Original Article

Radiomorphometric Evaluation of the Frontal Sinus in Relation to Age and Gender in Saudi Population

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Abstract

Background: Radiographs have been used for forensic identification purpose. At times when only skull remains are found and other means of identification fail, radiographs of skull may be used for identification purpose. **Aim:** The objective of this study was morphometric evaluation of the frontal sinus by using digital posteroanterior skull radiograph in relation to age and gender and to establish its forensic importance. **Materials and Methods:** The study was conducted at Alfarabi Private College for Dentistry and Nursing, Jeddah, Kingdom of Saudi Arabia. It included 400 subjects (200 males and 200 females), aged 14–70 years. Radiographs of the individuals were taken by digital radiography, and morphometric evaluation of frontal sinus was carried out by using Adobe Photoshop CS3 Extended. **Results:** Unilateral absence of sinus was noted in 2.5% males and 1.5% females. Bilateral absence was noticed in 2% males and 0.5% females. Right and left frontal sinus symmetry was seen in 83.20% of the individuals. The left-dominated asymmetry was observed in 6.98% individuals. The right-dominated asymmetry was observed in 9.82% individuals. Simple logistic regression analysis of gender by different variables showed right width and left width, which are most suited regressors for sex determination. The rate of accuracy in classification of males and females varied from 67.70% to 95.90%. Stepwise multiple regression analysis of estimation of age by different variables showed right sinus height is the best predictor of age. **Conclusion:** In this study, the radiographic images of the frontal sinus showed significant morphological difference in relation to age and gender in Saudi population. On the basis of this evidence, it is proposed that the morphologic evaluation of frontal sinus can be used for personal identification.

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Introduction

Human beings are born with an identity and deserve the right to die with an identity.[1] The term identity refers to the determination of the individuality of a person.[2] The identification of a dead body may be required in cases of sudden and unexpected fatalities such as explosions, fires, accidents involving different modes of transportation, mutilated or decomposed mortal remains, or criminal actions, which frequently need great medicolegal expertise.[2,3] Various methods are used to establish the identity of unknown remains. The reliability of each method varies and depends on the available bones and their condition.[4] The only method that can give a totally accurate result is the deoxyribonucleic acid (DNA) identification, but it cannot be used in all situations for several reasons.[2,4]

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Morphological features depicted on the radiographs must meet the following two requirements in order to be of forensic identification worth: first, the feature must be unique to the individual; second, it must remain unchanged over time despite the continuing life processes. The frontal sinuses fulfill both these criteria. The first study of the anatomy of the frontal sinuses using radiographic methods was conducted by Turner and Porter.[5]

The aim of this study was morphometric evaluation of the frontal sinus by using digital posteroanterior (PA) skull radiograph in relation to age and gender and to establish its forensic importance.

Materials and Methods

The study subjects were selected from the outpatients visiting the Department of Oral and Maxillofacial Surgery at Alfarabi Private College for Dentistry and Nursing, Jeddah, Kingdom of Saudi Arabia, between the age range of 14 and 60 years. The study approval was obtained by the institutional ethics committee (ethical approval letter number: 1907/01), and informed consent according to the World Medical Association, Declaration of Helsinki, was obtained from the patients who participated in the study. Sample size with a power of 90% was estimated before the start of the study and based on statistical analysis, the number of subjects (n) needed was 384 (so approximately 400 subjects were included in the study).

A total of 400 subjects (200 males and 200 females) were divided among various age groups of ≤20, 21–30, 31–40, 41–50, and 51–60 years, including equal number of both males and females. Subjects were included in the study after recording their demographic data, brief history of present illness, past medical or surgical history. A copy of birth certificate was obtained from the subjects (to compare with the radiographic results later).

Inclusion criteria

1. Apparently healthy individuals with no visible features of asymmetrical skull.
2. Age range of the patient 14 years onward.

Exclusion criteria

1. Hereditary facial asymmetries.
2. History of orthodontics treatment or orthognathic surgery.
3. History of maxillofacial trauma.
4. History or clinical characteristics of any type of systemic disorders such as bone diseases, nutritional and endocrinal diseases.

