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Original Research Article

Configuration of frontal sinuses: A forensic perspective

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ABSTRACT

Background: Identification of an individual whether living or deceased is of paramount importance in maintaining the integrity of the society. A simple, reliable, and efficacious method always finds a way for easier acceptance and inclusion in any discipline. Likewise, identification of an individual using the radiographic frontal sinus patterns is a simple technique which emphasized to conduct the study with a proven result. **Objective:** The objective of the study is to evaluate the radiographic configurations of frontal sinuses for their uniqueness based on different parameters. **Study Group and Methods:** Study group consisted of thirty individuals (15 males and 15 females) of age between 20 and 30. Individuals with the history of sinusitis, surgery, or any trauma were not included in the study. Paranasal sinus views were taken using standard exposure parameters, and the radiographs were assessed for their uniqueness. **Results:** The radiographs were assessed for area size, area asymmetry, superiority of the upper border, outline of the upper border, presence or absence of partial septa and supraorbital cells, and based on these results, a unique code number was assigned to each individual to prove the uniqueness. **Conclusion:** A frontal sinus comparison is particularly useful when no other means of an individual identification are available. Caution must be taken regarding the physiological and pathological changes (trauma, infection, old age, surgery, etc.) and postmortem changes and about the technical issues while taking a radiograph (distance, angle, orientation of the skull). In spite of all these issues, the configuration of frontal sinus is an excellent individualizing feature.

KEY WORDS: Forensic dentistry, frontal sinus, individual identification

The word "forensic" is derived from the Latin word "forensis" meaning the art or study of public. Identification of an individual, either living or deceased, is based on the theory that all individuals are unique.

Scientific identification of human remains might be accomplished by fingerprint, dental, anthropological, genetic, or radiological examination.[1] The identification of unknown human remains by comparison of antemortem and postmortem radiographs has found wide acceptance in recent years.[2] Although known since 1921, the personal identification using comparison of radiographs was successfully applied by Culbert and Law in 1927.[3] The considerable individual variation in the size and configuration of frontal sinuses was first recognized

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by Schuller.[4] It is not unusual that the dental history should include a sinus problem, and this may lead to the possibility of maxillofacial views taken in a hospital. It is said that the frontal sinuses, in particular, have a unique feature in every individual and are comprehended for its uniqueness even in monozygotic twins. Based on this background, this study was carried out to assess the uniqueness of the frontal sinus for individual identification using the classification system suggested by Yoshino *et al.*[5]

Materials and Methods

For analysis of frontal sinus configuration, individuals who came for paranasal sinus radiograph investigation were selected. The study population comprised thirty individuals (15 males and 15 females) between 20 and 30 years of age without any history of sinusitis, surgery, or any trauma.

Paranasal sinus views were taken using Planmeca OY 2002 CC machine (Helsinki, Finland). Loaded cassette of size 8 inch × 10 inch was placed in a cassette holder. The height of the cephalostat was adjusted until the positioning cones at the ends of the ear posts were at the level of the patient's ears.

The patient is positioned between the two ear posts so that he/she will be facing the cassette. The tilt of the patient's head was adjusted until the ala-tragal line was 35–40° from the horizontal. The exposure parameters used were 78 kV and 12 mA with an exposure time of 1.2 s. Exposure was made and the film was developed and dried which was then mounted on a view box for radiographic analysis of the frontal sinuses [Figure 1].

The radiographs were analyzed for area size, bilateral asymmetry in area size, unilateral superiority of area size, outline of upper border of frontal sinus (left and right side), presence or absence of partial septa or supraorbital cells [Figure 2].

The area of the sinus, which falls above the line drawn tangentially to the superior border of two orbits, was taken into consideration, and area of the frontal sinus was estimated as the combined sum of both the right and left sinuses. According to area size, the frontal sinuses were classified as small, middle, large, and very large and were assigned the Class number 1, 2, 3, and 4, respectively.

