Original Article

# Combined Use of Frontal Sinus and Nasal Septum Patterns as an Aid in Forensics: A Digital Radiographic Study

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## Abstract

**Background:** Skull radiographic examination is a potentially useful procedure for the personal identification in cases where fragments of skull persist with no likelihood of identification based on dental arch. **Aims:** The study was to determine the uniqueness and reliability of combined frontal sinus (FS) and nasal septum (NS) patterns as observed on posterioanterior (PA) cephalograms for personal identification. **Materials and Methods:** The randomly selected 149 digital PA cephalograms taken on Kodak 8000C Digital Panoramic and Cephalometric system were evaluated for patterns of FS and NS. Also the distribution of lobulations, area, and ratio of height/width of FS was calculated. The data obtained was statistical analyzed using Pearson's coefficient correlation. **Results:** FS symmetry was observed in 78.5% and asymmetry in 7.3% subjects. Bilateral aplasia was noticed in 5.3% and unilateral aplasia in 8.7% of subjects. The total lobulation of FS was noted more in males on both sides while center lobes were observed slightly more in females. The straight NS was maximally seen followed by reverse sigmoid. The mean ratio of width/height of FS was observed more in males and highly significant correlation was observed with both sexes. The mean area of FS was noted more in males. There was significant correlation found between patterns of NS and FS except in right dominated asymmetrical FS. **Conclusion:** The combined use of FS and NS patterns could be used as method for identification by exclusion in forensics.

**Keywords:** Frontal sinus, Nasal septum, Personal identification, PA cephalograms

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## Introduction

The radiographic comparative analysis, in which antemortem and postmortem records are compared, is frequently used for personnel identification either in human remains or in living persons.[1] Particular attention has been paid to the skull where several structures have the potential to identify an individual, including teeth, frontal sinuses (FS), mastoid processes, sella turcica, vascular groove patterns, nasal septum. The FS are paired, irregular-shaped air-containing chambers, lined by mucoperiosteum, and are located between the outer and inner tables of the frontal bone, posterior to the supercilliary arches, and at the roof of the nose.[2] They are seldom symmetrical. They point upwards beyond the middle part of the supercilious and backwards to the medial part of the orbital roof. The sinuses are divided into several recesses, which communicate with each other through incomplete bony septa.[3] The FS makes the skull lighter and add resonance to the voice. Occasionally, one or both sinuses may be absent. The FS become radiographically evident at the age of 5 or 6 years and develop fully by the age of 20 years. The

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posterioanterior (PA) skull projection is designed to provide a clear view of the frontal and ethmoid sinuses without loss of definition by superimposition of portions of the sphenoid bone. The FS alone has the clearest silhouette in this projection and presents the least chance for error in interpretation.

Schuller[4] suggested that the FS are slightly bigger in males than in females, and the presence of metopic suture is associated with the absence of FS. Some factors can modify the normal anatomy of the FS such as fractures, neoplasias, severe infections, growth hormone level, and mucoceles. In the forensic field, FS is a very convenient part of the human skeleton for personal identification. It is reported that no two persons have identical FS, including identical twins.[5] Other useful features include its relatively stable and resilient structure during adult life.[6] The FS has very strong walls and is preserved intact in human remains as its internal bony structure and arched nature protect it from damage and decomposition.[7] It has been suggested that FS radiographic size and patterns have a potential to be used as aids for personal identification, age, and sex estimation.[8]

The nasal septum (NS) is the bone and cartilage in the nose that separates the nasal cavity into the two nostrils. The cartilage is called the quadrangular cartilage and the bones comprising the septum include the maxillary crest, vomer and the perpendicular plate of the ethmoid. Normally, the septum lies centrally, and thus the nasal passages are symmetrical. A deviated NS is an abnormal condition in which the top of the cartilaginous ridge leans to the left/right or takes sigmoidal/reverse sigmoidal shape.[9] These patterns are stable throughout the adult life and are clearly visible on PA skull views.

This study was undertaken to examine the combined variations in patterns of FS and NS as observed on a PA cephalogram and to use the data in personal identification.

