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International Journal of Current Research
Vol. 9, Issue, 12, pp.62573-62578, December, 2017

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

ROLE OF FRONTAL SINUS AND NASAL SEPTAL PATTERNS IN PERSONAL IDENTIFICATION- A DIGITAL RADIOGRAPHIC STUDY

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ARTICLE INFO

Article History:
Received 20th September, 2017
Received in revised form
12th October, 2017
Accepted 28th November, 2017
Published online 27th December, 2017

Key words:

Forensic medicine,
Frontal sinus,
Nasal septum,
Personal identification.

ABSTRACT

Background: Human identification stays as one of the most outstanding fields of forensic sciences. Finger print analysis, dental comparisons and DNA analysis were most commonly employed personal identification methods. In circumstances like mass disasters, because of scarcity of available soft tissue remains, Forensic maxillofacial radiology plays an important role in personal identification by means of radiographic evaluation of human osteological remains. Frontal sinus and nasal septum, being unique to an individual can be best visualized in Postero anterior skull radiographs and thus can be used for personal identification.
Aim and objectives: To evaluate the morphology and effectiveness of frontal sinus and nasal septum using digital Postero anterior skull radiographs as an aid in personal identification.
Materials and Methods: 200 subjects were enrolled into present study. Digital Postero anterior skull radiographs were taken using Photo Stimulable Phosphor Sensor and were processed using Digora PCT scanner (Soredex). The obtained digital images were subjected to analysis of frontal sinus and nasal septal patterns using Digora windows software version 2.7 and the obtained information was subjected to statistical analysis.
Results: Frontal sinus and nasal septum showed high uniqueness and stability with a total of 1868 unique combinations. There were no significant gender variations in the patterns of frontal sinus and nasal septum except for the number of scalloping's and dimensions of frontal sinus.
Conclusion: Frontal sinus and nasal septum patterns could be a promising adjunctive tool for personal identification.

Citation: Kotha Pavani *et al.* 2017. "Role of Frontal Sinus and Nasal Septal Patterns in Personal Identification- A Digital Radiographic Study", *International Journal of Current Research*, 9, (12), 62573-62578.

INTRODUCTION

Human identification stays as one of the most outstanding areas of forensic sciences. Every human being has their own identity by which they preserve their rights both for family or juridical reasons (David and Saxena, 2010). Human identification can be done in two ways. Firstly, reconstructive group where there is no available previous record of the human remains and identification is based on extracting utmost information regarding age, sex, race, stature etc. Secondly, comparative group in which identification is based upon comparison with retained records or documents which include fingerprints, radiographs or photographs (Viken Sassouni, 1963). Post-mortem human identification is the foremost aspect of research in forensic dentistry and legal medicine (Ricardo Henrique Alves da Silva *et al.,* 2008). Forensic dentistry encompasses the means of identification grounded not only on the dental characteristics but also on the cranial features (Viken Sassouni, 1963).

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The most consistent means of identification includes fingerprints, dental comparisons and DNA analysis. Nevertheless, when there is loss of soft tissue remains, identification can only be established by anthropological method (David and Saxena, 2010). Forensic maxillofacial radiology utilising radiographic examinations of the osteological structures is a promisingtool for post mortem human identification (Pallagatti *et al.,* 2011). Radiological identification was first reported by Culbert and Law in 1926 by comparing the morphology of sinuses and mastoid air cells (Kahana, 1997). Cranial structures must be unique and remain stable over time to have forensic identification value (Uthman *et al.,* 2010). Quite a lot of structures have been exploited which include sella turcica, mastoid air cells, paranasal sinuses remarkably frontal sinuses for their uniqueness (Belaldavar *et al.,* 2014). Frontal sinuses are the paired pneumatic cavities situated in the frontal bone which gain their maximum size by twenty years and are visible radiographically by the age of seven (Anuj Jain, 2013). Frontal sinus has high uniqueness, resiliency and relative stability and shows variation even in monozygotic twins (Patil *et al.,* 2012). Nasal septum is a median osseocartilagenous partition separating the two halves

of the nasal cavity which completes its full growth by the age of 18 years. Nasal septum like other craniofacial structures show high individual variability but limited literature has documented the fact (Taniguchi *et al.,* 2013). Postero-anterior skull projection pronounced by Caldwell provides the best visualization of both frontal sinus and nasal septum in a single radiograph (Rubira-Bullen *et al.,* 2010). In view of the existing limited literature utilising nasal septum pattern for identification, the present study aimed to investigate the combined use of frontal sinus and nasal septum patterns as a tool in personal identification using digital Postero-anterior skull radiographs.

