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ASSESSMENT OF THE FRONTAL SINUS DIMENSIONS USING CBCT FOR GENDER DETERMINATION AMONG SAMPLES OF DUTCH AND TURKISH INDIVIDUALS

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Abstract: *Purpose.* Frontal sinus evaluation provide useful information for gender determination. Especially advanced imaging techniques offer improvements to the qualitative and quantitative morphological analysis of frontal sinus. The present study aimed to investigate the reliability of gender determination by means of frontal sinus measurements in two different population groups on CBCT scans.

Methods. The study sample consisted 97 individuals with ages ranging from 20 to 82yr, 47 of whom are Dutch individuals and 50 of whom are Turkish individuals. Measurements of length, width, height and volume of the frontal sinuses were conducted for the right and left side separately. The differences dependent on gender was calculated using logistic regression analysis.

Results. The results show that volume measurements of the right frontal sinus were statistically different between female and males ($p<0.05$). Gender prediction percentage accuracy for the volume measurement of right frontal sinus were 80.4 and 77,5 for Dutch and Turkish groups, respectively.

Conclusions. The results herein imply the potential use of the frontal sinus for gender determination with a reasonable accuracy in Dutch and Turkish samples. The assessment of frontal sinus as a gender indicator could make a potential contribution in addition to other gender assessment methods in forensic studies especially when only relatively small portions of the skeleton are available for analysis.

Keywords: frontal sinus, CBCT, gender determination, identification.

INTRODUCTION

The skull is an important part of the skeleton for gender assessment because it has many structures that are reported to be accurate for gender determination such as the supraorbital ridge, nasal aperture, mastoid process, zygomatic extension and gonial angle [1, 2]. Sometimes the skull is found in bad condition or not as a single entity. In such circumstances these structures cannot be assessed. The frontal sinuses often are a good option in that situation because they are resilient to trauma [3]. For this reason, in several studies the frontal sinuses were considered for forensic gender determination. Some researchers reported promising results [3-6], while others said the opposite [7-9].

The frontal sinus is a mucosa-lined air space within the frontal bone, the left and right side separated with a septum, located on or close to the mid-line and bilaterally posterior to the superciliary arches. Its development begins around the 16th week of intra-uterine life and the first pneumatization continues until the end of the first year. The second pneumatization happens between 1-4 years of age and after 3 years it may be seen on CT scans. Mature pneumatization continues until 18 years of age. After this time, there are almost no changes of the sinuses throughout life any-more although the sinus volume may be larger at an older age [10]. The shape of the left and right frontal sinus develops separately with a different resorption pattern of the bone. They are asymmetrical and also variable in shape and lobulated or not. It is common to see a larger sinus at one side (hyperplasia) while

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the other side is smaller (aplasia or hypoplasia). In the literature, bilateral and unilateral aplasia of the frontal sinuses is reported in less than 5% and 7% of the cases, respectively [10, 11].

Assessments of the frontal sinuses have been performed with different radiologic techniques such as conventional radiographs and CT [12]. Recent studies focus on CBCT to image the frontal sinuses [13, 14]. CT and CBCT scans provide views of axial, coronal, sagittal, and oblique directions which give three-dimensional information of the anatomical structures and can also be used for three-dimensional reconstruction. These reconstructions enhance the qualitative and quantitative morphological analysis. Hence, volume and linear measurements of the sinuses can be performed [15]. The dose of CBCT imaging is less than that of medical CT. This makes CBCT the preferred imaging modality if forensic assessment of living individuals is involved [16-18].

The aim of the present study is to assess the reliability of gender determination in two different population groups based on measurements of the frontal sinuses on CBCT scans.

MATERIALS AND METHODS

Ethical approval for this study was obtained from the Ethics Committee of Hacettepe University, Ankara, Turkey (protocol number 16/406).

