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Forensic Evaluation of Frontal Sinus, Nasal Bone, Nasal Septum Pattern and Piriform Aperture Using Postero-anterior Cephalogram

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Abstract

Background: Personal Identification with the help of radiographic examination of Skull is a potentially useful method in cases where fragments of skull persist with no likelihood of identification. Frontal sinus Nasal bone, piriform aperture and Nasal septum show racial and geographical variations and their shape can be used as one of the classic indicators of sexual dimorphism. The purpose of this study was to evaluate and classify the variations in the pattern of frontal sinus and nasal septum, the dimensions, size and the shape of the piriform aperture and their sexual dimorphism.

Material and methods: Postero-anterior cephalometric radiograph of 180 healthy individuals aged 20-70 years were traced for the morphology of frontal sinus and piriform aperture, pattern of nasal bone, nasal septum pattern using various classification systems.

Results: The most predominant pattern of frontal sinus seen in the study sample was the left dominant asymmetry 56.1% and the least predominant was symmetry 3.9%. The mean height of frontal sinus on right side in males was greater than in females and was statistically significant. The most predominant pattern of nasal bone was Type A (56.7%) and least predominant was Type C 2.8%. The most predominant pattern of nasal septum in males and females was found to be straight 62.2% and 63.3% respectively and rare type 1.1%. The proportions of pattern of nasal septum were not statistically different among males and females. The mean height and mean area of the piriform aperture was found to be greater in males as compared to females which was statistically significant ($p < 0.05$).

Conclusion: The frontal sinus, nasal bone, nasal septum and piriform aperture can be useful aids for forensic identification.

Keywords: Frontal sinus; Nasal bone; Nasal septum; Piroform aperture, Forensic; Postero-anterior cephalometric radiograph.

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Introduction

Human identification in forensic scientific discipline has played a key role in identification of living, decomposed or deceased human remains.[1,2] Though most challenging tasks faced by mankind, it has always been considered paramount importance to the society for personal, social and legal purposes.[1,3,4] The utility of such identification methods can also resolve issues during natural disasters, medical breakthroughs, criminal investigations and insurance settlements.[2–4]

Various morphometric and anthropometric methods have been employed till date. Amongst them, radiographic identification methods are efficient, comparatively easy, economical, more precise, accurate and reproducible.[5] The skeleton survives both natural and unnatural abuse or violence and is almost always available for identification. The skull is the second-best region for identification after the pelvis. It is sexually dimorphic and aids in identification with an accuracy of up to 92%. It has various structures that aid in identification such as the dentition, cranial suture patterns, vascular groove patterns, sella turcica area of sphenoid, frontal sinuses, mastoid pneumatic air cells, and sinuses.[6]

In establishing the identity of an individual from a defleshed skull, lateral cephalograms and postero-anterior (PA) radiograph assume a predominate role. Evidence based reports suggest that the use of frontal sinus, piriform aperture, nasal bone and nasal septum pattern aid in personal identification and sex determination.[1,3,7,8] Configuration of frontal sinus and nasal septal pattern is also said to be controlled by various environmental factors, although gender, race, and disease are known to affect its development.[8–10]

The morphometric assessment of these anatomical radiographic landmarks seen on the PA cephalogram, could be used as one of the aids for personal identification. Moreover, these methods are simple, less time consuming and can be easily employed by a general dentist, as it doesn't require expertise. Since there is a paucity of literature related to anthropometry, this study is aimed to report the characteristics of the frontal sinus patterns, nasal bone, nasal septum and the piriform aperture, anticipating that they would be further useful as essential tool to the researchers, clinicians and forensic experts related to this field.

Materials and Methods

An observational study was conducted after obtaining ethical approval from the Institutional review committee. Digital postero-anterior cephalometric radiograph of 180 (90 Males & 90 Females) apparently healthy individuals aged 20–70 years who were advised advised PA cephalogram were made utilizing PLANMECA apparatus using the Caldwell technique on Kodak radiographic film. (Size 18 × 24 cm) Individuals with facial asymmetries, history of trauma or surgery in mid facial region, history or clinical characteristics of any type of systemic disorders, bone diseases, nutritional and endocrinal diseases affecting the head and neck, acute/chronic rhinitis, sinusitis, deviated nasal septum (DNS) and pregnant women were excluded from the study.

