Study of Frontal Sinus and Nasal Septum Pattern using PA view of Skull as an aid for Personal Identification

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ABSTRACT

Introduction: Radiological examination of bone structures of human remains provides a means of positive identification. Frontal sinuses once developed do not change their size and shape and the morphology is different in each individuals. When we consider more than one anatomic structure like nasal septum pattern, in addition to the frontal sinus, for identification, the reliability increases.

With the above background this study was undertaken to determine the different patterns of frontal sinus and nasal septum and to study the possibility of combined use of frontal sinus and nasal septum patterns in personal identification and gender determination.

Materials and methods: Postero-anterior (PA) view radiographs (digital) of the skull of 50 individuals above the age of 20 years were analyzed. Radiographs were taken with PLANMECA PROLINE XC digital X-ray machine. Out of 50 individuals frontal sinus was absent in 5 individuals and they were excluded from the study. Radiographic images of the frontal sinuses and nasal septum were processed using a computer aided drafting program. These radiographs were used to evaluate frontal sinus area (right and left sides), bilateral asymmetry, superiority of sinus, outline of upper border of the right and left sinuses, and partial septa. The frontal sinus pattern of each individual was formulated as a code number which were determined by arranging the class numbers in each classification item as serial numbers. To this code number, the nasal septum pattern (straight, deviation to right and left side, sigmoid and reverse sigmoid) was also added in the form of capital letters.

Results: Out of 45 individuals analyzed 43 (95.5%) showed unique patterns of frontal sinus. When nasal septum patterns were added the result was 100%.The statistical values for gender determination was not significant (P value > 0.05).

Conclusion: Combined use of frontal sinus and nasal septum pattern using Postero-anterior view of skull is an effective method for personal identification and is not a reliable method for gender determination.

Keywords: Frontal Sinus, Nasal Septum, PA View of Skull, Personal Identification

INTRODUCTION

Forensic dentistry has been defined by the Federation Dentaire Internationale (FDI) as that branch of dentistry which, in the interest of justice, deals with the proper handling and examination of dental evidence, and with the proper evaluation and presentation of dental findings. Forensic odontology is the application of dentistry to the law[1]. Identification of human remains is one of the foremost goals in a medico legal investigation. Personal identification is done on the basic fact that each person is unique and it is a prerequisite for personal, social and legal reasons. An expedient and accurate identification is imperative to serve the family of the decedent and the medico legal system. In forensic odontology, this is done by using dental records, ante-mortem and post mortem radiographs, photographs and DNA[1]

Radiographic examination of skeletal structures is a potentially useful procedure for identification of human remains and living persons[2]. Personal identification can be made by comparing ante-mortem and post- mortem radiograph of a given body part. There are various landmarks used traditionally for the purpose of personal identification such as vascular groove pattern, margins of joints, trabecular pattern of rib and clavicle, costal cartilage calcification, mastoid process pattern and frontal sinus shape[3]. Out of these the frontal sinus is considered to be one of the reliable landmark for personal identification. Frontal sinuses, once defined does not change their size and shape throughout the life except for enlargement seen in old age and some diseases, which makes it a unique landmark.. Frontal sinus patterns

can sometimes differ depending on the position of the head in the radiographic examination. However, the horizontal diameter of the frontal sinus shows very little variation due to the flat configuration of the sinuses. Although the nasal septum also shows individual variation, less number of studies has been done using it as tool for personal identification[3]. Therefore, a combined use of the nasal septum and frontal

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sinus patterns may be more useful for identification, giving further individual variations, since both are practically easily identifiable in a radiograph.

With the above background this study was undertaken, to examine the different radiographic patterns of frontal sinus and nasal septum and its combined use for personal and gender determination.

The study was designed with the following aims and objectives:

1. To study different patterns of frontal sinus and nasal septum.
2. To study the possibility of personal identification using uniqueness of frontal sinus and nasal septum patterns.
3. To study the possibility of identification of gender by using these patterns.

MATERIALS AND METHODS

Total 50 individuals of age above 20 years were selected for the study. The selected patients were clinically examined for their purpose of visit. The whole study process and its experimental nature of the study was described to the patients and informed consent was taken.

Inclusion criteria : Healthy individuals above the age of 20 years.