Methodology

Radiographs of 400 individuals were taken using Kodak 9000 Extraoral Imaging System (Marne la Vallee Cedex 2, France). Digital PA views of the skull were taken by a single operator. The position of patient's head was standardized according to manufacturer's instructions. All radiographs were assessed so that only high-quality and correctly positioned radiographs were included. Carestream Dental imaging software 6.13.0 CS 3D (Toulouse Cedex 1, France) Imaging was used and the images were analyzed using Adobe Photoshop CS3 Extended software (San Jose, CA, USA).

Frontal sinus

Following measurements were taken on PA view as suggested by Camargo *et al.*[6]:

1. Right frontal sinus height and width
2. Left frontal sinus height and width
3. Left area, right area was obtained only for the portion of frontal sinus projected above the baseline, that is, superior border of the orbit

Linear measurements for each radiograph were obtained using Viewbox 3.0 software and expressed in centimeters. The reliability and reproducibility of frontal sinus measurements were assessed twice by two investigators within one-month interval, where the data of first session were masked at the second session. By this method, a general consensus was reached.

Comparison of the measurements showed no significant statistical difference.

Yoshino's frontal sinus pattern for each subject was established using following parameters:

1. Frontal sinus size
2. Bilateral asymmetry
3. Superiority of the side
4. Outline of upper border (left Ou1, right Ou2)
5. Partial septa (Ps)
6. Supraorbital cells (Sc)

Each of these parameters was allocated a code number for their characteristics to determine the frontal sinus pattern of the individual.

Following frontal sinus patterns were observed on PA radiograph:

1. Symmetrical (S)
2. Left-dominated asymmetry (LDA)
3. Right-dominated asymmetry (RDA)
4. Unilateral aplasia (UA)
5. Bilateral aplasia (BA)

Statistical procedures

Statistical data analysis was carried out using the Statistical Package for the Social Sciences (SPSS), version 20.00 package (SPSS, Chicago, Illinois).

Results

In this study, of 400 subjects, Unilateral absence of sinus was noted in five male subjects (2.5%) and three female subjects (1.5%). Bilateral absence was noticed in four male subjects (2%) and one female subject (0.5%) [Table 1]. UA and BA were excluded from the study so now total sample comprised 191 male and 196 female subjects.

Table 2 shows distribution of male and female by age groups. Mean age of male subjects was 31.72 years, and that of female subjects was 32.57 years. Therefore, mean age of total subjects altogether was 32.15 years.

Figure 1 shows comparison of male and females with frontal sinus pattern. The frontal sinus symmetry was observed in 83.20% of the individuals (154 males and 168 females). The leftdominated asymmetry was observed in 6.98% of the individuals (13 males and 14 females). The right-dominated asymmetry was observed in 9.82% of the individuals (24 males and 14 females).

The descriptive statistic mean values, standard deviation, and P value using Mann–Whitney U test are shown in Figure 2. The mean value for all variables is consistently higher in males compared to that in females. Likewise, all response variables are greater in left frontal sinus compared to those in right frontal sinus in both males and females. $P < 0.05$ is considered to be statistically significant.

Table 3 presents simple logistic regression analysis of gender by different variables, which shows right width and left width are most suited regressors for sex determination. The accuracy rate in classification of males and females varied from 67.70% to 95.90% and we also developed individual equation for Saudi population. The inclusion of all variables was measured using the formula:

$$y = a + b1 \times 1 + b2 \times 2 + b3 \times 3 + b4 \times 4 + b5 \times 5 + b6 \times 6$$

where, $x1$ is right height, $x2$ is left height, $x3$ is right width, $x4$ is left width, $x5$ is right area, and $x6$ is left area. The probability is calculated from the logit value (P) from the preceding expression by the following equation: $P = e^{\text{logit}}/(1 + e^{\text{logit}})$.

The measurements of association between estimated probability and observed responses [Table 3] are important to determine the prediction capacity of the proposed model. A concordance index of 95.90% was found, which indicated a model that shows good association between predicted response and observed sex. The results show that there is 4.10% wrong classifications. There are strong indications for the importance of the right width of the frontal sinus in the determination of sex (95.90%).

Stepwise logistic regression analysis of gender by different variables shows that right height, right width, left height, left width, left area, and right area are the best predictors of differentiation between males and females [Table 4].

Simple linear regression analysis of estimation of age by different variables shows P <0.05, which is statistically significant [Table 5].

Stepwise multiple regression analysis of estimation of age by different variables shows right height is the only one best predictor of estimation of age [Table 6].