## Materials and Methods

The study was conducted on patients coming for orthodontic treatment, in Surendera Dental College & Research Institute, Sriganganagar, Rajasthan, from March to August 2014. The 149 randomly selected patients comprised 74 males and 75 females aged between 20 to 45 years (mean age 26.01 ± 0.23 years). The exclusion criteria included non-visualization of the FS or NS on radiograph, history of trauma or surgery of the skull or nose, any pathology affecting the nasal cavity or FS, frontal rhinosinusitis, endocrinal or metabolic disorder affecting the growth, and development of FS or nose and syndromic patients. All the subjects were briefed about the purpose of study and a written informed consent was obtained. Institutional ethical approval was obtained to carry out the study.

A clinical examination was carried out for each patient and the selected patients were subjected to PA cephalometry using "Kodak 8000C Digital Panoramic and Cephalometric system" with exposure parameters of 74 kVp, 10 mA, and 13 seconds.

The selected radiographs were analyzed for FS and NS patterns by single Oral and Maxillofacial radiologist. The FS was classified according to symmetry as symmetrical, right or left dominant asymmetry, unilateral (right or left) and bilateral aplasia. [Figure 1] The greatest horizontal dimension was measured from the central septum on both sides. The difference in the right and left side dimensions was divided by the greatest dimension and multiplied by 100. If the result was more than 20%, then it was classified as asymmetrical. The number and highest point of lobulation including both sides and center were also recorded. The measurements were taken in mm using 6.12.24.0 Kodak Dental Imaging software according to the sequence:

1. Draw a line directly between both the orbital cavities, at the nasofrontal suture.
2. The diameter of the FS at the widest points that was the distance between two projected lines that delineate the maximum lateral limits of the right and left FS.
3. The height was measured by drawing a parallel line to the nasofrontal line at the highest superior point of the frontal sinuses.
4. Measure the distance between the both.

The measurements were accomplished according to the parameters[10] as: Only air-filled cavities were considered; two equally high points, measure the one closer to the

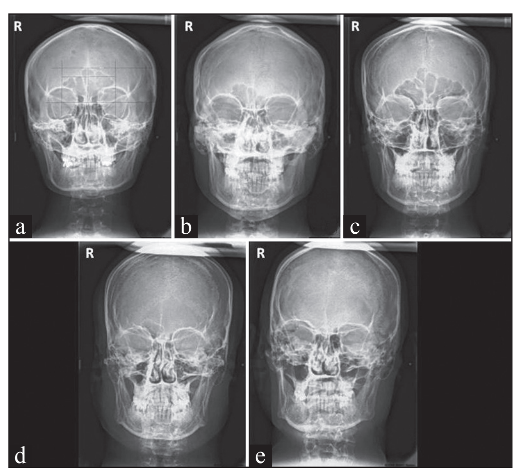


**Figure 1:** Various frontal sinus patterns (a) symmetrical (b) left dominated asymmetry (c) right dominated asymmetry (d) unilateral aplasia (e) bilateral aplasia, R = Right side

intersinus septum; when the highest point was located at a large open curve lobulation, measure the point at the middle of the lobulation; when the highest point was located at a plateau lobulation measure the middle of the plateau.

The NS patterns were recorded according to the features of deviation as seen on radiograph as: Straight (S), simple deviation to the left (L) or right (R), sigmoid type (RL), reverse sigmoid type (LR), and others (epsilon- and reverse epsilon-type; rare types) [Figure 2].

### Statistical analysis

The data obtained were tabulated and input to Statistical Package of Social Sciences (SPSS) software version 20 (SPSS Inc., Chicago, IL, USA). The correlation between various parameters of FS and NS was obtained using Pearson's correlation coefficient and Two tailed t-test.

## Results

The FS symmetry was observed in 78.5% of the individuals (58 males and 59 females) while asymmetry was observed in 7.3% of the subjects (6 males and 5 females). The FS bilateral aplasia was seen in 5.3% (4 males and 4 females) and unilateral aplasia was observed in 8.7% of the subjects. The highest point of the FS lobulations was noted on the left side (53.9%) followed by the right (28.4%) and center (17.7%) [Table 1].