MATERIALS AND METHODS

A prospective observational study was carried out on atotal of 200 subjects attending outpatient Department of Oral Medicine and Radiology in a dental institution in West Godavari district, Andhra Pradesh. Subjectswho gave their willingness and informed consent to participate were enrolled into the present study.The study sample was divided into two groups based upon the gender where Group I consisted of 100 males and Group II consisted of 100 females. The study protocol was approved by the institutional ethical review board (VDC/RP/2012-50).

Inclusion criteria

Patients who were advised Postero anterior skull radiographs for various diagnostic and treatment purposes were included in the present study.

Exclusion criteria

Subjects with a history of trauma or any surgeries to the skull, systemic diseases affecting the bone and hereditary facial asymmetries were excluded from the present study.

Procedure

Postero-anterior skull radiographs were taken withGendex machine using extra oral imaging plate cassette and photostimulable phosphor (PSP) sensors (Digora) using standardized radiographic technique and exposure parameters. PSP sensor was processed using Digora PCT scanner. The final images were obtained by accompanying software (Digora for Windows 2.7.103.437 network client, copyright © 1993-2010 Soredex) in Digital Imaging and Communications in Medicine (DICOM) format. All the obtained digital images were analyzed for nasal septum patterns and frontal sinus patterns including unilateral and bilateral aplasia, symmetry, number of scalloping's, width and height of frontal sinus (Taniguchi et al) using digital manipulation tools provided in the software.

Determination of height and width of frontal sinus (Rubira-Bullen *et al.*, 2010)

The measurements were done according to the sequence below (*Fig 1*)

- A horizontal line was drawn on the Postero-anterior skull radiograph between both orbital cavities at the frontonasal suture.
- A vertical line was drawn along the maximum lateral limits of both right and left frontal sinuses.
- The distance between the central septum and lateral limits of right and left frontal sinuses was determined which gives the width of frontal sinuses respectively.
- A horizontal line parallel to the frontonasal line was drawn at the highest superior point of the frontal sinuses and the distance between these two lines gives the height of frontal sinus.

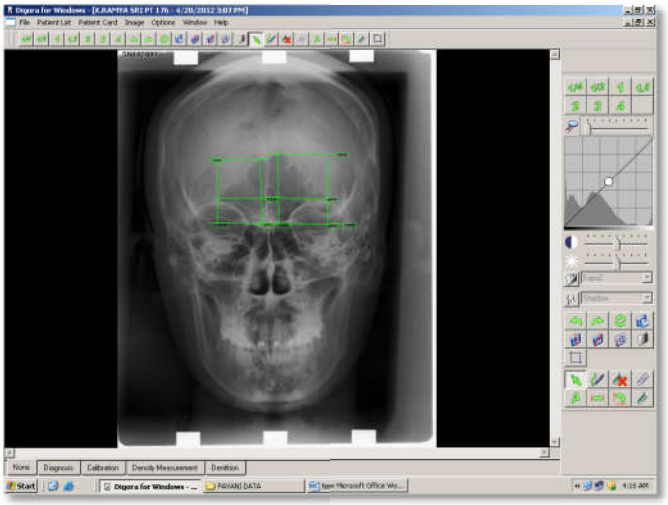

Fig. 1. Line diagrams showing linear calibrations using DIGORA software with inbuilt calibrations

Determination of symmetry of frontal sinus (David and Saxena, 2010)

The greatest horizontal dimension was measured from the central septum on either side. The difference in the right and left side dimensions was divided by the greatest dimension and multiplied by 100. If the percentage was more than 20% then it was classified as asymmetrical. Thus obtained descriptive data was converted to numerical data and subjected to statistical analysis using SPSS software.