Discussion

Identification of human remains is required for personal, social, and legal reasons.[7] Schuller was the first to report the use of radiographs for the purpose of identification in 1921.[3]

Table 1: Unilateral aplasia and bilateral aplasia of frontal sinus in different studies

Year	Other similar studies	Country	Unilateral aplasia	Bilateral aplasia
2003	Aydınlıoğlu *et al.*[22]	Turkey	4.8%	3.8%
2011	Danesh-Sani *et al.*[24]	Iran	5.66%	8.32%
2011	Çakur *et al.*[25]	Turkey	1.22%	0.73%
2012	Patil *et al.*[31]	India	3%	1%
2014	Kotrashetti *et al.*[16]	India	4.63%	3.2%
2015	Nikam *et al.*[29]	India	2.75%	5.50%
2016	Soman *et al.*[7]	India	3%	6.5%
2017	Pandeshwar *et al.*[8]	India	8%	6%
2019	Present study	Saudi Arabia	2%	1.25%

Table 2: Distribution of male and females by age groups

Age groups	Male	% among males	Female	% among females	Total	%
≤20 years	62	50.41	61	49.59	123	31.78
21–30 years	48	50.00	48	50.00	96	24.81
31–40 years	27	49.09	28	50.91	55	14.21
41–50 years	19	48.72	20	51.28	39	10.08
51–60 years	24	50.00	24	50.00	48	12.40
≥61 years	11	42.31	15	57.69	26	6.72
Total	191	49.35	196	50.65	387	100.00
$\chi^2 = 0.6032$, $P = 0.9883$						
Mean age	31.72		32.57		32.15	
SD age	16.03		16.56		16.28	

SD = standard deviation

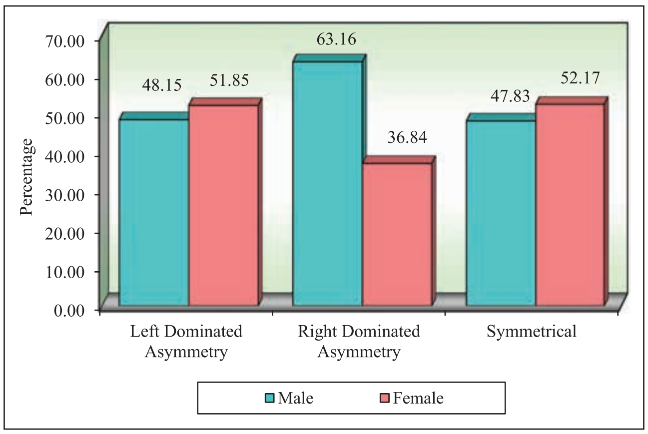

Figure 1: Comparison of male and females with frontal sinus pattern.

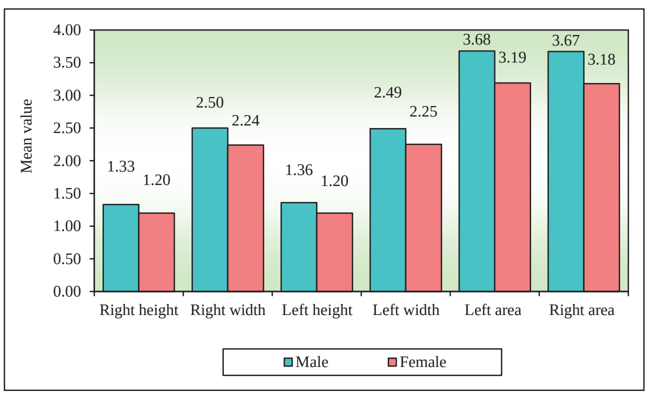

Figure 2: Comparison of male and female with different variables

In forensic identification, among the paranasal sinuses, the frontal sinus is the one that is of most interest and significance due to its irregular shape and because of its individual characteristics, which make the frontal bone unique for every individual, just as with fingerprints.[8-10]

Dental identification by radiographs forms the main crux of forensic odontology.[3]

Dental identification by radiographs is broadly of two types: comparative and reconstructive. Reports state that 72% of positive identification in modern forensics have been obtained by comparison of antemortem and postmortem radiographs.[11] In forensic identification, comparative radiography is most commonly used. To study the sinuses, Waters (sinus) projection of the skull is one of the most commonly used radiographs but it has been noted that PA radiograph of skull by Caldwell technique helps in better view of frontal sinus than Waters projection, where slight foreshortening of the image is seen.[11,12] Lateral cephalograms, conventional computed tomography (CT), and cone-beam computed tomography (CBCT) have also been used to study the frontal sinus.[12,14]