The total number of right and left lobulations was higher in males while center lobes were observed slightly more often in females. The maximum numbers of lobes were observed in the FS symmetrical pattern, followed by left asymmetrical and right asymmetrical patterns. A highly significant correlation was observed between

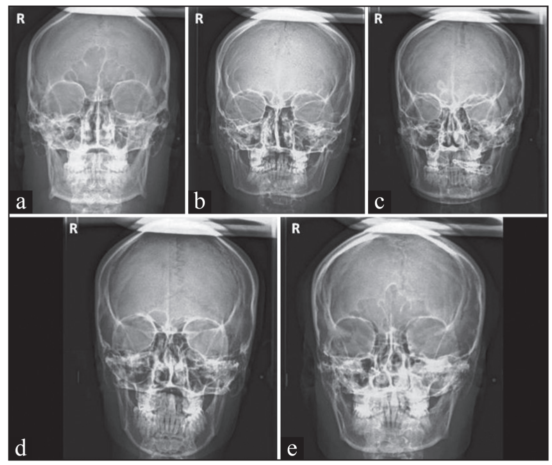

**Figure 2:** Various nasal septum patterns (a) straight (b) right deviated (c) left deviated (d) sigmoid (e) reverse sigmoid, R = right side

**Table 1: Distribution and correlation between frontal sinus patterns with both the genders and highest point of sinus lobulation**

| Gender | Sym | Asymmetry | | | Unilateral Aplasia | Bilateral Aplasia | | Total | | Pearson correlation (r) | | *P*-value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Rt | Lt | Total | | | | | | | | |
| Male | 58 | 2 | 4 | 6 | 6 | 4 | | 74 | | 1 | | – |
| Female | 59 | 1 | 4 | 5 | 7 | 4 | | 75 | | 1.00 | | 0.000** |
| Total | 117 | 4 | 8 | 11 | 13 | 8 | | 149 | | 1.00 | | 0.000** |
| Pearson correlation (r) | 1 | | 0.98 | | 0.99 | 1.00 | | | | | | |
| *P*-value | – | | 0.109* | | 0.075* | 0.009** | | | | | | |
| **Highest point** | **Sym** | **Rt** | **Lt** | **Total** | **Unilateral Aplasia** | **Bilateral Aplasia** | **Statistical analysis** | | **Total** | | | |
| | | | | | | | | | **M** | **F** | **Total** | |
| Right | 37 | 1 | 1 | 2 | 1 | 0 | Pearson correlation (r) | 1 | 20 | 20 | 40 | |
| | | | | | | | *P*-value | – | | | | |
| Left | 57 | 1 | 7 | 8 | 11 | 0 | Pearson correlation (r) | 0.99 | 41 | 35 | 76 | |
| | | | | | | | *P*-value | 0.012*** | | | | |
| Centre | 23 | 1 | 0 | 1 | 1 | 0 | Pearson correlation (r) | 1.00 | 9 | 16 | 25 | |
| | | | | | | | *P*-value | 0.000** | | | | |
| Total | 117 | 3 | 8 | 11 | 13 | 0 | | | 70 | 71 | 141 | |
| Pearson correlation (r) | 1 | | 0.96 | | 0.91 | – | | | | | | |
| *P*-value | – | 0.184* | | | 0.269* | – | | | | | | |

*Correlation is insignificant at *P*-value > 0.05, ** Correlation is significant at *P*-value < 0.05, ***Correlation is highly significant at *P*-value < 0.01 level (2-tailed) distribution of lobes and different patterns of FS. Also, a significant correlation was noted for distribution of lobes and both sexes (*P* = 0.001) [Table 2].

The observed order of NS patterns decreased from straight NS (40.9%), to reverse sigmoid (28.2%), sigmoid (20.1%), right deviated (8.05%), and left deviated (2.7%). No other NS pattern was observed in this study. A significant correlation was found between various patterns of NS and FS except in right dominated asymmetrical FS (*P* > 0.05) [Table 3].

The dimensions (width, height, and area) of FS were assessed in both the sexes. The mean width (46.93 ± 6.43 mm) and height (28.54 ± 3.67 mm) of FS was noted more in males. Also, the mean ratio of width/height of FS was observed more in males. A highly significant correlation was observed in both the sexes and ratio of width/height of FS. The mean area of FS was more in males than females [Table 4].