Interobserver reliability

30 Postero-anterior (PA) skull radiographs were randomly selected and reanalysed by second observer after necessary training and degree of interobserver reliability was tested using Kappa statistics.

RESULTS

All the 200 subjects who have participated in the study were randomly divided into four age groups as group I, II, III, and IV with age ranges between 20-25 yrs, 26-30 yrs, 31-35 yrs and 36-40 yrs respectively. Group I consisted of 67 females, 55 males; group II consisted of 15 females, 22 males; group III consisted of 13 females, 17 males and group IV consisted of 5 females, 6 males.

Presence of frontal sinus

Of 200 subjects, unilateral frontal sinus was seen in 13 subjects, bilateral frontal sinus was seen in 177 subjects and frontal sinus aplasia was seen in 10 subjects (Table 1). Mann Whitney U test is used to compare the presence of frontal sinus among males and females which showed a p-value of 0.14 which is statistically insignificant states that there are no gender variations.

Table 1. The presence of frontal sinus and its distribution among gender in the entire sample

		Total		Gender			
				Male		Female	
		Count	N %	Count	N %	Count	N %
Presence of frontal sinus	Only right present	2	1.0%	2	1 %	0	0%
	Only left present	11	5.5%	6	3 %	5	2.5%
	Present on both sides	177	88.5%	89	44.5%	88	44.0 %
	Absent on both sides	10	5.0%	3	1.5 %	7	3.5 %

Table 2. Symmetry of frontal sinus and its distribution among gender in the study sample

				Gender	
		Total		Male	Female
		Count	N%	Count	Count
Frontal sinus symmetry	Symmetry	75	39.5%	39	36
	Asymmetry	115	60.5%	58	57
	Right dominant asymmetry	42	36.5%	24	18
	Left dominant asymmetry	73	63.5%	34	39

Table 3. Presence of outline of upper border in both right and left frontal sinus and its distribution among both genders

Outline of upper border				Gender	
		Total		Male	Female
		Count	N%	Count	Count
Right frontal sinus	Present	155	81.6%	81	74
	Absent	24	13.1%	10	14
Left frontal sinus	Present	161	84.7%	86	75
	Absent	27	14.2%	9	18

Symmetry of frontal sinus

Of the total sample, frontal sinus aplasia was seen in 10 subjects. So a total of only 190 individuals were analyzed for different patterns of frontal sinus. Symmetry of frontal sinus was seen in 75 subjects whereas asymmetry of frontal sinus was seen in 115 subjects (Table 2). Mann Whitney U test is done to compare symmetry of frontal sinus between males and females. P value of 0.71 was obtained which is statistically insignificant.

Outline of upper border of frontal sinus

Outline of upper border of right frontal sinus was present in 155 subjects, absent in 24 subjects. In other 11 subjects there is unilateral absence of frontal sinus on right side. In left frontal sinus it was present in 161 subjects and absent in 27 subjects. Left frontal sinus was completely absent in remaining two subjects (Table 3). Mann Whitney U test was used to compare outline of upper border of frontal sinus on both right and left sides among males and females, a p value of 0.87 and 0.23 were obtained respectively which were not statistically significant.

Assessment of intersinus septa and intrasinus septa of frontal sinus

Intersinus septum is present in 172 subjects and absent in 5 subjects. Other 13 subjects showed unilateral presence of frontal sinus either on right or left side. Intrasinus septa in right frontal sinus were present in 63 subjects, absent in 116 subjects. In left frontal sinus intrasinus septa were present in 78 subjects, absent in 110 subjects (Table 4). Mann Whitney U test is used to compare intersinus septa, intrasinus septa in right frontal sinus, intrasinus septa in left frontal sinus among males and females and p-values of 0.98, 0.56 and 0.23 were obtained respectively which were not significant.

Assessment of number of scalloping's of frontal sinus

The mean number of scalloping's in right frontal sinus was 2.41 in males, 2.30 in females. In left frontal sinus the mean number of scalloping's were 2.65 and 2.30 in males and females respectively. Mean values were compared among both genders using independent sample t test and p value of 0.481, 0.051 were obtained in right and left frontal sinus respectively (Table 5) which showed statistically significant results in case of left frontal sinus.

