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Review Article

Frontal Sinus Cavities and Sex Determination: A Narrative Review

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Abstract

Frontal sinus radiographs are used extensively by forensic experts in cases where bodies are decomposed or dismembered and visual assessment is not possible. Frontal sinus assessment by radiographs can be chosen as skull is hard and retained well during the process of decomposition. Positive identifications are made by using ante-mortem radiographs if available as records and comparison is made to identify the individual. On the basis of demography and races there are many biological variations are observed which are supported by frontal sinus studies. Evolution, diversity and migration of human populations can be studied by physical anthropology using frontal sinus as one of the parameters. This review article aims to explore the diversity of dimensions of frontal sinus cavities and their use in determination of sex.

Keywords: Frontal Sinus; Positive Identifications; Patterns and Cavities of Frontal Sinus; Symmetry of Frontal Sinus

Introduction

Determination of sex using bones and radiographs has always been an active area of research among scientists. In the past morphological features of skull were used to determine the sex but use of frontal sinus in establishing sex is recent. On reliability of using frontal sinus as a tool to determine sex, there are mixed opinions. Other than anthropometry, forensics and sex determination frontal sinus morphometry provides general pattern of sinus in population of particular area [1,2]. Like finger prints, even the frontal sinus has been found to be very unique in every individual, even in monozygotic twins. The development is supposed to be completed at the age of 20 [3]. Radiographs of the frontal sinus are commonly recommended by doctors as the major research modality, and they are employed by archaeologists and forensic professionals to do the morphometric analysis.

Materials and Methods

The databases PUBMED, PUBMED CENTRAL, and Google Scholar were used to conduct a computer-based literature search. We evaluated and included relevant full-text articles written in English without specific range in years. Editorials, commentary, discussion papers, abstracts from conferences, reviews, and duplicate submissions were not accepted. Only cross-sectional studies with full-text papers were selected. Thirty three relevant articles were selected for the evaluation after being read carefully and review report was prepared.

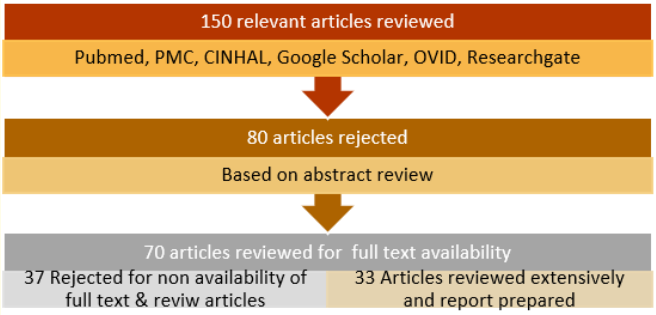

Figure 1: Literature Search.