Asymmetric index was used as a criterion of bilateral asymmetry in area size. The formula for asymmetric indices was given by: Asymmetric index = A1/A2 × 100

where A1 is the area of the smaller sinus and A2 is the area of the larger sinus. According to the degree of bilateral symmetry, they were classified as symmetry and almost symmetry (100–80), slight asymmetry (80–60), moderate asymmetry (60–40), strong asymmetry (40–20), extreme asymmetry (>20) and were assigned the Class number 1, 2, 3, 4, and 5, respectively.

Unilateral superiority of the upper border of the frontal sinus was also used as a parameter. Case in which the left side was superior to the right one was assigned as 1 and the reverse case as 2.

The outline of the upper border of the frontal sinus in each side was divided into different categories as absent, smooth, scalloped with two arcades, scalloped with three arcades, scalloped with four arcades, and scalloped with five arcades and were assigned Class number 0, 1, 2, 3, 4, and 5, respectively.

The presence or absence of partial septa and supraorbital cells was taken into consideration and classified as absent, present on the left side, present on the right side, present on both sides and were assigned Class Number of 0, 1, 2, and 3, respectively.

The frontal sinus pattern of a given person was formulated as a code number, which was determined by arranging the class numbers in order as the following: Area size, bilateral asymmetry, superiority of side, outline of the upper border (left and right side), and presence or absence of partial septa and supraorbital cells. The code number thus obtained from different individuals was checked for their uniqueness.



Figure 1: Paranasal sinus view

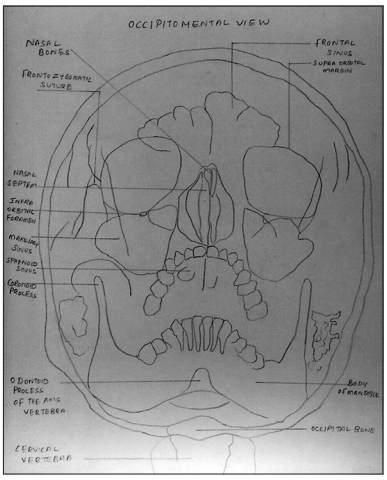


Figure 2: Tracing image of paranasal sinus view

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Armamentarium used for obtaining a paranasal sinus radiograph and for analysis of configuration of frontal sinus

- Planmeca 2002 CC X-ray machine
- Film cassette (8 × 10 inches)
- Radiographic film (8 × 10 inches)
- Processing solution
- View box
- Measuring scale
- Lead pencil.

Results

The frontal sinuses were examined in thirty individuals (15 males and 15 females) after obtaining a paranasal sinus skull radiograph. The radiograph was examined for area size, bilateral asymmetry, superiority of side, outline of upper border (left side and right side), and partial septa and supraorbital cells.

Based on the above findings, each individual was assigned a code in the same sequence of examination and was evident that the code for each person was different, indicating that the frontal sinus pattern was unique for each individual.

The frontal sinus areas ranged from 0.6 to 26.27 cm^2 for females and from 1.60 to 23.11 cm^2 for males. The frontal sinuses of both sexes were classified into four categories based on the sinus area measurements. Among the thirty individuals, most of them belonged to the categories of small and middle and only 20% and 13.33% of individuals belong to the large and very large category, respectively [Tables 1 and 2]. The mean value of the frontal sinus area for males was larger than that for females. The difference in means between both the sexes was not significant at the 0.05 level of confidence ($t = 0.632$, $P = 0.533$).

The classification of the degree of bilateral asymmetry of frontal sinus based on asymmetry indices is presented in Table 3 and their relative frequency distribution is presented in Table 4. In the thirty individuals examined, 15 appeared bilaterally symmetrical or almost symmetrical, of which ten were females and five were males. Six individuals showed bilateral asymmetry, which included 3 males and 3 females. Three showed moderate asymmetries who were male subjects. Strong asymmetry was present in 2 cases (1 male and 1 female) and extreme asymmetry in 2 cases (1 male and 1 female).

In addition to bilateral asymmetry of sinus size, the unilateral superiority of area size in frontal sinuses has used a parameter of classification of sinus patterns. The class number was given as follows: The case in which the left sinus was superior to the right one was assigned 1 and the reverse was 2. In the thirty individuals, twenty belong to the Class number 1 (11 females and 9 males) and ten belonged to the Class number 2 (4 females, 6 males) [Table 5].