The disadvantages of conventional CT and CBCT include higher doses than two-dimensional imaging and expensiveness when compared to radiographs.[15] Therefore, in this study, the methodology using digital PA radiography is simple and cost-effective, providing high accuracy in human identification using frontal sinus.[16]

In this study, all the response variables studied showed mean value to be consistently larger in males compared to that in females [Table 4], which can be attributed to the fact that the morphological differences in the cranium between the two sexes are determined mainly by genetic factors more so by nutritional, hormonal, or muscular factors.[17,18] These aspects explain why frontal sinus is on an average larger in males compared to that in females.[16,19]

Left frontal sinus was greater than the right side in both males and females, which is similar to the study conducted by Camargo *et al.*[6] and Pondé *et al.*[20] but is in contrast with the study conducted by Kotrashetti *et al.*[16] The existence of one side larger than the other is due to their independent development.[16,21] It is common to find one sinus larger than the other, and the larger

Table 3: Simple logistic regression analysis of gender by different variables

Variables	Coefficient	SE	Wald	*P* value	-2 Log likelihood	χ^2 for model fit	*P* value	% of overall corrected classification
Right height	8.72	1.16	56.55	0.0001*	456.3740	80.0570	0.0001*	67.70
Constant	−10.90	1.44	57.51	0.0001*				
Right width	22.27	2.29	94.3490	0.0001*	231.14	305.2920	0.0001*	95.90
Constant	−51.73	5.28	96.1190	0.0001*				
Left height	9.22	1.13	66.6920	0.0001*	435.93	100.5010	0.0001*	72.60
Constant	−11.61	1.41	68.1220	0.0001*				
Left width	21.37	2.10	103.8150	0.0001*	244.51	291.9180	0.0001*	95.10
Constant	−49.98	4.88	105.0370	0.0001*				
Left area	3.14	0.36	75.1410	0.0001*	416.57	119.8570	0.0001*	70.30
Constant	−10.91	1.28	73.2290	0.0001*				
Right area	3.35	0.38	78.0540	0.0001*	410.15	126.2810	0.0001*	78.00
Constant	−11.59	1.33	76.1970	0.0001*				

SE = standard error of the mean

*$P < 0.05$

Table 4: Stepwise logistic regression analysis of gender by different variables

Model	Variables	Coefficient	SE	Wald	*P* value	-2 Log likelihood	χ^2 for model fit	*P* value	% of overall corrected classification
Model 1	Right height	8.72	1.16	56.55	0.0001*	456.3740	80.0570	0.0001*	67.70
	Constant	−10.90	1.44	57.51	0.0001*				
Model 2	Right height	−17.67	4.02	19.27	0.0001*	202.3220	334.1090	0.0001*	95.86
	Right width	29.76	3.26	83.21	0.0001*				
	Constant	−47.66	4.51	111.84	0.0001*				
Model 3	Right height	−47.47	7.34	41.77	0.0001*	136.9240	399.5070	0.0001*	99.22
	Right width	38.48	4.53	72.02	0.0001*				
	Left height	21.10	4.39	23.11	0.0001*				
	Constant	−57.83	5.66	104.24	0.0001*				
Model 4	Right height	−80.19	26.47	9.17	0.0001*	117.8620	418.5690	0.0001*	99.48
	Right width	61.80	15.47	15.96	0.0001*				
	Left height	49.02	25.04	3.83	0.0500*				
	Left width	−20.45	13.76	2.21	0.1370				
	Constant	−58.63	6.32	86.01	0.0001*				
Model 5	Right height	−77.04	27.31	7.96	0.0050*	113.6480	422.7830	0.0001*	99.48
	Right width	62.58	16.52	14.35	0.0001*				
	Left height	48.09	25.69	3.51	0.0610				
	Left width	−25.17	14.92	2.85	0.0920				
	Left area	1.76	0.88	3.99	0.0460*				
	Constant	−58.26	6.37	83.65	0.0001*				
Model 5	Right height	−120.60	33.40	13.04	0.0001*	103.7460	432.6850	0.0001*	99.48
	Right width	77.33	18.80	16.93	0.0001*				
	Left height	90.39	31.61	8.17	0.0040*				
	Left width	−39.60	17.09	5.37	0.0200*				
	Left area	−49.30	21.23	5.39	0.0200*				
	Right area	51.59	21.41	5.81	0.0160*				
	Constant	−58.97	6.23	89.45	0.0001*				