Assessment of width and height of frontal sinus

Mean width and height of left frontal sinus showed statistically significant difference with greater dimensions found in males when compared to females (Table 6). In case of right frontal sinus mean width showed statistically significant difference and mean height is statistically not significant (Table 7). Discriminant function analysis was carried out for gender predictability using left and right frontal sinus dimensions.

Discriminant equation for left frontal sinus

D = 0.077(x) +0.032(y)-2.765. (if D>0 , then more probably males and vice versa).
Where x = left frontal sinus width, y= left frontal sinus height

Discriminant equation for right frontal sinus:

D =0.091(x)-2.173. (if D>0 , then more probably males and vice versa).
Where x = right frontal sinus width

Assessment of influence of age on frontal sinus dimensions

ANOVA was used to compare the mean width and height of right and left frontal sinus between four age groups of which variance is not significant which indicates that the measurements of the frontal sinus are independent of age after

Table 4. showing the presence of intersinus septa, intrasinus septa in the entire sample and its distribution among both genders

		Sex				p-value
		Total		Male	Female	
		Count	N%	Count	Count	
Intersinus septa	Present	172	90.5%	87	85	0.641; NS
	Absent	5	4.2%	2	3	
Intrasinus septa in right frontal sinus	Present	63	33.2%	36	27	0.214; NS
	Absent	116	61.1%	55	61	
Intrasinus septa in left frontal sinus	Present	78	41.1%	44	34	0.098; NS
	Absent	110	57.9%	51	61	

Table 5. comparison of number of scalloping's in right and left frontal sinus among both genders

Number of scalloping's	GENDER				p-value
	Male		Female		
	Mean	SD	Mean	SD	
Right frontal sinus	2.41	1.04	2.30	1.06	0.481; NS
Left frontal sinus	2.65	1.27	2.30	1.19	0.051; SIG

Table 6showing the comparison of width and height of left frontal sinus between males and females

	Gender	N	Mean	Std. Deviation	Std. Error Mean	p-value
Left frontal sinus width	Males	100	28.52	10.307	1.031	0.014*
	Females	100	24.94	10.123	1.012	
Left frontal sinus height	Males	100	23.48	8.019	.802	0.029*
	Females	100	20.98	7.956	.796	

*Statistically significant

Table 7showing the comparison of width and height of right frontal sinus between males and females

	Gender	N	Mean	Std. Deviation	Std. Error Mean	p-value
Right frontal sinus width	Males	100	25.56	11.279	1.128	0.037*
	Females	100	22.30	10.737	1.074	
Right frontal sinus height	Males	100	21.67	9.398	.940	0.065; NS
	Females	100	19.23	9.164	.916	

*Statistically significant

Table 8. The distribution of nasal septal patterns in the entire sample

				GENDER	
		Total		Male	Female
		Count	N%	Count	Count
Nasal septal patterns	Straight	98	49.0 %	53	45
	Left deviation	47	23.5%	22	25
	Right deviation	32	16.0%	17	15
	Sigmoid	9	4.5%	3	6
	Reverse sigmoid	10	5.0%	4	6
	Other types	4	2.0%	1	3

complete formation i.e. they do not vary with age of the patient. They remain constant once they attain full development.

Assessment of nasal septum patterns in the entire sample

Of the 200 subjects, straight nasal septum was present in 98 subjects (49%), left deviation in 47 subjects (23.5%), right deviation in 32 subjects (16%), sigmoid type in 9 subjects (4.5%), reverse sigmoid type in 10 subjects (5.0%) and other rare types were seen in 4 subjects (2.0%) (Table 8). Mann Whitney U test is used to compare the nasal septal patterns between males and females which showed no statistically significant difference (p-value; 0.35)

Assessment of unique combinations between all parameters of frontal sinus and nasal septum patterns

The number of unique combinations in the entire sample was assessed and the total number of possible combinations between nasal septum patterns and all the parameters of frontal sinus in the study are 1868. The number of combinations is much higher in males (944) when compared to females (924).

Interobserver reliability

Kappa statistics was used to assess interobserver reliability of all the observations and there was almost perfect agreement between both observers.