The CBCT scans of the frontal sinus used for this study were obtained from two sources. The first sample consisted of 47 CBCT scans of patients between 20 and 82 years old from the digital archive of the Department of Oral and Maxillofacial Radiology, Academic Centre for Dentistry Amsterdam. This archive included CBCT scans made with a NewTom 5G (QR systems, Verona, Italy) (110 kV, 4 mA, 18 × 16 cm field of view, 0.3 mm slice thickness). The second sample was obtained from the digital archive of the Department of Oral and Maxillofacial Radiology, Hacettepe University, and consisted of 50 CBCT scans taken with an i-CAT Next Generation CBCT scanner (Imaging Sciences International, Hatfield, PA, USA) (120 kV, 5 mA, 23 × 17 cm field of view, 0.4 mm slice thickness). The samples were selected using the following inclusion criteria: normal adults over 20 years of age (when the frontal sinus development is completed) who underwent CBCT scanning for reasons not related to the frontal sinus region. The exclusion criteria were as follows: presence of sinus pathology, surgical history, fractures, perforations and foreign objects in the frontal sinus.

The images were anonymized before the analysis. They were numbered and saved sequentially as raw data in Dicom (Digital Imaging and Communication in Medicine) format. The images were imported into a specific software program Amira (v5.3, Visage Imaging Inc., Carlsbad, CA, USA) in order to make measurements of the images. Numbered images were analyzed by an oral and maxillofacial radiologist.

The right and left frontal sinus in every individual were assessed separately. Each side of the sinus was examined slice by slice. In order to avoid eyestrain, only two frontal sinuses per day were assessed and measured. The optimum air-bone threshold grey value for frontal sinus was chosen by the observer for each individual dataset. For each side of the sinus, air connections to the other side were erased slice by slice with the editing tool in order to constrain the volume to be measured to one sinus only. Connections with neighbouring sinuses were closed similarly. The narrowest part of the frontal ostium was chosen as the boundary slice at the bottom. The volume of the sinus after this thresholding was saved as a mask and then measurements of the volume (in mm^3), height, width and length (in mm) were done. The height and width measurements were calculated on coronal reconstructions and antero-posterior length measurements were done on axial reconstructions. Volume was calculated by multiplying the voxel size and number of voxels in the 3D object. Then the same was applied to the contralateral sinus. To assess intraobserver agreement, 10 Dutch and 10 Turkish individuals were selected randomly and frontal sinuses of these individuals were reevaluated 2 weeks later.

Statistical analysis

Statistical analysis of the data was performed with SPSS 23 (Statistical Package for Scientific Studies, SPSS Ltd, Chicago, IL, USA). Quantitative variables were summarized as mean values and standard deviations. Intra-observer agreement was assessed by intraclass correlation coefficients (ICC). The mean differences between measurements taken from left and right are compared using paired Student's t test. We performed binary logistic regression analysis using frontal sinus measurements to discriminate gender in both samples. Statistical significance level was set at 0.05.

RESULTS

There was one individual (2%) in the Turkish sample with bilateral frontal sinus aplasia. Bilateral

frontal sinus aplasia was not seen in the Dutch sample. There were two individuals with unilateral frontal sinus aplasia in each samples. One of them was on left side and other one was on right side. The frequency of unilateral aplasia of the frontal sinus was 4.2% in the Dutch sample and 4% in the Turkish sample, respectively.

Figure 1 summarizes the age and sex characteristics of the samples. There was no statistically significant difference in both samples ($t_{0.95,45}$=1.1146, p = 0.258 for the Dutch sample, $t_{0.95,48}$=0.468, p = 0.642 for the Turkish sample).

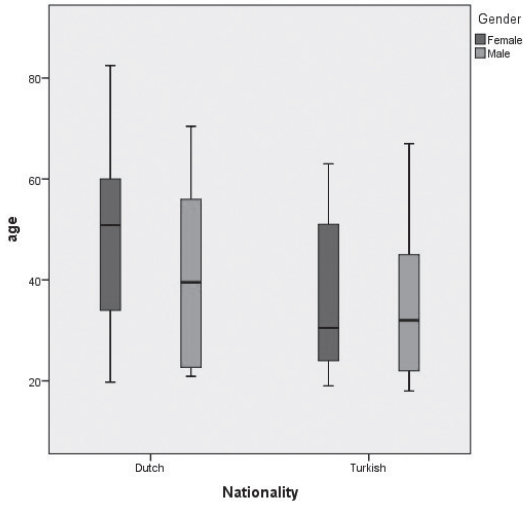

Figure 1. Age and gender distribution according to Dutch and Turkish samples.