Exclusion criteria: Pregnant patients, Individuals below the age of 20 years**,** Individuals with history of orthodontic treatment or orthognathic surgery, Individuals with history of trauma or any surgery of the skull, Individuals with history or clinical characteristics of endocrine disturbances, nutritional deficiency, Individuals with hereditary facial asymmetry.

Study Procedure : Postero-anterior (PA) Radiographic View (digital) of the skull of selected subjects were taken with PLANMECA PROLINE XC digital X-ray machine. Exposure parameters were 70kV and 10 mA. Images were stored in computer. Radiographic images of frontal sinuses and nasal septum which are usually apparent, and were assessed by tracing using tracing paper processed using computer software.(Figure 1) These radiographs were used to evaluate frontal sinus area (right and left side),bilateral asymmetry superiority of sinus, outline of upper border of the left and right sinuses and partial septa. The frontal sinus pattern of each individual was formulated as a code number which were determined by arranging the class numbers in each classification item as serial numbers. For this code number, the nasal septum pattern code also was added. The observations recorded.

STATISTICAL ANALYSIS

Data was analyzed using computer software, Statistical Package for Social Sciences (SPSS) version. To elucidate the associations and comparisons between different parameters, Chi- square test was used as nonparametric test. Student's t test was used to compare mean values between two groups. Multivariate Pearson correlation analysis was employed to find out relationship between various parameters. For all statistical evaluations, a two-tailed probability of value, < 0.05 was considered significant.

RESULTS

Analysis of different patterns of frontal sinus and nasal septum

Gender Distribution: Out of 50 individuals, 25 (50%) persons were males and 25 (50%) were females. Among these 50 individuals frontal sinus was absent in 5 persons (10%). So they were excluded from the study.(Table 1)

Distribution of Area of Frontal sinus: Among the 45 individuals 15 (33.3%) were having small frontal sinus area, 23 (51%) were having frontal sinus which comes under middle category and 7 (15.6%) having large frontal sinus. The result shows more than 50% of the individuals having middle category frontal sinus (6-12cm^2) (Table 2)

Distribution of Asymmetry index of Frontal Sinus : Extreme asymmetry of frontal sinus was noted in 4 (8.9%) individuals, strong asymmetry in 4 (8.9%) individuals, moderate asymmetry in 10 (22.2%) individuals, slight asymmetry in 10 (22.2%) individuals and bilateral symmetry in 17 (37.8%) individuals. **(Table 2)**

Distribution of Superiority of Frontal Sinus: Right side superiority of frontal sinus was noted in 28 (62.2%) individuals and left side superiority was noted in 17 (37.8%) individuals, showing right side superiority is majority.((Table 2)

Distribution of Outline of Upper border of Frontal Sinus: Smooth outline of frontal sinus was noted in 5 (11.1%) individuals. Frontal sinus with 2 arcades in 2 (4.4%) individuals, three arcades in 5 (11.1%) individuals, 4 arcades in 8 (17.8%) individuals, and 5 arcades in 25 (55.6%) individuals were noted. (Table 2)

Distribution of Partial septa of Frontal Sinus : Partial septa of frontal sinus was absent in 13 (28.9%) individuals. Partial septa was present only on the left side was present in 7 (15.6%) individuals and on right side in 11 (24.4%) individuals. In 14 (31.1%) individuals partial septa was present bilaterally. (Table 2)

Distribution of Nasal Septum pattern: Straight nasal septum was present in 19 (38%) individuals. Deviation of the nasal septum towards left side was seen in 4 (8%) subjects and right side deviation was seen in 11 (22%) subjects. Sigmoid type of nasal septum was found in 5 (10%) persons and reverse sigmoid pattern was noted in 11 (22%) persons. (Table 3)

Analysis for gender identification

Association between Gender and Sinus area: Small type frontal sinus was noticed in 7 (31.80%) males and 8 (34.80%) females. Middle type frontal sinus was noticed in 12 (54.50%) males and 11 (47.80%) females. Large type sinus was noticed in 3 (13.60%) males and 4 (17.40%) females. In the analysis, the P value was > 0.05 which is statistically not significant and gender determination was not

possible with sinus area. (Table 4)

