
Scalloped With 3 arcades	Class 3	35	23.97%
Scalloped With 4 arcades	Class 4	21	14.38%
Scalloped With 5 arcades	Class 5	11	7.53%
Scalloped With 6 arcades	Class 6	3	2.05%
Scalloped With 7 arcades	Class 7	1	0.68%
	Total	**146**	**100%**

Table14. Ratio of left frontal sinus width to left orbital width

Classification	Class Number	Number	Percentage
Greater than or Equal to1.0	0	36	22.78%
1.0-0.9	1	21	13.29%
0.9-0.8	2	18	11.39%
0.8-0.7	3	27	17.09%
0.7-0.6	4	26	16.46%
0.6-0.5	5	12	7.59%
0.5-0.4	6	11	6.96%
0.4-0.3	7	4	2.53%
0.3-0.2	8	3	1.90%
<0.2	9	0	0%
	Total	**158**	**100%**

Table 15. Ratio of right frontal sinus width to right orbital width

Classification	Class Number	Number	Percentage
Greater than or equalto1.0	0	21	14.38%
1.0-0.9	1	21	14.38%

0.9-0.8	2	15	10.27%
0.8-0.7	3	20	13.70%
0.7-0.6	4	28	19.18%
0.6-0.5	5	20	13.70%
0.5-0.4	6	14	9.59%
0.4-0.3	7	3	2.05%
0.3-0.2	8	3	2.05%
<0.2	9	1	0.68%
	Total	**146**	**100%**

Discussion

The present study included subjects between the age group of 25 to 45 years with a mean age of 32.01 years. The following age group was selected because frontal sinus has great variability and its structure does not change after the age of 20 years. Frontal sinuses are not apparent at birth. They begin to develop during the second year of life and are radiographically visible at 5 years of age. They reach their maximum size at the age of 20. The anatomy of the frontal sinus remains stable throughout the course of life until old age when gradual pneumatisation can occur from atrophic changes[7].

Absence and Presence of Frontal Sinus

Of 200 subjects (100%), bilateral absence of frontal sinus was observed in 17 (8.50%) subjects, bilateral presence of frontal sinus was observed in 153 (76.50%) subjects and unilateral presence of frontal sinus was observed in 30 (15.00%) subjects. In otherwise normal individuals, both frontal sinuses fail to develop in 4% of the population. Several studies conducted on different populations have found varying percentages of absence and presence of frontal sinuses[3,8,11–13]. If there is persistence of a metopic suture, the frontal sinuses are small or absent[14]. The pneumatisation of frontal sinuses varies greatly in size and shape, for reasons as yet unknown. During the fetal period, the frontal sinus and posterior ethmoidal cells are still rudimentary surrounded by cartilage. It is possible that earlier ossification of the cartilage will interfere with their further development, manifesting as hypoplastic. It has also been said that an absence of pneumatisation in the frontal bone results in frontal sinus aplasia[15].

Unilateral Presence of Frontal Sinus

Unilateral presence of frontal sinus was observed in 30 (15%) subjects. Of 30 (100%) subjects with unilateral presence of frontal sinus, 21 (70%) subjects had unilateral presence of frontal sinus on left side and 9 (30%) subjects had unilateral presence of frontal sinus on right side.

Unilateral Absence of Frontal Sinus

Of 30 (100%) subjects with unilateral absence of frontal sinus, 9 (30%) subjects had frontal sinus absence on left side and 21 (70%) subjects had frontal sinus absence on right side. The frequency of bilateral and unilateral agenesis of the sinuses in our study differed from frequencies reported for most ethnic populations. Constitutional (age, gender, hormones and craniofacial configuration) and environmental (climatic conditions and local inflammations) factors control the frontal sinus configuration within each population and contribute to the abnormal development of the frontal sinus. There is a direct relationship between the mechanical stresses of mastication and frontal sinus enlargement and if there is a persistence of a metopic suture, the frontal sinuses are small or absent. The form of the face and forehead in the presence of a metopic suture conforms to the evolutionary trend of the skull.