Summary of reviewed articles

Prossinger and Bookstein on studied 300 plain radiographs related to the adults including both sexes. The analytical outcome of the study indicated that the results were variable for both sexes. The patterns observed were distributed log-normally but with a high degree of variance. The mean of the distribution was found to be the function of the age and the variances differ by sex. The study results revealed the implications of frontal sinus parameters for biological aspects [4]. Frontal sinus has been used as a tool for identification of unknown bodies in cases where no physical identification is possible due to decomposition of soft parts. Though he used both CT and radiographs of paranasal sinuses of 100 cases out of which 38 were of males and 62 were of females. Three parameters used in this study were frontal sinus (F), inter-sinus septum (S) and the scalloping (S), as a whole these were called as FSS system. The results of study exhibited a success rate of 98% in identification of sex. However, the researcher had stated that measurements were prone to bias so the success rate may decline in actual practice of FSS in sexual dimorphism [5]. The pattern of frontal sinus studied on Brazilian population by Rubaira., *et al*. using 158 plain radiographs in Caldwell view were analyzed. The mean age of sample was 34 years. The participants enrolled in study were 80% males and 20% females. Five groups were constructed on the basis of age of participants; first group had 14 to 20 years of age, second group had 21 to 30 year of age, third group had had 31 to 40 years of age, 4th group had 41 to 50 years of age and last fifth group had participants above the age of 51 year. The distribution of subjects was 11.7% in first group, 24.1% in second group, 33.8% in third group, 15.2% in fourth group and 3.5% in 5th group. The analysis of data revealed that highest point of frontal sinus was on midline in 78% of cases, on left side in 13.1% of cases and on right side in 8.9% of cases. The morphometric results revealed a mean height of 39 mm and a mean width of 68 mm. However, the sizes of the cavities were fairly variable. 21.4% of the subjects exhibited larger right side, 39.3% had larger left side while 39.3% had almost the same size of both the frontal sinus cavities. Overall pattern of frontal sinus in the studied population (N = 158) exhibited 1.3% agenesis, 3.8% unilateral frontal sinus and 3.2% consisting of two or three small individual cavities within it. The results also revealed a significant correlation between the width and height but not among the different age group. As there were no significant differences among various age groups and cavities of right and left sinus was also almost symmetrical.2 100 Paranasal sinus radiographs in Water's view were analyzed by Goyal., *et al.* to test whether the frontal sinuses are predictor of sex. There were 50 males and 50 females among the total subjects included in the study. Parameters studied were dimensions of the frontal sinus cavities and outline of upper border. However, there were unique patterns of frontal sinus among both males and females but regression analysis exhibited only 60% success rate in sex determination. However, the sample size was small to make generalization and the researcher stated that current frontal sinus classification may lead to loss of information when the features requiring visual observation are grouped together. Moreover there are differences in frontal sinus parameters according to race, ethnicity and demographic conditions. The results obtained were statistically not significant or of limited value for sex determination purpose by using frontal sinuses. The lower value of regress for sexual dimorphism may be due to the fact that frontal sinuses vary significantly with individuals. The results have suggested that frontal sinus alone may not be useful for prediction of sex but they can be used only as adjunct to other methods [6].

In another study carried out on 66 subjects consisting of 40 females and 26 males in Tehran reported that there were differences in morphometric dimensions among males and females. The archival records of 2003 to 2012 were considered for the measurements. The average age of samples included in study was 19.28 ± 4.46 years (13 to 31 years). In two female patients (3%) bilateral aplasia was observed and in three cases (4.5%) (two males and one female) had unilateral sinus aplasia. Intra-class correlation coefficient (ICC) for inter-examiner reliability was

found to be 0.81, which is considered as an excellent correlation. The size of the frontal sinus exhibited many variations. The average area of the left and right frontal sinus came out as 3.55 ± 1.76 cm and 3.49 ± 1.96 cm respectively, which was not significantly different (p value = 0.534). The results had shown the mean of dimensions in both sagittal and frontal plans were greater in males compared to females; however, such differences were not statistically significant except the sinus width in frontal plane (p value = 0.17). Scallops were found to vary extensively in both males and females.[7] When the pattern of frontal sinus i.e., symmetry or asymmetry and nasal septum pattern were used together can support the personal identification and sex determination. The combination of frontal sinus pattern and nasal septum pattern was applied on 80 individuals enrolled in the study consisting of 40 males and 40 females in Jodhpur, Rajasthan. The result of the study revealed nine classifiable patterns of frontal sinus in 32.5% of individuals and in 67.5% of cases had unique and unclassifiable patterns. The average width of frontal sinus in males was observed as 61.66 ± 8.38 mm while width in case of females was 36.67 ± 6.59 mm which was found to be highly significant statically with p value 0.001. 77.5% of total individuals' i.e., 62 cases had bilaterally symmetrical pattern and 22.5% of total cases i.e., 13 individuals had asymmetrical pattern of frontal sinus. The nasal septum pattern observed had shown an order of 41.25% straight, 21.25% left deviated, 27.5% right deviated, 6.25% sigmoid and 3.75% reverse sigmoid. Combination of frontal sinus pattern and nasal septum pattern as per this study are can independently be used in positive personal identifications [8].