Association between gender and asymmetry index: Extreme asymmetry of frontal sinus was noted in 2 (9.10%) males and 2 (8.70%) females. Strong symmetry was noted in 2 (9.10%) males and 2 (8.70%) females. Moderate

asymmetry was noted in 5 (22.70%) males and 5 (21.70%) females. Slight asymmetry was noted in 5 (22.70%) males

Gender	Frequency	Percent
Male	25	48.9
Female	25	51.1
Total	50	100

Table-1: Gender distribution

Various Patterns of Frontal sinus	Frequency	Percent
Area of frontal sinus (cm²)		
Small (0-6)	15	33.3
Middle (6-12)	23	51.1
Large (12-18)	7	15.6
Total	45	100
Asymmetry index		
Symmetry	17	37.8
Slight Asymmetry	10	22.2
Moderate Asymmetry	10	22.2
Strong Asymmetry	4	8.9
Extreme Asymmetry	4	8.9
Total	45	100
Superiority Index		
Right	28	62.2
Left	17	37.8
Total	45	100

Table-1: Gender distribution

Outline of Upper Border		
Smooth	5	11.1
Two Arcades	2	4.4
Three Arcades	5	11.1
Four Arcades	8	17.8
Five Arcades	25	55.6
Total	45	100
Partial septa		
Absent	13	28.9
Left Side	7	15.6
Right Side	11	24.4
Both Sides	14	31.1
Total	45	100

Table-2: Various patterns of frontal sinus (Area of frontal sinus , Asymmetry index, Superiority Index, Outline of Upper Border, Partial septa)

Nasal Septum	Frequency	Percent
Straight	19	38.0
Left Deviation	4	8.0
Right Deviation	11	22.0
Sigmoid Type	5	10.0
Reverse Sigmoid	11	22.0
Total	45	100

Table-3: Distribution of nasal septum pattern

Area (cm2)	Gender		Total
	Male	Female	
Small (0-6)	7	8	15
	31.80 %	34.80 %	33.30%
Middle (6-12)	12	11	23
	54.50 %	47.80%	51.10%
Large (12-18)	3	4	7
	13.60%	17.40%	15.60%
Total	22	23	45
Chi Square: 0.231; P > 0.05			

Table-4: Association between gender and sinus area

Asymmetry Index	Gender		Total
	Male	Female	
Extreme Asymmetry	2	2	4
	9.10%	8.70%	8.90%
Strong Asymmetry	2	2	4
	9.10%	8.70%	8.90%
Moderate Asymmetry	5	5	10
	22.70%	21.70%	22.20%
Slight Asymmetry	5	5	10
	22.70%	21.70%	22.20%
Symmetry	8	9	17
	36.40%	39.10%	37.80%
Total	22	23	45
Chi Square: 0.037; P > 0.05			

Table-5: Association between gender and asymmetry index

Superiority of Sinus	Gender		Total
	Male	Female	
Right	13	15	28
	59.10%	65.20%	62.20%
Left	9	8	17
	40.90%	34.80%	37.80%
Total	22	23	45
Chi Square: 0.181; P > 0.05			

Table-6: Association between gender and superiority of sinus

Outline of Upper Border	Gender		Total
	Male	Female	
Smooth	3	2	5
	13.60%	8.70%	11.10%
Two Arcades	1	1	2
	4.50%	4.30%	4.40%
Three Arcades	2	3	5
	9.10%	13.00%	11.10%
Four Arcades	4	4	8
	18.20%	17.40%	17.80%
Five Arcades	12	13	25
	54.50%	56.50%	55.60%
Total	22	23	45
Chi Square: 0.418; P > 0.05			

Table-7: Association between gender and outline of upper border

Figure-1: PA view of skull showing frontal sinus and nasal septum

Partial septum	Gender		Total
	Male	**Female**	
Absent	8	5	13
	36.40%	21.70%	28.90%
Left side	4	3	7
	18.20%	13.00%	15.60%
Right side	1	10	11
	4.50%	43.50%	24.40%
Both sides	9	5	14
	40.90%	21.70%	31.10%
Total	22	23	45
Chi Square: 9.324; P < 0.05			
Table-8: Association between gender and partial septa			