The outline of the upper border of frontal sinus on each side was divided into the following category as 0, 1, 2, 3, 4, and 5.

Table 1: Area of the frontal sinus in the sample group of both males and females

Females (area in cm^2)	Males
0.6	1.60
10.73	13.14
13.03	10.86
0.75	6.04
6.78	16.72
24.53	10.72
4.26	1.71
5.83	13.24
8.94	7.12
3.70	23.11
8.80	11.55
3.56	12.9
6.60	7.79
26.27	19.94
12.06	4.05

Table 2: Classification of area size of frontal sinuses and relative frequency distribution of area size in sample

Area size	Range (cm^2)	Relative frequency (%)		Class number
		Male	Female	
Small	0-6	20	40	1
Middle	6-12	40	33.33	2
Large	12-18	26.66	13.13	3
Very large	>18	13.33	13.13	4

Table 3: Degree of bilateral asymmetry of the frontal sinus in the sample group of both males and females

Females	Males
5 (<20)	5 (<20)
1 (80-100)	3 (60-40)
1 (80-100)	2 (80-60)
2 (80-60)	3 (60-40)
2 (80-60)	3 (60-40)
1 (80-100)	1 (80-100)
1 (80-100)	4 (40-20)
1 (80-100)	2 (80-60)
1 (80-100)	1 (80-100)
4 (40-20)	1 (80-100)
1 (80-100)	1 (80-100)
1 (80-100)	2 (80-60)
2 (80-60)	3 (60-40)
1 (80-100)	2 (80-60)
1 (80-100)	1 (80-100)

Table 4: Classification of the degree of bilateral asymmetry in frontal sinuses and relative frequency distribution of degree of bilateral asymmetry in samples

Degree	Range asymmetry index	Relative frequency (%)		Class number
		Male	Female	
Symmetry and almost symmetry	8-100	33.33	66.66	1
Slight asymmetry	80-60	26.66	20	2
Moderate asymmetry	60-40	26.66	0	3
Strong asymmetry	40-20	6.66	6.66	4
Extreme asymmetry	<20	6.66	6.66	5

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The relative frequency distribution and outline of upper border in both sex and on each side are given in Tables 6 and 7.

The presence or absence of partial septa and supraorbital cells was classified into four categories and is presented in Tables 8 and 9, respectively, with their relative frequency distribution in Table 10.

Based on the above radiographic findings of frontal sinus, a code number [Table 11] is assigned to each individual corresponding to the class number of each finding in the above order, which indicates that the frontal sinus pattern is unique for each individual.

The above study gives an idea about the uniqueness of the frontal sinus and its application in the identification of an individual.

Table 5: Superiority of side of the frontal sinus in the sample group of both males and females

Females	Males
2	1
1	1
1	2
2	1
1	1
1	2
1	2
2	2
1	2
1	1
1	1
2	1
1	2
1	1
1	1

Table 6: Outline of upper border of the frontal sinus in the sample group of both males and females

Females		Males	
Right	Left	Right	Left
1	0	0	1
2	1	1	5
3	2	2	1
1	2	2	3
2	3	3	5
5	5	4	3
1	1	3	2
2	3	4	3
4	2	2	2
1	1	5	5
2	3	3	2
2	1	2	3
3	3	1	2
4	5	5	5
4	5	3	2

Table 7: Classification of the outline of the upper border of the frontal sinuses and relative frequency distribution of the outline of upper border in samples

Outline of upper border	Relative frequency (%)				Class number
	Male		Female		
	Left	Right	Left	Right	
Absent	0.0	6.66	6.66	0	0
Smooth	13.33	13.33	26.66	26.66	1
Scalloped with two arcades	33.33	26.66			2
Scalloped with three arcades	26.66	26.66	26.66	13.33	3
Scalloped with four arcades	0	13.33	0	20	4
Scalloped with five arcades	26.66	13.33	20	6.66	5

Discussion

The frontal sinus is usually a paired, irregularly shaped, pneumatized cavity located in the frontal bone, which develops embryonically from an ethmoidal cell.[6]