The radiographs were then traced using tracing paper, pencil and film illuminator with magnifying lens for the morphology of frontal sinus.[11] The Classification of frontal sinus pattern was done Taniguchi M et al.[12] 2003 and morphology of piriform aperture as given by Hwang et al. 2005[13] (Fig. 1,2,3). In order to define the types of the nasal bone, shapes of the nasal bone were classified into five types given by (Fig. 4). Nasal septum patterns were classified according to Taniguchi et al. (Fig. 5) 2003.[12]

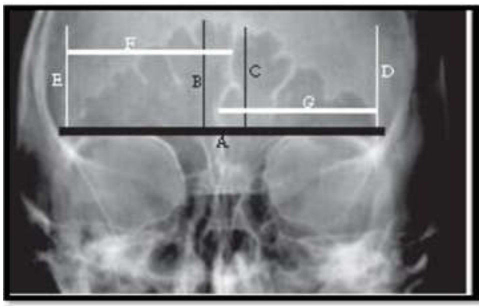


Fig. 1: Diagram of Caldwell radiograph showing demarcations of frontal sinus and identification of the measurements. A denotes reference baseline; B, C denote greatest height of the frontal sinus on left and right side respectively; D,E denote lateral most points on right and left side of frontal sinus. F,G denote largest width of frontal sinus.[11]

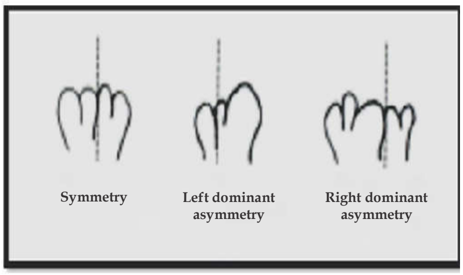


Fig. 2: Classification of frontal sinus pattern according to Taniguchi et al.[12]

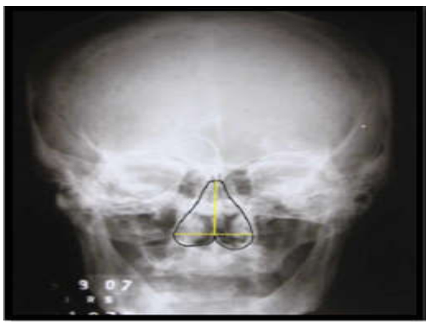


Fig. 3: Morphometry of piriform aperture on PA cephalometric radiograph according to Hwang et al.[13]

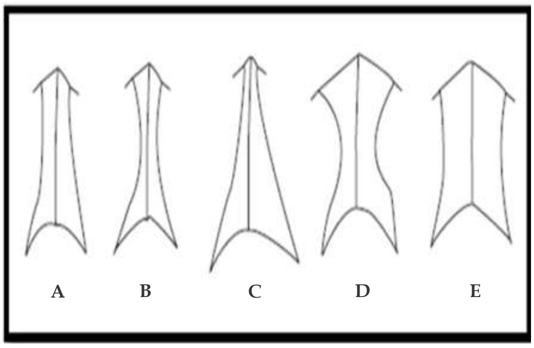


Fig. 4: Classification of Nasal bone pattern according to Hwang et al. (2005).

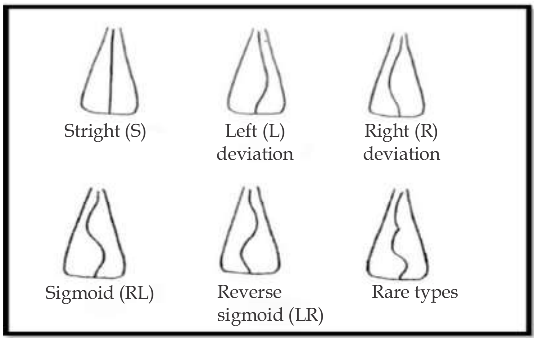


Fig. 5: Classification of nasal septum pattern.[12]