Nasal septum	Gender		Total
	Male	**Female**	
Straight	8	5	13
	36.40%	21.70%	28.90%
Left Deviation	4	3	7
	18.20%	13.00%	15.60%
Right Deviation	1	10	11
	4.50%	43.50%	24.40%
Sigmoid Type	9	5	14
	40.90%	21.70%	31.10%
Reverse Sigmoid		9	9
		39.10%	20.00%
Total	22	23	45
Chi Square: 11.852; P < 0.05			
Table-9: Association between gender and nasal septum			

and 5 (21.70%) females. Bilateral symmetry was noted in 8 (36.40%) males and 9 (39.10%) females. In the analysis the P value was > 0.05, which showed there was no association between gender determination and asymmetry index (Table 5)

Association between gender and superiority of sinus: Superiority of frontal sinus on right side was noted in 13 (59.10%) males and 15 (65.20%) females. Superiority of frontal sinus on left side was noted in 9 (40.90%) males and 8 (34.80%) females. In the statistical analysis the P value was > 0.05. This value was statistically not significant and gender determination is not possible.(Table 6)

Association between gender and outline of upper border of frontal sinus: Frontal sinus with smooth upper border was noticed in 3 (13.60%) males and 2 (8.70%) females. Frontal sinus with two arcades was noticed in 1 (4.50%) males and 1 (4.30%) females. Frontal sinus with three arcades was noticed in 2 (9.10%) males and 3 (13.00%) females. Frontal sinus with four arcades was noticed in 4 (18.20%) males and 4 (17.40%) females. Frontal sinus with five arcades was noticed in 12 (54.50%) males and 13 (56.50%) females. In the statistical analysis the P value was > 0.05. As the value was statistically not significant gender determination was not possible.(Table 7)

Association between gender and partial septum: Partial septum of frontal sinus was absent in 8 (36.40%) males and 5 (21.70%) females. Partial septum on left side of frontal sinus was noted in 4 (18.20%) males and 3 (13.00%) females. Partial septum on right side of frontal sinus was noted in 1 (4.50%) males and 10 (43.50%) females. Partial septum on both sides of frontal sinus was noted in 9 (40.90%) males and 5 (21.70%) females. In the statistical analysis the P value was < 0.05, which was a significant value for gender determination. (Table 8)

Association between gender and nasal septum : Straight nasal septum was found in 9 (40.90%) males and 7 (30.40%) females. Deviation of nasal septum towards left side was found in 2 (9.10%) males and 2 (8.70%) females. Deviation of nasal septum towards right side was found in 7 (31.80%) males and 4 (17.40%) females. Sigmoid type nasal septum was noted in 4 (18.20%) males and 1 (4.30%) females. Reverse sigmoid type of nasal septum was absent in males and it was noted in 9 (39.10%) females. In the statistical analysis the P value was < 0.05 and can be used for gender determination.(Table 9)

Parameters	Gender	Mean	±SD	t value	p value
Area (cm^2)	Male	7.54	4.18	-0.593	>0.05
	Female	8.27	4.13		
Asymmetry Index	Male	62.40	28.71	-0.313	>0.05
	Female	65.03	27.61		
Pearson correlation coefficient (r) between area and asymmetry index is 0.322 (P<0.05), which shows a positive relationship between two variables.					
Table-10: Comparison of different parameters between gender					

Comparison of different parameters between gender: In this study, it was shown that the frontal sinus pattern (area, asymmetry index, superiority of sinus, outline of upper border and presence or absence of partial septa) achieved a classification of 43 (95.5%) different patterns and a combined use of the frontal sinus and nasal septum pattern of the deviation (straight, simple deviation to the left or right, sigmoid, reverse sigmoid and other rare types) gave a result of 45 (100%) different patterns. This result suggests that this classification is very much effective in personal identification. (Table 10)

The frontal sinus pattern of a given person was formulated as a code number which were determined by arranging the class numbers in each classification item as serial numbers. For this code number, the nasal septum pattern (straight, deviation to right and left side, sigmoid and reverse sigmoid) also was added. Out of 45 individuals analyzed 43 (95.5%) individuals showed unique patterns of frontal sinus. When nasal septum patterns added the result was 100%. The statistical values for gender determination was not significant (P value > 0.05)

DISCUSSION

It has been established by prior studies that the radiographic pattern of the frontal sinus is highly variable and unique to every individual.[3, 4] The frontal sinus has an anatomically special characteristic configuration, showing considerable individual differences [3,5]. Although the nasal septum also shows individual variation, no population data are available. [6] Therefore, a combined use of the frontal sinus and nasal septum patterns may be practical for identification by comparison of ante-mortem and postmortem frontal skull radiographs.[6]