## Discussion

The uniqueness of FS was initially observed by Zukerkandl[11] in 1875 due to its asymmetrical morphology. In 1927, Culbert and Law described the first human identification through morphological analysis of FS that was accepted in a United States court of law.[12] The study was conducted on subjects of 20 years and above, as the growth of FS completes in both sexes by that age. The selection of age conformed to earlier studies by Camarago *et al.*,[13] and David *et al.*[14] The present study utilized PA cephalogram as FS and NS patterns could be easily assessed with minimal distortion from a single standardized radiograph, if previous records are available.

During the fetal period, the FS 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 a hypoplastic or aplastic sinus. In the present study,

**Table 2: Distribution and correlation of frontal sinus lobes with gender and patterns of frontal sinus**

| Gender | Right lobes | | | Left lobes | | | Centre lobes | | | Total | | | Pearson correlation (r) | *P*-value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Male (M) | 116 | | | 134 | | | 10 | | | 260 | | | 1 | — |
| Female (F) | 95 | | | 110 | | | 16 | | | 221 | | | 0.99 | 0.001* |
| Total | 211 | | | 244 | | | 26 | | | 481 | | | 1.00 | 0.000* |
| **Pattern** | **M** | **F** | **Total** | **M** | **F** | **Total** | **M** | **F** | **Total** | **M** | **F** | **Total** | | |
| Sym | 107 | 87 | 194 | 120 | 91 | 211 | 8 | 15 | 23 | 235 | 193 | 428 | | |
| Rt Asym | 4 | 2 | 6 | 3 | 1 | 4 | 1 | 1 | 2 | 8 | 4 | 12 | | |
| Lt Asym | 4 | 6 | 10 | 6 | 10 | 16 | 1 | 0 | 1 | 11 | 16 | 27 | | |
| Uni Apla | 1 | 0 | 1 | 5 | 8 | 13 | 0 | 0 | 0 | 6 | 8 | 14 | | |
| Bilat Apla | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Total | 116 | 95 | 211 | 134 | 110 | 244 | 10 | 16 | 26 | 260 | 221 | 481 | | |
| Pearson correlation (r) | 1 | | | 0.99 | | | 0.99 | | | 1.00 | | | | |
| *P*-value | — | | | 0.000* | | | 0.000* | | | 0.000* | | | | |

*Correlation is highly significant at *P*-value < 0.01 level (2-tailed)

**Table 3: Correlation of different patterns of frontal sinus and nasal septum**

| Pattern | Gender | | | Frontal sinus parameters | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | F | T | Sym | | | Rt. Asym | | | Lt. Asym | | | Unilateral Aplasia | | | Bilateral Aplasia | | |
| | | | | M | F | T | M | F | T | M | F | T | M | F | T | M | F | T |
| Straight | 29 | 32 | 61 | 27 | 25 | 52 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 3 | 4 | 1 | 2 | 3 |
| Right deviated | 5 | 7 | 12 | 3 | 7 | 10 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Left deviated | 1 | 3 | 4 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 |
| Sigmoid | 15 | 15 | 30 | 11 | 14 | 25 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 1 | 1 | 1 | 1 | 2 |
| Reverse Sigmoid | 24 | 18 | 42 | 16 | 14 | 30 | 0 | 1 | 1 | 3 | 1 | 4 | 3 | 1 | 4 | 2 | 1 | 3 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 74 | 75 | 149 | 58 | 61 | 119 | 2 | 1 | 3 | 4 | 4 | 8 | 4 | 7 | 11 | 4 | 4 | 8 |
| Pearson correlation (r) | 1 | 0.99 | 0.99 | 1.000 | | | 0.49 | | | 0.89 | | | 0.86 | | | 0.95 | | |
| *P*-value | — | 0.000* | 0.000* | 0.000* | | | 0.261** | | | 0.006* | | | 0.014*** | | | 0.001* | | |

*Correlation is highly significant at *P*-value < 0.01 level, **Correlation is insignificant at *P*-value > 0.05, ***Correlation is significant at *P*-value < 0.05; (2-tailed)