Statistical analysis

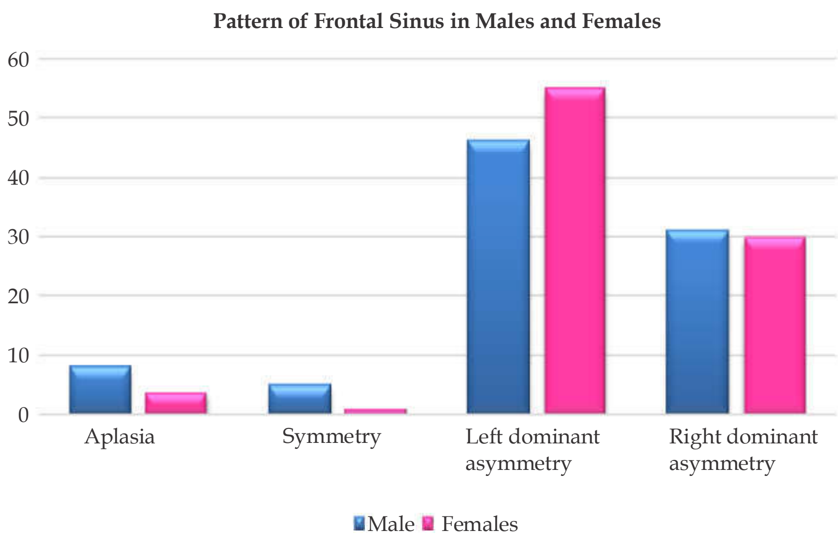
Quantitative characteristics (dimensions of the frontal sinus, height, width and area of pyriform aperture) were compared between males and females using Mann-Whitney U test. Association of qualitative characteristics (pattern of frontal sinus, Pattern of nasal septum, pattern of nasal bone between gender were done using Fishers exact test.

Results

The mean age of the population assessed was 45.53 years (±14.77). The most predominant pattern of frontal sinus seen in the study sample was the left dominant asymmetry 56.1% and the least predominant was symmetry 3.9% (Table 1).

The most predominant pattern of frontal sinus in males and females was left dominant asymmetry in 51.1% and 61.1% and least predominant was symmetry in 5.6% and 1.1% respectively (Graph 1).

The association between most predominant pattern of frontal sinus in males and females with advancing age was not statistically significant (Table 1).



Graph 1: Frequency of most predominant pattern of frontal sinus in males and females.

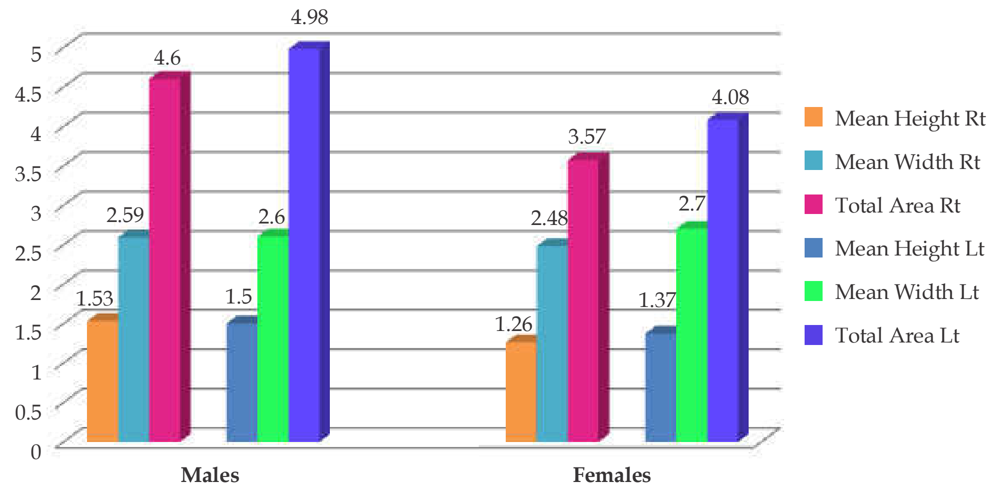
Table 1: Most predominant pattern of frontal sinus in males and females with advancing age