SE = standard error of the mean

*$P < 0.05$

Right height, right width, left height, left width, left area, and right area are the best predictors of prediction between male and females

sinuses may cross the midline and even overlap the other.[22] We also found the morphology of each frontal sinus of both males and females was different and also asymmetrical, consequently confirming the findings of various studies performed in the past [Figure 3].[8,22-26] Asymmetry for the frontal sinus of both sides is a rule

Table 5: Simple linear regression analysis of estimation of age by different variables

Variables	Constant	Estimate	*R* value	R^2	*P* value
Right height	14.8211	13.7039	0.1646	0.0271	0.0012*
Right width	5.9540	11.0690	0.1484	0.0220	0.0034*
Left height	18.3902	10.7500	0.1475	0.0217	0.0036*
Left width	10.7857	9.0181	0.1164	0.0136	0.0220*
Left area	19.7880	3.6008	0.1064	0.0113	0.0364*
Right area	19.5517	3.6829	0.1070	0.0115	0.0353*

*$P < 0.05$

Table 6: Stepwise multiple regression analysis of estimation of age by different variables

Models	Variables	Coefficient	SE	*t* value	*P* value	*R*	R^2	*F* value	*P* value
Model 1	Constant	14.8211	5.3543	2.7681	0.0059*	0.1646	0.0271	10.7281	0.0011*
	Right height	13.7039	4.1840	3.2753	0.0012*				
Model 2	Constant	13.4410	10.3555	1.2980	0.1951	0.1648	0.0272	5.3623	0.0005*
	Right height	12.5018	8.7806	1.4238	0.1553				
	Right width	1.2255	7.8667	0.1558	0.8763				
Model 3	Constant	13.6165	10.3830	1.3114	0.1905	0.1656	0.0274	3.5987	0.0131*
	Right height	16.2294	14.8664	1.0917	0.2757				
	Right width	0.8830	7.9526	0.1110	0.9117				
	Left height	−3.1864	10.2481	−0.3109	0.7560				
Model 4	Constant	14.2942	10.6587	1.3411	0.1807	0.1662	0.0276	2.7133	0.0297*
	Right height	15.0358	15.4509	0.9731	0.3311				
	Right width	3.2246	11.3820	0.2833	0.7771				
	Left height	−2.4445	10.5790	−0.2311	0.8174				
	Left width	−2.3889	8.2979	−0.2879	0.7736				
Model 5	Constant	12.6507	10.6963	1.1827	0.2377	0.1828	0.0334	2.6345	0.0233*
	Right height	22.8022	16.2589	1.4024	0.1616				
	Right width	2.0367	11.3901	0.1788	0.8582				
	Left height	−8.1727	11.2212	−0.7283	0.4669				
	Left width	−6.2613	8.6714	−0.7221	0.4707				
	Left area	3.2446	2.1475	1.5109	0.1316				
Model 5	Constant	11.0662	10.7748	1.0270	0.3051	0.1922	0.0369	2.4298	0.0257*
	Right height	29.1563	17.1191	1.7031	0.0894				
	Right width	7.9844	12.4497	0.6413	0.5217				
	Left height	−15.2089	12.7013	−1.1974	0.2319				
	Left width	−11.1629	9.6105	−1.1615	0.2462				
	Left area	31.3577	23.9156	1.3112	0.1906				
	Right area	−28.1874	23.8820	−1.1803	0.2386				

*$P < 0.05$

Right height is only one of the best predictor of prediction of age

because of the unequal resorption of the dipole during sinus development.[21]

The variable difference by each research can be attributed to the influence of environmental and genetic factors on the frontal sinus. The systemic factors, which influence the frontal sinus morphology within each population, are craniofacial configuration, frontal bone thickness, and growth hormone levels [Table 7].[22]

Comparison of frontal sinus pattern in males and females showed frontal sinus symmetry in 83.20% of the individuals (154 males and 168 females). LDA was observed in 6.98% of the individuals (13 males and 14 females). RDA was observed in 9.82% of the individuals (24 males and 14 females).