Central Septa

Presence and Absence of Central Septa

Of 153 (100%) subjects with bilateral presence of frontal sinus, central septa was present in 137 (89.55%) subjects, while 16 (10.46%) subjects showed absence of central septa. Tang *et al* found central septa absence in 17.6% individuals[6]. Yoshino classification with Jian Pin Tang's modifications for frontal sinus measurements along with Cameriere's modifications for orbital measurements could be applicable in our study to 167 out of 200 subjects that are those individuals with presence of frontal sinus with central septa presence. According to Yoshino and Tang *et al.,* class numbers could be awarded for the following variables namely, central septa, asymmetry index of height of frontal sinus, asymmetry index of width of frontal sinus, height superiority of left and right frontal sinus and width superiority of left and right frontal sinus. Ratio of left frontal sinus width to left orbital width, ratio of right frontal sinus width to right orbital width was

measured, and class numbers were awarded for these variables according to Cameriere.

Classification of Central Septa

Of 153 (100%) subjects with central septa, 37 (24.18%) subjects had central septa located in the midline.

Asymmetry Index

In this study, the asymmetry index of bilateral sinus areas of Yoshino was replaced with the asymmetry indices of bilateral sinus dimensions as per Cameriere. In our study frontal sinuses were bilaterally symmetrical in height in 59 (43.07%) subjects (Class 1) bilaterally symmetrical in width in 58 (42.34%) subjects (Class 1). From varying asymmetry index in other studies it is suggested that degree of bilateral asymmetry differs from race to race. The frontal sinuses of both sides are asymmetrical in configuration as a rule because of unequal resorption of diploe during development of the sinuses. As the right and left frontal sinuses develop independently, at different rates of osseous resorption, a significant asymmetry between both sides can arise in the same individual.[5]

Height and Width Superiority of Left and Right Frontal Sinus

In our study, the superiority of area size given by Yoshino was substituted by the unilateral superiority of height and width as per modification by Cameriere. In the present study, we observed that the left frontal sinus height and width was superior to the right frontal sinus. Our findings are in accordance with previous studies who also found left frontal sinus to be superior to right frontal sinus[6,7]. As the right and left frontal sinuses develop independently at different rates of osseous resorption, a significant asymmetry between both sides can arise in the same individual. The frontal sinus pneumatisation increases up to 19 years of age synchronous to craniofacial growth. In adult, the individual and left-right variations in size are significant and may be caused by inflammatory factors[3].

Outline of Upper Border of Frontal Sinus

We observed more subjects with frontal sinuses with scalloped outline with 3 arcades, 44 (27.85%) belonging to class number 3 on the left side and more subjects with frontal sinuses with scalloped outline with 2 arcades 39 (26.71%) belonging to class number 2 on the right side. Our findings were in contrast to the study conducted by Tang *et al.*[6].

Ratio of Unilateral Frontal Sinus Dimensions to Unilateral Orbit

The ratio of the area size of unilateral frontal sinus to unilateral orbit area was replaced with width of the unilateral frontal sinus to the unilateral orbit, respectively as per Cameriere's method. We observed 36 (22.78%) subjects belonged to class 0 on left side and 21 (14.38%) subjects belonged to class 0 and class 1. Our results were in agreement with study by Tang *et al.*

Guidelines for certain variations in frontal sinuses such as bilateral absence of frontal sinus and central septa absence have not been clearly established. We did not exclude such variations from the study as these also are peculiar traits for an individual. Hence to improve the identification in such individuals the total height and total width of frontal sinus was measured for cases with central septa absence as per Tatlisumak and Uthman. In cases of bilateral absence of frontal sinus, inter-orbital width was measured as suggested by Ribeiro. An additional parameter of total orbital width was measured for individuals with bilateral absence of frontal sinus and absence of central septa. We measured total width of frontal sinus for those samples where there was absence of central septa since Yoshino's classification was not applicable for such individuals. Of 153 subjects with bilateral presence of frontal sinus, 16 (10.46%) subjects showed absence of central septa. The total height and total width of frontal sinus was measured for these 16 subjects. The mean total height was 24.46mm and the mean total width was 58.89mm. Our measurements were consistent with Uthman *et al* and in contrast to study conducted by Tatlisumak *et al.*

Inter-orbital Width

Inter-orbital width was measured for subjects with bilateral absence of frontal sinus as per Ribeiro's standardizations. Inter-orbital width was measured for these 17 (8.50%) subjects with bilateral absence of frontal sinus and the mean value observed was 28.66 mm.

Total Orbital Width

Total orbital width was measured for the combined 33 (16.5%) subjects that are 17 (8.5%) subjects with bilateral absence of frontal sinus and 16 (10.46%) subjects with absence of central septa and the mean value was 114.78 mm.