	Aplasia		Symmetry		LDA		RDA		Total
	M	*F*	*M*	*F*	*M*	*F*	*M*	*F*	
21–25		1 (11.1%)	–	–	7 (77.8%)	5 (55.6%)	2 (22.2%)	3 (33.3%)	18
26–30		–	–	–	7 (77.8%)	6 (66.7%)	2 (22.2%)	3 (33.3%)	18
31–35		–	–	–	5 (55.6%)	7 (77.8%)	4 (44.4%)	2 (22.2%)	18
36–40		–	2 (22.2%)	–	5 (55.6%)	7 (77.8%)	2 (22.2%)	2 (22.2%)	18

	Aplasia		Symmetry		LDA		RDA		Total
	M	*F*	*M*	*F*	*M*	*F*	*M*	*F*	
41–45	2 (22.2%)	–	–	–	4 (44.4%)	6 (66.7%)	5 (55.6%)	3 (33.3%)	18
46–50	2 (22.2%)	–	–	–	3 (33.3%)	3 (33.3%)	4 (44.4%)	6 (66.7%)	18
51–55	1 (11.1%)	1 (11.1%)	–	–	4 (44.4%)	5 (55.6%)	3 (33.3%)	3 (33.3%)	18
56–60	2 (22.2%)	1 (11.1%)	2 (22.2%)	1 (11.1%)	2 (22.2%)	4 (44.4%)	4 (44.4%)	3 (33.3%)	18
61–65	1 (11.1%)	1 (11.1%)	1 (11.1%)	–	2 (22.2%)	5 (55.6%)	4 (44.4%)	3 (33.3%)	18
66–70	8		–	–	7 (77.8%)	7 (77.8%)	1 (11.1%)	2 (22.2%)	18
Total	3.86	4	5	1	46	55	31	30	180
Fishers exact test	0.93		1.66		2.99		3.1		
p-value			>0.99		0.97		0.98		

The mean height of frontal sinus on right side in males was greater than in females and was statistically significant. On the left side mean height and total area of frontal sinus were statistically significantly greater in males than in females (Table 2, Graph 2).

Dimension of frontal sinus in males and females



Mean height, width, area of frontal sinus on right and left sides in male and female

Graph 2: Mean dimensions of frontal sinus on right and left side in males and females.

Table 2: Dimensions of frontal sinus in males and females

	Right			Left		
	Mean Ht ± sd	Mean Wt ± sd	Mean Total area ± sd	Mean Ht ± sd	Mean Wt ± sd	Mean Total area ± sd
Males	1.53 ± 0.87	2.58 ± 1.09	4.6 ± 3.21	1.58 ± 0.88	2.6 ± 1.13	4.98 ± 3.32
Females	1.26 ± 0.69	2.48 ± 0.94	3.58 ± 2.38	1.37 ± 0.69	2.7 ± 0.89	4.08 ± 2.71
Mann–Whitney U	3247	3723.5	3375.5	3254	3810.5	3321.5
Asymp. Sig. (2-tailed)	0.021*	0.35	0.054	0.023*	0.492	0.037*

*statistically significant

The most predominant pattern of nasal bone was Type A (56.7%) and least predominant was Type C 2.8% which was not statistically significant (Table 3).

Table 3: Frequency of pattern of nasal bone in males and females

Pattern of nasal bone	Males	Females
Type A	48 (53.3%)	55 (61.1%)
Type B	4 (4.4%)	6 (6.7%)
Type C	2 (2.2%)	3 (3.3%)
Type D	17 (18.9%)	17 (18.9%)
Type E	19 (21.1%)	9 (10%)
	Fishers exact test 3.73	
	p-value 0.44	

The most predominant pattern of nasal septum in males and females was found to be straight 62.2% and 63.3% respectively and rare type 1.1%. The proportions of pattern of nasal septum were not statistically different among males and females (Table 4).