Stepwise multiple regression analysis of estimation of age by different variables shows right height is the best predictor of age. There are, however, limitations in the use of the frontal sinus in establishing individual identity, moreover its size varies with the role of genetic, environmental, and systemic factors.[26]

However, there is no doubt that interpopulation variation seriously affects the frontal sinus

Table 7: Comparison of some previous similar studies

Ref. no.	Year	Authors	Type article	Subjects	Method	Anatomical region	Analyzed implication	Results	Conclusions
[3]	2018	Doggalli *et al.*	Review	-	Radiograph	Frontal sinus	Human identification	Frontal sinus cannot be used to identify developing skulls. However, the idiosyncratic nature of frontal sinus akin to that of fingerprints, results in it being the method of choice when other identification techniques cannot be used.	Frontal sinus is a useful aid in identification when Ante-Mortem dental records are absent. Identification by frontal sinus is not common practice due to lack of a standard technique and error rates.
[26]	2018	Nethan *et al.*	Research	100, 50 M:50 F	Digital paranasal sinus (PNS) view radiographs	Frontal sinus	Gender determination	Frontal sinuses showed low accuracy in predicting gender, that is, 62% accuracy in predicting females and 46% accuracy in predicting males.	The frontal sinuses may be used in forensic odontology for gender determination. However, it should be kept in mind that there may be a scope for variations in the dimensions of the frontal sinuses or their interindividual variability, owing to environmental or genetic factors.
[12]	2018	Luo *et al.*	Research	475	Digital lateral cephalograms	Frontal sinus	Sex discrimination	In this study, the maximum height, depth, area of the frontal sinus, and the frontal sinus index (ratio of the maximum height to the depth of frontal sinus) were computed. Results of statistical analysis showed significant differences in the frontal sinus index and area between males and females. Discriminant function equation derived from this study differentiated between sexes with 76.6% accuracy.	The results demonstrated that the use of frontal sinus index and area for sex discrimination was more accurate than using the frontal sinus index alone.
[27]	2018	Sheikh *et al.*	Research	100, 50 M:50 F	Paranasal sinus (PNS) views	Maxillary sinus and frontal sinus	Sex determination	The sidewise comparison of maxillary sinus height showed higher values on left than right in both males and females, whereas when width was compared, right width was higher than left width in both males and females. The sidewise comparison of frontal sinus parameters both width and height showed higher values on the left side than the right side in both males and females, but the values of both the sinuses were statistically insignificant.	The width of left maxillary sinus and frontal sinus can be used as best discriminate parameter to study sexual dimorphism with an accuracy of 59% and 58%, respectively.

Table 7: Continued

Ref. no.	Year	Authors	Type article	Subjects	Method	Anatomical region	Analyzed implication	Results	Conclusions
[8]	2017	Pandeshwar *et al.*	Research	100	Paranasal radiographs	Frontal sinus	Sexual dimorphism	Application of discriminative analysis to the data accurately identified the gender in merely 65.7% of cases.	The radiomorphologic features of frontal sinus alone have limited value in gender determination and may be used as an auxiliary method.
[13]	2017	Eboh DE *et al.*	Research	216	Posteroanterior radiographs	Frontal sinus	Sex determination	All dimensions were higher in males than in females, wherein the left side height and width were statistically significant ($P < 0.05$). Left side frontal sinus width gave the highest accuracy of 60% in sex determination using logit regression.	The dimorphic nature of the left dimensions has implications for human identification.
[7]	2016	Soman *et al.*	Research	200, 100/100, M:F	PA cephalogram radiograph	Frontal sinus	Human identification	The mean values for length, width, and area of the frontal sinus were found to be higher in males as compared to those in females and area of frontal sinuses increases with age except in males who were 45 years and above.	The morphologic evaluation of frontal sinus is a useful technique to determine gender and seems promising in personal identification.
[28]	2015	Verma *et al.*	Research	149	Digital PA cephalograms	Frontal sinus and nasal septum	Human identification	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, whereas 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. There was significant correlation found between patterns of NS and FS except in right dominated asymmetrical FS.	The combined use of FS and NS patterns could be used as method for identification by exclusion in forensics.