The threshold value for the frontal sinuses as chosen by the observer turned out to be between −471 and −40 in this study.

Table 1 and Table 2 presents the descriptive statistics of the measurements and shows mean and standard deviation for right and left sides of the frontal sinus. There was a significant intra-observer agreement in the re-evaluated measurements. ICCs for all measurements were between 0.84 and 0.99, which are between good and excellent [19].

The frontal sinus measurements for the left and right side were evaluated separately. There were no significant differences in the frontal sinus measurements between right and left side in both samples (p values for height, length, width and volume was 0.326 0.410 0.336 and 0.395, respectively in the Dutch sample. p values for length, height, width and volume were 0.379, 0.230, 0.364 and 0.064, respectively in the Turkish sample). The results were statistically significant for right side volume measurements in both samples between males and females (p=0.042 and p= 0.023 in the Dutch and Turkish samples, respectively). The right volume measurements were used to construct the logistic regression models in each samples and the logistic regression model was statistically significant ($\chi^2_{0.95,4}$=12.667, p < 0.05 in Dutch sample and $\chi^2_{0.95,4}$= 17.132, p < 0.05 in Turkish sample). The model explained 35% (Nagelkerke R^2) of the

Table 1. Measurements in the Dutch sample according to right and left sides of the frontal sinus

Nationality	Dutch Sample							
Sex	Female				Male			
Parameter	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum
R_height	19.1	8.5	5.0	39.0	24.9	9.5	10.0	40.0
L_height	20.7	7.7	7.0	40.0	23.9	7.6	12.0	37.0
R_lenght	9.9	4.4	4.0	21.0	13.3	4.4	7.0	21.0
L_lenght	10.6	4.1	3.0	24.0	12.8	3.4	9.0	20.0
R_width	21.6	8.5	6.0	37.0	27.3	8.3	14.0	42.0
L_width	24.1	8.1	8.0	44.0	25.5	8.9	10.0	43.0
R_volume	2154.9	1405.2	150.0	4580.0	4652.5	3562.6	763.0	12444.0
L_volume	2564.9	1575.9	113.0	6248.0	4165.7	3446.1	386.0	13509.0

Table 2. Measurements in the Turkish sample according to right and left sides of the frontal sinus

Nationality	Turkish sample							
Sex	Female				Male			
Parameter	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum
R_height	18.9	6.0	7.2	31.2	22.1	5.7	10.8	31.0
L_height	19.4	5.9	8.8	31.6	23.5	8.0	10.4	41.6
R_lenght	6.6	2.0	2.8	10.4	8.9	2.9	4.0	14.8
L_lenght	7.1	2.6	3.6	14.0	10.1	3.3	4.4	15.2
R_width	20.8	7.3	7.2	40.8	23.3	5.9	16.0	36.0
L_width	22.1	6.4	10.0	35.2	24.1	7.2	10.8	36.4
R_volume	2427.9	1567.1	194.7	7119.7	4319.5	2307.1	664.7	9323.1
L_volume	3004.0	2381.5	433.1	9132.1	5079.5	3442.7	736.7	11392.0

Table 3. Sensitivity and specificity of the regression model

Country	Observed		Predicted Gender		Percentage Correct
			Female	Male	
Dutch	Gender	Female	32	2	94.1
		Male	7	5	41.7
	Overall Percentage				80.4
Turkish	Gender	Female	28	3	90.3
		Male	8	10	55.6
	Overall Percentage				77.6

variance in Dutch sample and correctly classified 80.4% of individuals. The model explained 40% (Nagelkerke R^2) of the variance in Turkish sample and correctly classified 77.6% of individuals.

Sensitivity (Se) or the proportion of the correctly predicted females and Specificity (Sp) or the proportion of correctly predicted males, were calculated and summarized in Table 3. Sensitivity and specificity of the regression model were 94% and 42%, respectively in Dutch sample(positive predictive value 82% and negative predictive value 42%). Sensitivity and specificity of the regression model were 90% and 56% in Turkish sample (positive predictive value 78% and negative predictive value 77%).