In another study on 149 digital radiographs in Sri Ganganagar, Rajasthan dimensions of frontal sinus and nasal septum pattern were observed. 74 males and 75 females with a mean age of 26.01 ± 0.23 year were enrolled in the study. 78. 5% of individuals among which were 58 males and 59 females had shown frontal sinus symmetry while only 7.3% had asymmetric frontal sinus. Out of total 149 subjects 5.3% had bilateral sinus aplasia and 8.7% of subjects had unilateral sinus aplasia. Mean values of width in males was found to be 51.48 mm while in case of females it was 42.38 mm and it came out as statically significant. For the pattern of nasal septum, the results revealed 40.9% subjects with straight nasal septum followed by reverse sigmoid 28.2% after that was sigmoid in 20.1%, right deviation in 8.05% and lowest were cases of left deviation i.e., 2.7% [9]. In karnataka, radiographs of 200 subjects were extensively studied by Soman., *et al*. [10]. by subdividing in different age groups. Among the enrolled participants 100 were males and 100 were females. Four groups were formed with age groups 14 to 20 year, second group had age from 21 to 30 year, third group had age group between 31 to 45 year and fourth group consisted of participants above the age of 45 years. The mean values of width and height were higher in males than in females. The mean of right width in males was 2.36 ± 1.29 mm and females it was 2.24 ± 1.04 mm. Similarly the mean of left width in males was found to be 2.92 ± 1.04 mm while in case of females it was 2.61 ± 0.82 mm. it was observed that the left width of frontal sinus increased with age in both the sexes except in the last group where participants had age more than 45 year. The average frontal sinus area was higher in males i.e. 5.00 cm2 than that of females which was 3.89 cm2 and had shown statically significant results. Bilateral asymmetry was also found to be having statically significant values [10].

Pandeshwar., *et al*. studied 100 paranasal radiographs to evaluate the uniqueness of configuration of frontal sinus and in determining sex for personal identification. The range of age of study participants was 21 to 54 years. Partial septa and supraorbital cells were studied. It was observed that right partial septa were statically highly significant with p-value of 0.001. Discriminative analysis performed on collected data revealed that only 65.7% of the cases could be identified accurately by assessing septa and supraorbital cells of frontal sinus. Out of this 65.7%, the identification was more accurate in case of females with 67.3% of diagnosis than males which were only 64.0% only. The 6% of total subjects enrolled exhibited bilateral sinus aplasia while 8% of them had unilateral aplasia. The results of this particular study were not in support of using frontal sinus as a tool for sex determination [11]. 140 PA cephalograms were studied by Varsha Kanjani., *et al*. in Devangere. The study consisted of 70 male and 70 female radiographs which were evaluated for frontal sinus dimensions and nasal septum pattern. The mean age of male participants was 27.37 ± 6.78 years and that of females was 24.38 ± 5.30 years. The mean of frontal sinus height in males was more i.e., 21.28 ± 2.64 mm than in females which was found to be 15.64 ± 2.05 mm. 78.57% of total subjects exhibited symmetry of frontal sinus. Bilateral aplasia of frontal sinus was observed in 17 subjects out of which 8 were

males and 9 were females. Right unilateral aplasia was observed in 9 males and 9 females while left unilateral aplasia was found in 3 males and none in females. The nasal septum pattern was in order of type straight in 71%, left deviation in 13%, right deviation in 11%, sigmoid in 3% and reverse sigmoid in 2%. The outcome of the study was in support of using frontal sinus for sex determination purposes but only as an adjunct to other methodologies of personal identification [12].