Table 8: Partial septa of the frontal sinus in the sample group of both males and females

Females	Males
0	0
0	1
3	0
0	0
3	1
3	2
0	3
3	3
1	0
0	3
1	2
2	3
3	1
3	3
3	0

Table 9: Supraorbital cells of the frontal sinus in the sample group of both males and females

Females	Males
1	1
0	0
2	0
2	3
0	0
0	0
1	0
0	0
3	1
2	1
1	0
1	3
1	0
3	0
0	0

Table 10: classification of the presence or absence of partial septa and supraorbital cells and relative frequency distribution of them in samples

	Partial septa (%)		Supraorbital cells (%)		Class number
	Male	Female	Male	Female	
Absent	33.33	33.33	66.66	33.33	0
Present on the left side	20	13.33	20	33.33	1
Present on the right side	13.33	6.66	0	20	2
Present on both sides	33.33	46.66	13.33	13.33	3

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Table 11: Code number for identification of individuals in the sample group based on the radiographic interpretation of frontal sinus of both males and females

Females	Males
1520101	1511001
2111200	3315110
3112332	2221200
1222102	2313203
2213230	3315310
4115530	2123420
1111101	1422330
1123230	3223430
2112413	2122201
1411102	4115531
2113211	2112320
1121221	3213233
2213331	2322110
4115433	4215530
3115430	1112300

It varies enormously in its size and shape and is considered as one of the unique anatomical structure. Radiographically, frontal sinuses normally appear by the 2nd or 3rd year of life. They rapidly develop in puberty and complete their definitive configuration at the 20th year of life.[7]

Considering this factor, our study group included individuals above 20 years of age and they were assessed for various parameters. The mean value of the frontal sinus area for males (10.69 cm^2) was found to be higher than the mean value of the frontal sinus area of females (9.09 cm^2) and this correlates with the previous study.[5]

Although the sinus area of males tended to be large than that of females, the statistical difference of means between them was not statistically significant. Thus, the measurement of frontal sinus area might be of no validity for determination of sex since sinus area measurements were very variable among the individuals, which is correlating with the earlier findings.[5] Various studies have been undertaken to assess if the configuration of the frontal sinuses is used as a factor for determining the sex of an individual. The studies have concluded that it lacks in the level of accuracy and may have limited application as the soul predictor of sex.[8,9]

The degree of bilateral asymmetry in frontal sinus was classified into five categories based on the asymmetry index. About 66.66% of females and 33.33% of males belonged to 80–100, and about 26.66% of females and 20% of males belonged to 60–80. In the previous study, 40% of the samples in each sex belonged to asymmetry index 40–60, and in a study done by Szilvassy among Austrians, about 40% of males belonged to 60–80 and 40% of females belonged to 80–100.[5] From these findings, it was suggested that the degree of bilateral asymmetry in frontal sinus differs from race to race. This is in correlation with the study done by Yoshino *et al.* and Szilvassy.[5,10]

In the present study, morphological characteristics of the upper border of frontal sinus showed no significant difference between both sexes. This feature correlated with the findings of Yoshino *et al.*[5]

Males and females were not significantly different in the presence or absence rates of partial septa and supraorbital cells. Based on the radiographic findings of frontal sinus pattern, a code number was assigned to each individual and was found that the numbers of no two individuals resembled each other, which is in concordance with the previous findings that the frontal sinus patterns are unique for every individual.[5,11]

Our study did not include twin population. Variations have been reported in the frontal sinuses of monozygotic and dizygotic twins.[12]

Thus, the usage of configuration of frontal sinuses for identification of an individual is gaining wide acceptance. A study with large sample size along with the various advanced imaging modalities will aid in substantiating the uniqueness of frontal sinus pattern in an individual.

Conclusion

A frontal sinus comparison is particularly useful when no other means of an individual identification are available. Caution must be taken regarding the physiological and pathological changes (trauma, infection, old age, surgery, etc.) and postmortem changes and about the technical issues while taking a radiograph (distance, angle, orientation of the skull). In spite of all these issues, the configuration of frontal sinus is an excellent individualizing feature.

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Conflicts of interest

There are no conflicts of interest.

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