DISCUSSION

Identification of human skeleton is one of the most important aspects of forensic dentistry. During situations like mass disasters, when all the soft tissue remains became lost identification is based on anthropological method using skull radiographs by comparing ante-mortem and post-mortem data (Kahana, 1997). Frontal sinus and nasal septum because of their uniqueness have shown importance in forensic dentistry. So the present study was aimed to investigate the role of frontal sinus and nasal septum patterns in personal identification. In our study frontal sinus aplasia was seen in 10

subjects (5%) with a greater frequency in females (3.5%) when compared to males (1.5%). This finding is in accordance to the findings ofKrogmen *et al.,* (1962) who observed frontal sinus absence in 5% of the adultsand Gulisano *et al.,* (1978) observed its absence in 4.8% of the cases. This finding is in contradictory to studies done by Goyalet al., 2013 Anuj Jain *et al.,* (2013). Where the incidence of frontal sinus absence was very low (2%). These variances may be due to different genetic and climatic factors in the study population (Aydinlioglu *et al.,* 2003). Another possible reason is the association of frontal sinus aplasia with the persistence of metopic suture (Anuj Jain *et al.,* 2013). Literature suggested that a correlation exists between masticatory stresses and enlargement of frontal sinus (Anuj Jain *et al.,* 2013).

In our study asymmetry of frontal sinus is present in 60.5% whereas symmetry of frontal sinus is seen in 39.5% of the sample which is in correlation with the study done by Taniguchi *et al.,* (2003) in Japanese population who reported frontal sinus asymmetry in 56.6% of the sample and symmetry in 43.1% of the sample. But the results of this finding did not correlated with David & Saxena et al (2010) who reported symmetry of frontal sinus in 58% of the individuals whereas asymmetry in 32% of the sample. The results showed disparity in different populations which might be due tofrontal bone thickness, configuration of craniofacial structures and levels of growth hormone (Belaldavar *et al.,* 2014; Anuj Jain, 2013). In the present study the number of scalloping's in left frontal sinus showed a male predominance when compared to females where as in the case of right frontal sinus it showed no gender predilection which is similar to the finding of Goyal *et al.,* (2013) Yashino *et al.,* (1987) who did not found any sexual dimorphism for the number of scalloping's on the superior border of sinus. This lack of sexual dimorphism may be due to high interindividual variability.

In our study other qualitative variables like presence of outline of upper border, presence of intersinus and intrasinus septa was studied and there is no significant difference between males and females which is similar to the other studies conducted by Yashino *et al.,* (1987), M.Goyalet al., (2013), Uthman *et al.,* (1987). The dimensions of frontal sinus were compared between four age groups and the variance was not significant during the adult life. This finding is in correlation with the results of Rubira– Bullen *et al.,* (2010). In the present study the mean dimensions (width and height) of frontal sinus were assessed and there is statistically significant difference with males having greater dimensions when compared to females. This finding is in accordance to the findings of Belaldavaret al., (2014), HemantMathur *et al.,* (2013), which can be explained by the fact that the gender differences in the dimensions of frontal sinus is influenced by genetic, nutritional, muscular or hormonal factors (Belaldavaret al., (2014), HemantMathur *et al.,* (2013). In the present study straight nasal septum was present in 49% of the individuals which were in contrast to Taniguchi *et al.,* (2003) who observed 13.4% of individuals with straight nasal septum and David and Saxena *et al.,* 2010 who reported 22% of the sample with straight nasal septum.There are no gender variations among nasal septal patterns in the present study which is in correlation with the findings of Taniguchi *et al.,* (2003) and David and Saxena (2010). When the combined use of all the parameters of frontal sinus and nasal septum patterns were assessed we obtained a total of 1868 combinations suggesting a high efficacy and possible usefulness of these patterns to establish a systemic identification procedure.

Conclusion

In conclusion, our results suggest that skull radiographs showing frontal sinus and nasal septum will be a helpful adjunctive tool for forensic identification of particular individual, if appropriate ante mortem data are available. Hence there exists a need to maintain proper patient record to help the forensic team in near future for identification of individual and also for overcoming various annoying situations.

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