Table 4: Predominant pattern of nasal septum in males and females

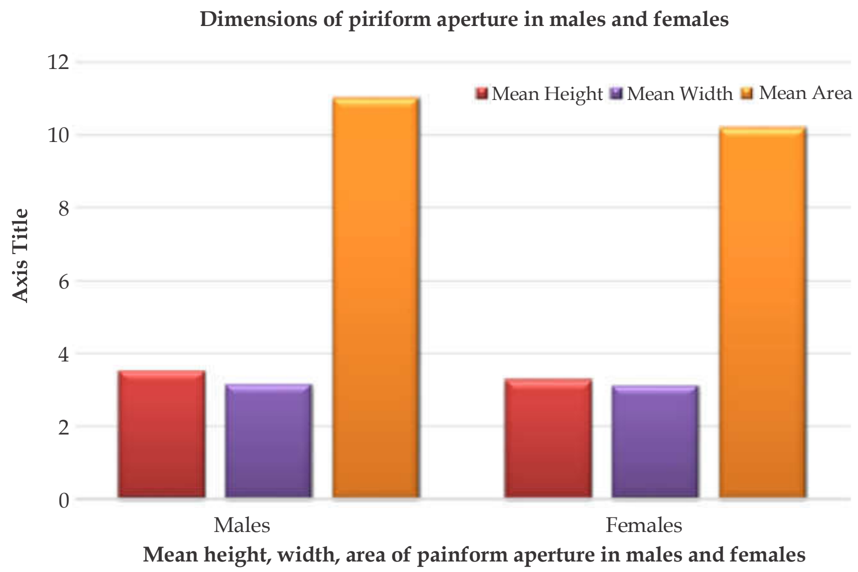
Type of nasal septum	Straight	Right deviation	Left deviation	Sigmoid	Reverse sigmoid	Rare types
Males	56 (62.2%)	14 (15.6%)	11 (12.2%)	6 (6.7%)	2 (2.2%)	1 (1.1%)
Females	57 (63.3%)	10 (11.1%)	15 (16.7%)	1 (1.1%)	6 (6.7%)	1 (1.1%)
			Fishers exact test 6.839			
			p-value 0.21			

The mean height and mean area of the piriform aperture was found to be greater in males as compared to females which was statistically significant ($p < 0.05$) [Table 5, Graph 3].

Table 5: Mean height, width and area of piriform aperture in males and females

	Mean Height ± sd	Mean Width ± sd	Mean area ± sd
Males	3.5 ± 0.39	3.14 ± 0.34	10.99 ± 1.78
Females	3.3 ± 0.41	3.12 ± 0.34	10.2 ± 1.76
Mann–Whitney U	2861	3858	2954
Asymp. Sig. (2–tailed)	0.001**	0.581	0.002**

**statistically highly significant



Graph 3. Mean dimensions of piriform aperture in males and females.

Discussion

Radiographs have become an invaluable tool in forensic sciences since they capture distinct anatomical features. The accuracy for gender differentiation is about 80–100% and radiographs form a standardized technique for morphometric analysis.[2, 14] In the present study PA Cephalogram was utilised to study the different parameters for personal identification that could be assessed with minimal distortion from a single radiograph. A total of 180 healthy individuals (90 males and 90 females) with a mean age of 45.53 years (± 14.77) were included.

Frontal sinus patterns have been evaluated as a parameter to establish post-mortem identity, and empirical data suggest that their configuration is mostly characteristic to each individual.[5] Radiographically, frontal sinuses normally appear by the 2nd or 3rd year of life. They rapidly develop in puberty and complete their definitive configuration at about 20th year of life.[7,15,16] In the present study individuals above 20 years were included to exclude the possibility of incomplete growth leading to false results. The selection of age was conformed to earlier studies.[3,5,9,12,17] (McLaughlin RB et al. 2001 and Tatlisumak E et al. 2008 have stated that as the age increases the frontal sinus tends to expand until the age of 40 years, due to hormonal and mechanical stresses of mastication and osseous resorption.[15,16] In the present study statistically significant association of age was not seen with dimensions of frontal sinus.