Conclusion

The frontal sinus has long been accepted as an ideal structure for individualization, dating back to the 1920s due to its inherently variable morphology, permanency throughout adulthood, resiliency to damage and the moderate availability of adequate antemortem radiographs. In the present study out of a total 200 subjects, for 167 subjects with presence of frontal sinus with central septa presence, class numbers were allocated in accordance with Yoshino along with modifications by Cameriere and Tang *et al*. We found that all the 167 subjects revealed distinct combinations of class numbers with none being identical. This demonstrates that frontal sinus is unique to each individual. Thus, we conclude that frontal sinuses are unique to each individual and can emerge as a useful paradigm in the evolving front of forensic medicine. Orbital morphology can enhance the discriminative power of frontal sinus in personal identification. We therefore recommend the combined use of frontal sinus and orbital measurements as they can be a valuable, cost-effective adjunct to positive human identification in forensic science.

References

1. Shekar BRC, Reddy CVK. Role of dentist in person identification. Indian J Dent Res 2009; 20(3):356–60. PMid: 19884723. https://doi.org/10.4103/0970-9290.57377
2. Patil KR, Mody RN. Determination of sex by discriminant function analysis and stature by regression analysis: A lateral cephalometric study. Forensic Sci Int. 2005; 147:175–80. PMid: 15567623. https://doi.org/10.1016/j.forsciint.2004.09.071
3. Bullen R, Rubira, Saramento, Azevedo. Frontal sinus size on facial plain radiographs. J Morphol Sci. 2010; 27(2):77–81.
4. David S. Why a dentist for identification? Dent Clin North Am. 2001; (45):2. https://doi.org/10.1016/S0011-8532(22)01760-8
5. 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. https://doi.org/10.1016/0379-0738(87)90041-7
6. Tang JP, Hu DY, Jiang HG, Yu XJ. Assessing forensic applications of the frontal sinus in a Chinese Han Population. Forensic Sci Int. 2009; 183:104e1–e3. PMid: 19081689. https://doi.org/10.1016/j.forsciint.2008.10.017
7. Tatlisumak E, Ovali GY, Aslan A, Asirdizer M, Zeyfeoglu Y, Tarhan S. Identification of unknown bodies by using CT images of frontal sinus. Forensic Sci Int. 2007; 166:42–8. PMid: 16647829. https://doi.org/10.1016/j.forsciint.2006.03.023
8. Uthman AT, Al-Rawi AH, 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–e7. PMid: 20097024. https://doi.org/10.1016/j.forsciint.2009.12.064
9. De Ribeiro FAQ. Standardized measurements of radiographic films of the frontal sinuses: An aid to identifying unknown persons. Ear Nose Throat J. 2000; 79(1):26–33. PMid: 10665188. https://doi.org/10.1177/014556130007900108
10. Cameriere R, Ferrante L, Math D, Mirtella D, Rollo FU, Biol D *et al*. Frontal sinuses for identification: Quality of classifications, possible error and potential corrections. J Forensic Sci 2005; 50(4):1–4. https://doi.org/10.1520/JFS2004343
11. Aydinhoglu A, Kavakh A, Erdem S. Absence of frontal sinus in Turkish individuals. Yonsei Med J. 2003; 44(2):215–8. PMid: 12728460. https://doi.org/10.3349/ymj.2003.44.2.215
12. Cakur B, Sumbullu MA, Durna NB. Aplasia and agenesis of the frontal sinus in Turkish Individuals: A retrospective study using dental volumetric tomography. Int J Med Sci. 2011; 8:278–82. PMid: 21537381 PMCid: PMC3085142. https://doi.org/10.7150/ijms.8.278
13. Goyal M, Acharya AB, Sattur AP, Naikmasur VG. Are frontal sinuses useful indicators of sex? J Forensic Leg Med. 2012: 20(2):91–4.

14. Som PM, Shugar JMA, Brandwein MS. Sinonasal Cavities: Anatomy and physiology. 4th ed. Peter M Som: Mosby; 2003.

15. Camargo JR, Daruge E, Prado FB, Caria PHF, Alves MC, Silva RF *et al*. The frontal sinus morphology in radiographs of Brazilian Subjects: Its forensic importance. Braz J Morphol Sci 2007; 24(4):239–43.

How to cite this article: Akanksha, A. and David, M. P. Evaluation of Frontal Sinus as an Aid in Personal Identification - A Digital Radiographic Study. J Forensic Dent Sci 2021;13(1):10-17.

Access this article online	
Website: www.jfds.org	**Quick Response Code**