It has been well accepted that frontal sinus pattern vary too much when studied on radiographs and it has shown particular pattern for each individual too. Manual human identification studies involve utilization of frontal sinus radiographs. A comparison of ante mortem and post mortem radiographs have shown equal importance in identifying an individual by image superimposition and matching experiments. Equal error rate came out as 11.56 percent for a threshold value of 92 and calculated by using area, width and diameter. Other parameters used in study were perimeter, height and circularity which were not significant. The result of study favored the use of frontal sinuses in semiautomatic way for personal identification. The most important benefit of this method was that it can be helpful for forensic identification even if the image quality of radiographic films is poor or below average [13]. Hussein., *et al*. studied comparative assessment of sinuses using x-ray technique and CT technology. A total of 240 patients were studied out of which 129 were females and 111 were males. The age study participants were between 8-95 years. The pattern of sinus pathology was observed and it was found maximum in the age group of 19 to 29 year and minimum in the age above 74 years old. The frontal sinus and other sinuses except maxillary sinus were drained under the effect of gravity where no anatomical or pathological obstruction was observed. For the purpose of clinical diagnosis in case of sinus cavities, the use of radiography was not highly recommended because specificity of sinus cavity condition could not be estimated. However, the extensions of cavity can be clearly seen on radiographs but for establishing clinical diagnosis CT technology can be more helpful at early stages of sinus pathologies. The efficacy of radiographic films in diagnosing polyps and mucocele was found to be 66.7% and 30.8% but 0% in diagnosis of fungal sinusitis [14]. Positive identifications are required mainly for medico-legal purposes. This approach can be made by comparing ante-mortem and postmortem radiographs. Ante-mortem radiographs are usually available with family doctor or police records which can be used for comparison. Nowadays this technique has become popular and one of the preferred applied techniques in medico-legal investigations. This method has been successfully used for the identification of unknown bodies. The study brought attention to the potential use of frontal sinus variability in this context. The technique basically relies on the concept that characteristics of bones visible on radiographs may be adequately unique to offer the aid in the confirming the identity of a person based on the uniqueness of these features. Often, such positive identifications are done by utilizing several features in combination, but radiographic identification can be done on the basis of a single bony feature if it is deemed to be distinctly unique.

As of now, the comparative radiography has been recognized well for purpose of personal identification in the field of forensic anthropology. Apart from this it can be more reliable than as compared to fingerprint and dental identifications. However, many have recognized that the richness of normal anatomical details revealed on radiographs is very important. There is occurrence of non-pathological anatomical features available for comparison in most radiographs which can be used for identification by Joblanski and Shum in 1989 [15]. This technique makes many parts of the skeleton usable for identification, and while those that tend to be more variable may be more reliable, nearly every bone in the body has been used for identification [16]. It is suggested that in the regions where the weather is very cold or cold-dry, the populations has adapted and exhibit smaller sinus cavities and reported that Alaskan Eskimos have relatively small sinus surface areas with a high frequency of bilateral absence. West Hudson Bay Eskimos are reported to have sinus surface areas smaller than Alaskans. A strong positive correlation was found between annual seasonal temperature fluctuation and frontal sinus dimensions [17]. In an extensive study involving 946 radiographs studied the uniqueness of frontal sinus pattern using outline of upper border. 305 of cases involved in study had ante mortem and post mortem records. The variability was assessed by using a new approach known as elliptical fourier analysis which was basically a geometric morphometric approach. Quantitative analysis of data generated set of coefficients and curve of data sets revealed a significant difference in shapes when compared with Euclidean distance between the elliptical fourier analysis based outlines. There were

significant results in positive identifications particularly in cases where ante mortem and post mortem radiographs were available. Various ratios obtained using elliptical fourier analysis, coefficients revealed very high probability of correct identifications using sinus outlines and probability of wrong identification was relatively small. The results of study concluded uniqueness of frontal sinus upper border outline and sufficient enough to use in personal identification by forensic experts. However, the study was limited to population of Knoxville only so the results can be said to be applicable to that population till more researchers favor the result [1].