Table 7: Continued

Ref. no.	Year	Authors	Type article	Subjects	Method	Anatomical region	Analyzed implication	Results	Conclusions
[29]	2015	Nikam *et al.*	Research	109	Radiograph	Frontal sinus	Human identification	The maximum height and the maximum width of the frontal sinus for the given sample varied between 0.2 and 3.1 cm and between 2.5 and 9.3 cm, respectively.	The frontal sinus of each individual is unique and, as a consequence, frontal sinus pattern matching can be useful as a technique in some cases of forensic identification.
[16]	2014	Kotrashetti *et al.*	Research	300	Radiograph	Frontal sinus	Human identification and sex determination	The mean values of the frontal sinus height, width, and area are greater in males. Right frontal sinus is larger than the left sinus in both the sex. Logistic regression analysis gives an average concordance index for sex determination of 64.6%.	The frontal sinus offers average accuracy in determining sex, but high precision in human identification.
[11]	2013	Navdeep *et al.*	Research	50	Radiograph	Frontal sinus	Sex determination	No statistically significant difference was found between mean area of frontal sinus between males and females.	The frontal sinus analysis is not reliable to assist sex discrimination.
[14]	2013	Mathur *et al.*	Research	40	Radiograph	Frontal sinus	Sex determination	A highly significant difference was observed in both width and height of frontal sinus between males and females.	The frontal sinus can be used as an auxiliary method in sex prediction.
[30]	2013	Goyal *et al.*	Research	100	Radiograph	Frontal sinus	Sex determination	Multivariate logistic regression equations allowed correct sex identification in 60% of cases only.	The frontal sinuses may have limited application as the sole predictor of sex.
[31]	2012	Patil *et al.*	Research	100	Radiograph	Frontal sinus	Human identification	The comparative identification by superimposition of the frontal sinus was 100% positive. The size, shape, unilateral or bilateral presence, absence, and septa were observed to be unique in each case; neither had the measurements changed over a period.	The frontal sinus is unique to each individual.

Table 7: Continued

Ref. no.	Year	Authors	Type article	Subjects	Method	Anatomical region	Analyzed implication	Results	Conclusions
[19]	2010	Uthman *et al.*	Research	90	Spiral computed tomography	Frontal sinus and other skull measurements	Human identification	The discriminative analysis showed that the ability of the frontal sinus to identify gender was 76.9%, adding the skull measurements to the frontal sinus measurements gave a higher overall classification accuracy for gender (85.9%).	Frontal sinus measurements are valuable method in differentiating gender. Adding skull measurements to the frontal sinus measurements can significantly improve accuracy of gender determination using discriminant analysis.
[32]	2010	Besana and Rogers	Research	116	Radiograph	Frontal sinus	Human identification	The research finds that most sinus traits are dependent on one another and thus cannot be used in probability combinations. When looking at traits that are independent, this research finds that metric methods are too fraught with potential errors to be useful. Discrete trait combinations do not have a high enough discriminating power to be useful.	Only superimposition pattern matching is an effective method of identifying an individual using the frontal sinuses.
[33]	2009	Carvalho *et al.*	Review	-	Radiograph and computed tomography	Frontal sinus	Human identification	The analysis of antemortem and postmortem radiographic and tomographic images has become an essential tool for human identification in forensic dentistry, particularly with the refinement of techniques resulting from developments in the field of the radiology itself as well as the incorporation of information technology resources to the technique.	The observation of the frontal sinus pattern is already a good established technique for personal identification.
[34]	2009	Tang *et al.*	Research	165	Radiograph	Frontal sinus	Human identification	The unilateral frontal sinus scalloped with one arcade has few parameters applied to personal identification, and shows the poorer discrimination power.	The frontal sinus can be applied to personal identification.

Table 7: Continued

Ref. no.	Year	Authors	Type article	Subjects	Method	Anatomical region	Analyzed implication	Results	Conclusions
[35]	2008	Falguera	Research	90	Radiograph	Frontal sinus	Human identification	The method based on Image-Foresting Transform has shown itself efficient in frontal sinus segmentation from radiograph images. Techniques for extracting frontal sinus geometrical and shape-based descriptors were investigated and implemented as well.	Individuality, accuracy, and usability of the frontal sinus for human identification.
[36]	2008	Iordan and Ulmeanu	Review	-	Radiograph	Frontal sinus	Human identification	Paranasal sinuses can be explored by different methods, but the most accessible and easy to perform is conventional radiological imaging.	Radiographs can be evaluated to establish the individuality from frontal sinus.
[6]	2007	Camargo *et al.*	Research	100	Radiograph	Frontal sinus	Sex determination	The mean values of the frontal sinus were greater in males and the left area was larger than the right area, based on Student's *t*-test at the 5% level of significance. The mathematical model based on logistic regression analysis gave a concordance index for gender of 79.7% in the cases studied.	The frontal sinus analysis may be useful in sex determination.
[37]	2005	Christensen	Research	808	Radiograph	Frontal sinus	Human identification	Results show that Euclidean distances between outlines of different individuals are significantly larger than those between replicates of the same individual, and typicalities show that the probability of finding two different individuals with Euclidean distances less that that between a particular case's replicate is very small.	The differences between the frontal sinuses are significant and measurable between individuals.
[38]	2003	Taniguchi *et al.*	Research	24	Radiograph	Frontal sinus	Human identification	Comparison of the ante and postmortem films (*n* ¼24) gave an identical result in about 75%.	Frontal sinus radiographic patterns are useful for human identification.