A statistically significant sexual dimorphism was found in relation to frontal sinus in the present study, while in literature though males showed larger frontal sinus diameters than females it was not statistically significant.[5,11,16,18–21] In a study by Porbonikova et al. 1974 and Ponde et al. 2008, it was reported that females have proportionally larger antero-posterior diameter frontal sinuses than males, when compared to the sagittal diameter.[7,22]

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.[23] In the previous studies bilateral and unilateral aplasia was found to be ranging between 1–18% and 1–9% which is in accordance with the present study.[3,12,19,20,24] In our study, bilateral aplasia was found more on right side (21.1%) as compared to left side (11.1%). The variable difference by each research can be attributed to the influence of environmental and genetic factors on the frontal sinus. Three systemic factors that is the craniofacial configuration, the thickness of the frontal bone and growth hormone levels influence the frontal sinus morphology within each population.[25,26]

The pattern of frontal sinus in the present study population was based upon the classification given by Taniguchi M et al. 2003 as it is easy and less time consuming.[12] Schuller A and Asherson N stated that frontal sinus pattern of no two individuals are alike.[20, 24] Yoshino et al.[19] proposed the classification of frontal sinus pattern of a given individual, which assesses several parameters and requires expertise. In the present study, symmetry was found in (3.3%), left dominant asymmetry was found in (56.1%) and right dominant asymmetry in (33.9%), which was in accordance to the previous studies.[9,12]

The numbers of septa on right and left side were from 0-8 (0.6%). The most prevalent number on right and left was 2(26.7%) and 1 (31.7%) respectively. The numbers of lobulations and septa on the left and right side were: 1–6 each in the symmetrical type, 1–4 in the left and 0–4 in the right, respectively in the left dominant asymmetrical type, and 0–5 in the left and 1–4 in the right, respectively, in the right dominant asymmetrical type. The tendency of number of lobulation in males was found to be greater than in females but the difference was not statistically significant.

The pattern of nasal septum found in the present study, predominantly was straight (62%) which was slightly lesser than that reported by Reddy S et al.[9] (92.3%) and more than Verma P et al.[17] (40.9%). The nasal septum reported to be more prevalent in previous studies was Left deviation by Taniguchi M et al.[12] (37.6%) and Talaiepour et al.[25] (31.5%) respectively. In the present study however, no significant association was found between gender and nasal septum pattern which was in accordance with the previous studies.[3,12]

The morphological variations of the piriform aperture and nasal bone can be used in Forensic sciences, because its knowledge may be applied to the sexual and ethnic differentiation. However, quantitative data on the piriform aperture remains rare.[27]

Anthropological studies suggest that climate influences the breadth and height of the piriform aperture and for this reason, it is speculated that the shape of the piriform aperture is adapted to the environment in a way that reflects geographical variations.[28,29,30,31] Reported findings indicate that the piriform aperture continues to develop even after 20 years of age. The width of the piriform aperture increases twice from childhood to adulthood.[29,31,32]

In the present study, statistically significant correlation was found between mean height of piriform aperture and gender ($p < 0.05$) which is in accordance with the previous studies.[12,26,27,31,33] The mean height of piriform aperture in males 3.5cm was in accordance with the study conducted by Hwang et al. on Korean population.[30] The mean width of the piriform aperture in our population is 3.1cm which was higher as compared to the study conducted in North Indian population by Asghar A & Dixit A[27]. Also, in the present study, statistically significant correlation was found in the mean area of piriform aperture and the gender.

The shape and the size of the nasal bone vary in different races, ethnic groups and climates. Various studies have been reported on type of nasal bone in the literature.[27,34,35] In the present study, the most predominant pattern of nasal bone is Type A in 56.7% followed by Type D 18.9%, Type E 16.1%, Type B 5.6% and Type C 2.8%. The most predominant pattern of nasal bone found in the present study was Type A in 56.7% is in accordance with the studies conducted by Lang and Baumeister et al.[32] on German population (68.3%), Prado et al.[28] on Brazilian population (28.6%) and Adil Asghar et al.[27] (45%) on Indian population respectively.

Conclusion

The need to establish a reliable, low-cost, and easily reproducible method for human identification prompted the elaboration of technical, precise, and accessible parameters, such as the evaluation of the pattern, area, asymmetry, and shape of the frontal sinus, nasal bone, nasal septum and piriform aperture. As stated, genetic and environmental factors control the configuration of all these mentioned anatomic structures within each population. Thus, no single parameter can prove to be most accurate in sex determination and a need for the use of combination of various parameters arises. A further research with larger sample size and modified methods with higher calibrations are to be proposed. Thus, the combined use of all the above-mentioned parameters can prove to be a useful, reliable, economic and extremely simple tool for gender identification.

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