Frontal sinus being the second largest among sinuses and being in close proximity to frontal lobe of brain remain the topic of interest to clinicians, anthropologists and forensic experts. Various methods have been employed to study different aspects of frontal sinus dimensions and the cavity. Other than computed tomography and manual assessment on radiographs there other methods used for morphometric purposes like auto-cad image analysis, photoshop and automatic sinus identification by java are also used. This study used radiographic films image analysis by auto-cad to confirm whether the frontal sinus can be used as a growth indicator in children or not. The archival radiographs of 30 children ranging from 8 to 11 years were studied for assessing vertical growth pattern, horizontal growth pattern and average growth pattern assigning 10 children for each pattern. The mean values of frontal sinus are for horizontal, vertical and average group was found to be 96.8 ± 58.3, 107.5 ± 48.2 and 227.6 ± 56.9 respectively. The growth of frontal sinus is synchronous with craniofacial growth hence the result of study supported the evidence of using frontal sinus to predict the growth [18]. A sexual dimorphism study on 300 digital radiographs was conducted by Beladvar., *et al*. in the region of Belgaum, Karnatka for evaluating sex dimorphism. The age of participants was from 18 to 30 years and gender distribution was 150 males and 150 females and the analysis was done in adobe photoshop. Bilateral sinus aplasia was notice in a total of 4% individuals and unilateral sinus aplasia in 1.3% of male participants and 3.33% of female participants. The statistical analysis on remaining 288 participants exhibited an average right height of 1.47 ± 0.749 cm in males and 1.17 ± 0.558 cm in females while average left height was 1.35 cm in males and 0.96 cm in females. Mean values of right width 2.64 ± 0.875 cm in males and 2.22 ± 0.722 cm whereas left width was found to be 2.33 ± 0.787 cm in males and 1.94 ± 0.696 cm in females. The area observed was more in males than in females for both the cavities. All the parameters were statically highly significant. Left height and left area were found to be most important in sex determination upon applying regression analysis. The accuracy rate was found to be 64.6 percent in females and 59.4 percent in case of males. For this study the concordance index was favorable in sex identification with 50% probability of error [19]. Another study on archival records of 80 patients studied the frontal sinus morphometric and interrelationship with craniofacial features. The age of participants was from 16 to 25 years with a mean of 17.76 years. The mean of frontal sinus area was found to be 310.50 which was statically significant for estimation of mandibular size. Size of sinus cavity was directly proportional to size of mandible. The results also revealed that the area was larger in cases with mal-occlusion which can contribute to variation in development of facial features. Frontal sinus area was found to be statically significant in predicting mandibular length, symphysis width and condylar length. However the morphometric dimensions assessed in the study were also used for finding correlation with cranial deflection and facial axis angle for which no significant reading was observed [20].

Rennie., *et al*. studied 480 patients at Durban, South Africa including 276 males and 204 females studied paranasal sinuses individually. The study participants were from the age 1 to 25 years old with the mean of 14.5 years. It was observed that up to the age of 18 years the growth patterns were similar both in males and females but after the age of 18 growths were less in case of females than in males. The cavity of right frontal sinus was statically significant and found to be larger in males. The pattern of growth was synchronous with age with peak growth observed during puberty. The growth in al paranasal sinuses is slow from 1 to 7 year of age and gradually increases thereafter and reaching the peak during 14 to 18 years of age. The cavity favored more sex difference in older age than during younger age. It was also demonstrated by the study that growth of cavity can continue even after the age of 25 years. Other sinuses have not shown significance in sex dimorphism but size of cavities of all the sinuses were found to vary considerably among all age groups. The outcomes of study variables of South African population can be used in comparative