**Table 4: Correlation between male and female for frontal sinus dimensions**

| Variable | Gender | Mean | Statistical analysis | | 95% Confidence Interval of the Difference | | Pearson correlation (r) | *P*-value |
|---|---|---|---|---|---|---|---|---|
| | | | | | Upper | Lower | | |
| Age (years) | Male | 25.85 | Mean±SD | 26.01±0.23 | 28.04 | 23.98 | 1.00 | – |
| | Female | 26.17 | | | | | | |
| Width (W) (in mm) | Male | 51.48 | Mean±SD | 46.93±6.43 | 104.74 | -10.88 | -1.00 | 0.000*** |
| | Female | 42.38 | t-test | 10.31 | | | | |
| | | | *P*-value | 0.062* | | | | |
| Height (H) (in mm) | Male | 31.13 | Mean±SD | 28.54±3.67 | 61.51 | -4.44 | -1.00 | 0.000*** |
| | Female | 25.94 | t-test | 10.99 | | | | |
| | | | *P*-value | 0.058* | | | | |
| Ratio (W/H) (in mm) | Male | 1.67 | Mean±SD | 1.65±0.04 | 1.96 | 1.33 | -1.00 | 0.000*** |
| | Female | 1.62 | t-test | 65.80 | | | | |
| | | | *P*-value | 0.010** | | | | |
| Area ($mm^2$) | Male | 1602.57 | Mean±SD | 1350.95±355.84 | 4548.03 | -1846.12 | -1.00 | 0.000*** |
| | Female | 1099.34 | t-test | 5.37 | | | | |
| | | | *P*-value | 0.117* | | | | |

*Correlation is insignificant at *P*-value > 0.05, ** Correlation is significant at *P*-value < 0.05, ***Correlation is highly significant at *P*-value < 0.01 level (2-tailed)

the bilateral aplasia of FS was 5.4% whereas Tang *et al.*,[15] reported non-existence of FS in Chinese Han population to be 16.6%, White and Pharoah[16] had mentioned FS absence in 4%. Similarly, Ponde *et al.*,[17] had found aplasia of 24.7% in their study. A highly significant correlation was found between the aplasia of FS and both sexes in the present study whereas no significant difference was found by Verma *et al.*[18] In our study, the symmetry of FS was found in 78.5% of subjects, whereas Taniguchi *et al.*,[19] obtained 43.1% symmetry in the Japanese population and in a study by David and Saxena[14] symmetry of FS was reported in 58% of the subjects. The unilateral aplasia was seen in 8.7% subjects. The results were consistent with those of Krogman *et al.*,[20] studies. The discrepancy between the frequency in our population and other populations may be due to the number of patients examined, the patient sample, the difference in examining techniques and equipment. In addition, individual health and environmental factors control the FS configuration within each population, contributing to its variability.

In accordance with previous studies, the mean width, height and area of FS in males was significantly larger than females.[21] Morphological differences in the cranium between both sexes are determined mainly by genetic factors which might be the reason for larger FS in males.[22] According to Prossinger and Bookstein,[23] the estimated maximum growth rates of FS for males occur 3.02 years later than females. This variability is considered to be a useful tool in forensic identification.

Varied nasal septum deviation forms were seen in our study. The straight NS was maximally seen followed by reverse sigmoidal. These results are in accordance with Taniguchi *et al.*,[19] and David and Saxena[14] studies. Genetic factors, trauma, compression of nose during childbirth, some genetic connective tissue disorders such as Marfan syndrome, Ehlers-Danlos syndrome, Homocystinuria cause deviated NS. In the present study, all other causes were ruled out except genetic.

In the present study, the highest point of FS was located maximally at the left cavity (53.9%), whereas Rubira-Bullen *et al.*,[24] found it over midline (78%). Gulisano *et al.*,[25] observed that left FS lobes tend to be larger than the right ones, a fact that could be observed by Ponde *et al.*,[3] though they did not find any difference between the sexes.

There was a significant correlation found between various patterns of NS and FS except in right dominated asymmetrical FS ($P > 0.05$). These results were in accordance with Taniguchi M *et al.*,[19] studies, hence it has been suggested that the combined use of different FS and NS patterns contributes to a more precise identification than using either pattern alone.

The current study has a few limitations. First, only individuals age 20 years and above were considered due to the varying FS size in childhood development. Second, area was measured by a mathematical method, thus a more precise measuring tool should be used with less margin of error.

## Conclusion

A significant correlation was found between patterns of NS and FS except in right dominated asymmetrical FS pattern, hence combined use of FS and NS patterns could strongly be used in forensics for identification by exclusion.

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