Gender Distribution: Among the 50 individuals, frontal sinus was absent in 5 persons (10%). This was in accordance with a study conducted by Schuller et al[7] where bilateral absence of frontal sinus in adults were observed in radiographs of about 5% of all cases and unilateral absence was observed in 1% of cases[7]. Similar results were also seen in studies conducted by Nowak and Mehls et al[8] and Adinlioglu et al[9]. The reason for the absence of frontal sinus can be related to the incomplete pneumatisation of the frontal sinus. Pneumatization of the frontal sinus follows a marrow transition phase from red to yellow marrow in the first few years of life. After marrow transformation has occurred, pneumatization progresses into the frontal bone. The earliest pneumatization occurs at on shortly after age 2 years. By age 4 years, the cranial extent of the frontal sinus reaches half the height of the orbit, extending just above the top of the most anterior ethmoidal air cells.[10]. The pneumatisation continues and completes their definitive configuration by 18 years.[11]Interruption in this process can lead to arrested pneumatisation and sometimes absence of frontal sinus. Schuller (1943) emphasized that the prescence of metopic suture is associated with the absence of frontal sinus.[7,14]

Patterns of frontal sinus : In the present study, it was shown that more than 50% of the individuals having middle category frontal sinus (6-12cm^2).This was in accordance with studies conducted by Guerram A et al[12] and Meltem Özdemir et al[13]. The sinus shape is largely detertmined by the interaction of three factors such as endocrine,mechanical and factors inherent in the mucous membrane.[14]

In the present study, asymmetry index value is slightly higher in females (Mean value:65.03).Asymmetry of the frontal sinus can be because of the unequal resorption of the dipole during sinus development.[15,16]

Right side superiority of frontal sinus was noted in 62.2% of individuals, in the study. This was in accordance with a study conducted by Belaldavar, et al.[16]

This can be attributed to the fact that the right and left frontal sinuses develop independently and it is common to find one sinus is larger than the other, and the larger sinus may cross the midline and even overlap the other.[15]

Distribution of Outline of Upper border of Frontal Sinus showed 5 arcades in maximum number of (55.6%) individuals. Schuller mentioned that the arcades of the scalloped upper border of frontal sinuses were smaller and more numerous in female skulls than in male skulls[7]. However in the present study, morphological characteristics of upper border of frontal sinuses showed no significant difference between both sexes.

In the present study, partial septa in right side of frontal sinus was observed 43.50% of females. This is in accordance with a study conducted by Yoshino M, males and females were not significantly different in the presence or absence of partial septa.[3] Contrary results were observed in a study conducted by Acar et al.[17] where significantly higher prevalence were found in in males than in females. The discrepancies in the prevalence of the incomplete septa documented in literature could be attributed to genetics, race and ethnicity.[18]

Straight nasal septum was present in maximum number of individuals (38%). followed by reverse sigmoid pattern (22%). This was in accordance with a study conducted by Taniguchi et al.[19] Taniguchi M showed that there was no significant difference in the gender distribution based on nasal septum pattern. In the present study reverse sigmoid pattern was absent in males. While 9 (39.10%) females presented with reverse sigmoid pattern, which was statistically significant.

The nasal septum is completely cartilaginous at the beginning of gestation and the PPE is formed by endochondral ossification from the 6 month of gestation.[20,] Any trauma, compression of nose during childbirth can cause alterations in pattern of nasal septum. Other factors include Genetics, connective tissue disorders such as Marfan syndrome, Ehlers-Danlos syndrome, Homocystinuria can cause deviated NS.[21]

CONCLUSION

In the present study, the following conclusions were made: It is possible to analyze different patterns of frontal sinus and nasal septum; It is an effective method for personal identification whereas determination of gender is not possible. Frontal sinus and nasal septum pattern matching is a useful

means for forensic identification. This technique can be applied in cases where antemortem frontal sinus radiographs are available and is useful in instances when dental matching cannot be completed, especially when a subject is edentulous or has missing dentition due to postmortem disturbance. The uniqueness of these anatomic areas and the relative ease of pattern matching make frontal sinus and nasal septum pattern matching a viable adjunct tool for the forensic investigator.

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