study with other populations [21]. A comparative study was undertaken by Fernandees on 53 crania of two different races in London. The two different races included in the study were European (N = 26) and Zulu (N = 27) (a South African race). There were 13 adult male and 13 adult female crania of age between 19 to 75 years in the European race and 13 adult male and 14adult female crania of age between 60 to 90 years old. The mean age of European race was 49.42 years while in that of Zulu race is 40.16 years. The highest cavity of frontal sinus was observed in European males with an average of 25. 99 mm while the European females had minimum height of sinus cavity with an average dimension of 14.17 mm. Sex determination was possible in 91.8% of cases with combination of ethmoidal, sphenoid and frontal sinus dimensions. Individual sinus parameters were not found significant in sex identification. Chinese researchers conducted a study to evaluate the application and importance of the frontal sinus patterns in forensics. 198 subjects of Chinese Han population were examined and out of which 165 subjects had bilateral presence of the frontal sinus cavity. The study was based on Yoshino's model of frontal sinus patterns. A total of 12 parameters of the frontal sinus were studied. Only three subjects from this study exhibited similar codes as per Yoshino's method. The cases with unilateral sinus and fewer arcades on upper border of sinus cavity were less likely to be identified. The parameters studied showed better discrimination power in Chinese population and thereby concluding the success of study to be applied for personal identification [22].

Lateral cephalograms were primarily used for detecting cranial injuries and various outlines were used for purpose of basic identifying features of an individual. The cranial vault outline can be studied either by visual comparisons of radiographs or by elliptical fourier analysis which estimates the morphometric dimensions. The analysis performed on 858 adults and 148 juveniles revealed that probability of identification was 97% in case of lateral cranial radiographs while it was 99 percent when radiographs of cervical vertebrae were used. Numbers of concordance points were established for making positive identifications. In case of lateral cranial cephalograms the points were based on frontal sinus cavity, orbital plates, glabella, sella turcica, and cribriform plates. The 97% of positive identification in cranium were made by at least two concordance points. Only 79 percent of lumbar vertebrae radiographs were able to correctly identify the individual when the concordance points were four or less while only one or more point of concordance was required for cervical region to get a result of 99% correct identification. The study could develop a system for comparing radiographs of various regions. However vault shape was not found to be unique and thereby not significant for making positive identifications [23].

Radiographs of 50 individuals including 25 males and 25 females were analyzed to study morphometric parameters and their efficacy in personal identification. The age of study participants was in a range of 25 to 50 years. Pattern of Frontal sinus was observed in term of symmetry or asymmetry and Nasal septum patterns were observed in terms of degree of deviation. Classification done on the basis of these patterns, 41 unique combinations were obtained. Nine subjects exhibited the same pattern as that of one of the 41 unique patterns observed. Symmetrical frontal sinus cavity was observed in 13 cases of males and 16 cases of females accounting for a total of 29 out of 50 subjects. The 4% of participants exhibited bilateral sinus aplasia and 6% of total participants had unilateral aplasia. The study results revealed that these unique patterns of frontal sinus and nasal septum patterns had significant individual variation [24].

In another study 98 radiographs of Italian population were analyzed for study of frontal sinus. The age of study participants were ranging from 17 year to 98 years. The pattern of frontal sinus was studied by tracing the outlines of upper border of frontal sinus cavity on right and left sinus. This study was intended to develop an approach for positive identifications. They followed the Yoshino's method for constructing patterns of frontal sinus except first two features. These features were size of frontal sinus and bilateral asymmetry of the cavities and these were replaced by left frontal sinus area/left orbit area and right frontal sinus area/ right orbit area respectively. There were two groups containing 99 kinship samples and 98 control samples. In kinship group there were 11 bilateral cases of sinus aplasia and 2 cases of unilateral sinus aplasia (1 on right side and 1 on left side). In the control group, there were 10 cases of bilateral sinus aplasia and 8 cases of unilateral sinus aplasia (5 on left side and 3 on right side). The results of this study revealed the efficacy of frontal sinus patterns in identifying the unknown skeletal remains in the field of forensic anthropology [25].