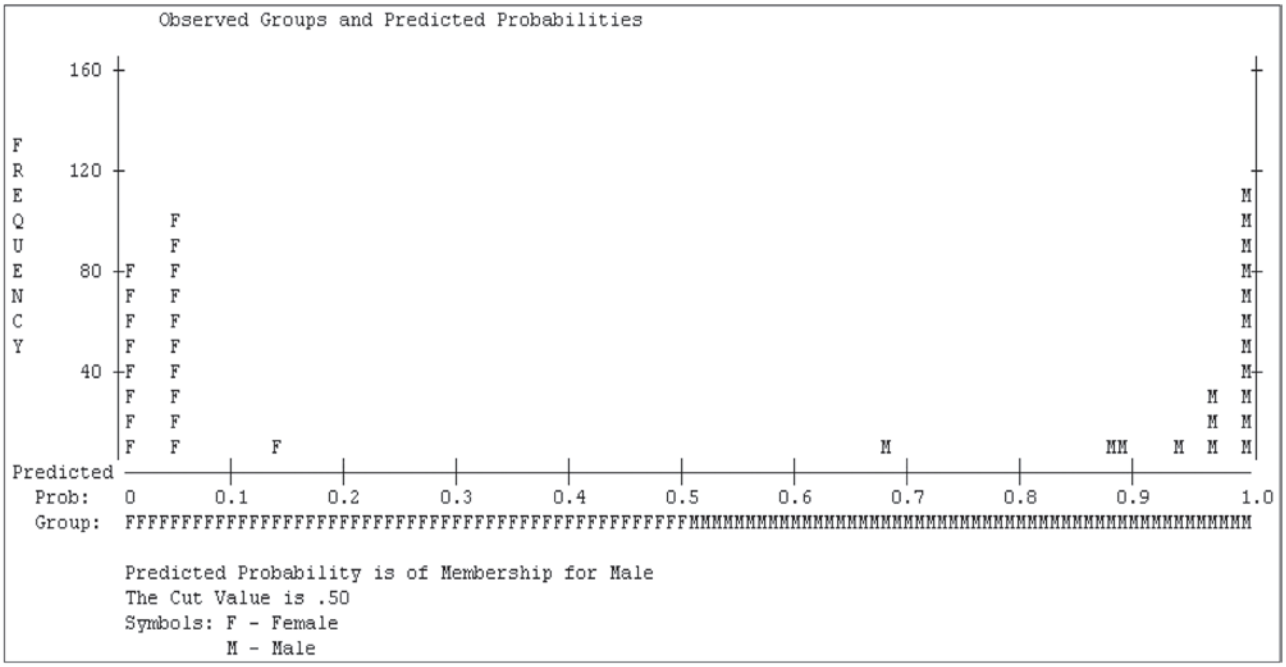

Figure 3: Observed groups and predicted probabilities

morphological features. The results reported in this study indicate that it is possible to achieve accuracy and precision using a discrete number of morphological features of the frontal sinus to determine the sex and for the personal identification of unknown skeletal remains. It has been suggested that the frontal sinus has the potential to be used for personal identification, age estimation, and sexual dimorphism.

Conclusion

The morphologic evaluation of frontal sinus is a useful technique to determine gender and age of an individual in Saudi population. Logistic regression analysis of frontal sinus is a simple, reliable, and low-cost method to determine gender in an adult individual. Simple linear regression analysis of frontal sinus can be used in the estimation of age. Further studies on frontal sinus morphology are required with larger sample size to ascertain the accuracy level in determining sex and age of an individual.

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Conflicts of interest

There are no conflicts of interest.

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