The importance of application of frontal sinus dimensions in personal has been documented by Silva., *et al*. Silva., *et al*. published a case of correctly identified skeletonized body with the help of frontal sinus morphology. The skeleton was found in Goias, Brazil and remains were studied with various approaches. With the help of radiographs and CT scans, images were processed and skull structure was reconstructed. Post mortem radiographs of skull with clear frontal sinuses were traced with medical records of police and hospitals. Post-mortem radiographic records were matched with ante-mortem records available. Finally they were able to find a matching ante mortem radiograph with completely similar morphological features as per post-mortem frontal sinus dimensions which was taken seven years before the skeleton found. Tracing the records and history it was confirmed that the ante-mortem and post-mortem radiographs were of same person thus successful personal identification was made. The parameters of frontal sinus which were taken into consideration for identification purpose were bilateral expansion of sinus cavity, side of greater expansion, number of lobes present on right and left side, presence of median septum and intermediate septa. The results of study were undoubtedly facilitating the use of frontal sinus in personal identification [26].

In another study on 216 subjects which was carried out by Erica Crosta has put an emphasis on frontal sinus morphometry among different age groups. Total of one twenty-four females and ninety-two males were included in the study. Three sub-groups were formed with varying age groups. First group consisted of age between seven to eleven years, second group had age range of twelve to fifteen years and third group had the subjects from the age of sixteen to twenty years and dimensions of frontal sinus were recorded. The average maximum height of right frontal sinus in males was found to be 9.7 mm in group one, 11.6 mm in group two and 14.16 in group three while in case of females it was 8.3 mm in group one, 11.6 mm in group two and 11.45mm in group three. On the other hand, the average maximum height of left frontal sinus in males was found to be 9.7 mm in group one, 12.9 for group two and 14.15 in group three while in females it was observed as 8.8 mm in group one, 12.04 in group two and 11.99 in group three. The results of this study revealed that maximum height of right frontal sinus was significantly higher than maximum height of left frontal sinus. Comparing the average width of right frontal sinus in males and females the dimensions observed in males were 21.7 mm in group one, 24.3 mm in group two and 25.7 mm in group three while in case of females it was found to be 20.3 mm 23.04 mm and 22.8 for group one, two and three respectively. The left frontal sinus had average width of 20.5 mm, 24.5 mm and 25.9 mm in males and in case of female it was 21.6 mm, 25.6 mm and 23.4 mm for group one, two and three respectively [27]. Another study was carried out on frontal sinus radiographs of one hundred and eighty six individuals. Out of 186 subjects only one hundred and forty were found suitable for study as per inclusion criteria. The average age of included males was 27.37 years and 24. eighty-six females. The average maximum height of frontal sinus was observed as 21.28 ± 2.64 mm in males and 15.64 ± 2.05 mm in females. The results exhibited average height to be statically highly significant with p-value of 0.000. The average width of frontal sinus was recorded to be 53.15 ± 7.15 mm in males while 33.22 ± 8.87 mm in females. 78.57% of subjects exhibited symmetrical frontal sinus cavity. Rest 21.43% subjects exhibited asymmetrical patterns of frontal sinus which accounted for 30 subjects. The 9 of them has right asymmetric pattern and 21 has left asymmetric frontal sinus cavity. Bilateral frontal sinus aplasia and unilateral frontal sinus aplasia was observed in 16 and 21 subjects respectively. Nasal septum patterns were also observed Page | 28 for which the results revealed 66.66% straight, 12% left deviated, 10.66% right deviated, sigmoid in 2.6% and reverse sigmoid in 1.33% of cases [23].

A retrospective study was conducted in Nigeria by Eboh., *et al*. on radiographs of 216 subjects. The radiographs of Caldwell's view of the years between 2005 and 2015 were analyzed. The results revealed by this study have shown great significance for almost every parameter studied. The average height of right-side frontal sinus cavity in males was 3.86 ± 1.13 cm while in females it was 3.63 ± 1.13 cm with p-value 0.11. The average height of left frontal sinus cavity noticed was 3.97 ± 0.10 cm and in females 3.59 ± 0.11 cm with p-value of 0.01 i.e., highly significant. On the other hand width of right side frontal sinus cavity in males was observed to be 3.41 ± 0.10 cm and in females it was 3.36 ± 0.11 with p-value of 0.719. Width of left frontal sinus cavity in males was found to be 3.21 ± 0.11 cm with p-value of 0.00. However, the value of all the parameters measured was found to be higher in males than females but maximum significance was shown by left width while the right

width was of least significance. In the Nigerian population the frontal sinus parameters were found to support the identification of sex for various purposes [28]. The results of study conducted by Eboh., *et al*. were also supported by Mathur., *et al*. in which 40 subjects were considered for study (20 males and 20 females). In his study the average maximum width of frontal sinus cavity of both sides was measured on plain radiographs was found 80.6mm in case of males and in females it was 72.75 mm in females. The male frontal sinus cavity had average maximum height of 38.5 mm among males while it was measured 33.1 mm. both the parameters were more in males than in females and with statically significant results. Hence, favor the determination of sex using study results [29].

In an extensive study conducted by Taniguchi., *et al*. in Osaka City using one hundred and sixty three clinical cases and two hundred and nine autopsy cases for analyzing nasal septum patterns and frontal sinus dimensions revealed interesting results which are shown in the tables below.[30] Parameters of frontal sinus cavity in many studies have been found to be slightly larger in males and it is also documented by Verma., *et al*. She studied height and width of frontal sinus cavity on either side on radiographs of 100 subjects (50 males and 50 females). 8 radiographs were excluded due to unilateral and bilateral aplasia. The mean width of left frontal sinus cavity was recorded to be 28.4 mm in case of males while 27.4 mm in case of females. On the other hand, width of right frontal sinus cavity in males was 30.4 mm while in females it was 27.4 mm in females with significant statistical results. Left frontal sinus cavity had an average dimension of 20.9 mm in males and 17.9 mm in females. On right side the average size of frontal sinus cavity was 19.3 in males and 17.5 in females. Statistical significance of results favors the importance of radiographic frontal sinus anthropometry in personal identification [31]. In another study, the patterns of frontal sinus and nasal septum were studied on radiographs of 52 subjects in Bhimavaram area of India which had significant results. The 66% of cases among males and 78% of cases among females exhibited asymmetric patterns of frontal sinus cavity. Lobulations were found more in males as compared to females and it was statically highly significant. As far as nasal septum pattern was concerned, in males 97% of cases were found with straight nasal septum pattern, 3% were with left deviated nasal septum and no other pattern was observed among study subjects. In case of females, straight nasal septum pattern was found in 87% of cases, deviated to left in 9% of cases and 4% of them exhibited right deviated nasal septum pattern [32]. A therapist must be aware of the pattern and appearance of frontal sinus cavity in the population they treat, even if it may or may not be a reliable indicator of sex for use in forensics [33].

Conclusion

It is clear from review of above research studies that frontal sinus measurements cannot be used as a rigid guide for gender identification. The differences in the outcomes of various groups are astounding. It may provide even average identification utilising frontal sinuses; however, it might not be reliable for identifying purposes for one group. However, it is crucial that different populations be aware of the frontal sinus structure and its proportions. Knowledge of the potential size and pattern of the frontal sinus cavity may help with better treatment of sinus-related issues, whether they are caused by illness, a condition, or trauma to the cavity. It has been shown that the growth and development of the frontal sinus cavity are influenced by both environmental factors and genetic composition. The architecture of the sinus cavity in every population is influenced by factors such as growth hormone levels, the density of the frontal bone, and general face and cranial structure.

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Conflict of Interest

NIL.

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