DISCUSSION

Frontal sinuses being unique to the individual and also remaining stable over time during life are valuable for forensic investigations [20]. Previous studies evaluated morphometric measurements of the frontal sinus for gender determination on conventional radiographs or CT scans [5, 21, 22, 6, 8, 3, 12, 4]. The current study focused on the determination of gender from the morphometric measurements of frontal sinuses from two samples belonging to two different populations on CBCT scans.

The use of CBCT is becoming more popular and affordable in the field of dentistry and forensic sciences. This study used CBCT scans to perform frontal sinus measurements and evaluated the possible use of these measurements for gender determination in two different samples.

Intraclass correlation coefficients for the measurements showed good or excellent reliability. These results can be attributed to the anatomic structures whose contours are well recognizable because of the high contrast between the air space of the inside of the sinus and the surrounding bone.

In the present study, there was one individual with bilateral aplasia in the Turkish sample. Bilateral aplasia was not observed in the Dutch sample. The frequencies of bilateral aplasia are very variable depending on the population (ranging from 0% to 43%) [21, 23, 24]. Unilateral absence of the frontal sinus was observed in four cases. Two (1 on the left and 1 on the right) of them were male and Dutch while other two (1 on the left and 1 on the right) were female and Turkish. The difference between the gender in the Dutch and the Turkish sample does not have a clinical significance due to the small number of the unilateral sinuses in the total sample. In the literature, the percentage of bilateral aplasia ranged from 1.1% to 43%, [24, 21]. The observed percentages in this study were 4.2% and 4%. Our results are comparable to most other studies. Some with higher values could be due to inter-population differences.

In the present study, special attention was paid to the right and left side measurements because of their independent development. Hence, each measurement was made separately on each side. Some studies claimed that the left frontal sinus is usually bigger than the right one [25, 23, 26]. Tatlisumak *et al.* [23] and Yüksel Aslier *et al.* [26] found that all measurement were larger in the left side in their volumetric study of CT scans and these findings were statistically significant. In our study, all measurements in the Turkish sample were also larger in the left side. Unlike the studies mentioned before, our results did not yield a statistically significant difference between sides. These was also true for the Dutch sample where frontal sinus measurements showed no significant difference between right and left side. Likewise our study, Emirzeoglu *et al.* [27], and Michel *et al.* [12] reported no significant left and right differences. The effect of race, methodology or sample size could be the reason of these conclusions.

In the literature, there are several studies claiming that there is a significant difference between the measurements of male and female individuals [28, 5, 25, 29, 8, 27]. Motawei *et al.* [29] used CBCT scans and Akhlaghi *et al.* [8] Tatlisumak *et al.* [23] and Uthman *et al.* [21] used CT scans for their measurements. They all reported significant differences between the

quantitative measurements of the frontal sinus with respect to gender. Ponde *et al.* [25], Emirzeoglu *et al.* [27] and Kim *et al.* [28] found significant differences for the frontal sinus volume among genders on CT scans. On the other hand, some studies give outcomes contrary to these results [30, 31]. In our study, the right frontal sinus volume measurement was found statistically different between males and females. In the literature, it is reported that the frontal sinus morphology and dimensional features are affected by inter-population variation. Also, craniofacial configuration, thickness of the frontal bone and hormonal growth factors affect frontal sinus within the population [21, 32]. These may be responsible for different results in different studies.

Goyal *et al.* [3] assessed the potential use of frontal sinus patterns such as number of septa and scallops for gender determination. Their gender prediction accuracy was 60% and according to this finding they reported that the use of these parameters may be useful when other methods are not available.

Earlier studies assessed the height of the left frontal sinus for sex determination in different populations and reported different results of accuracy. In Akhlaghi's [8] study on Iranians, Belaldavar's [6] study on Indians, and Uthman's [21] study on Iraqies, the prediction accuracy levels were 61.3%, 64.6% and 76.9%, respectively. The first two studies show an average accuracy while the last study shows a higher accuracy. The chosen radiological method was different in each study such as conventional radiographs (Antero-Posterior) or three dimensional images (CT, CBCT). Thus, different findings may also be attributable to differences in study design. In contrast to these findings, we observed no statistical difference for the height of the left frontal sinuses in both the Dutch and the Turkish samples.

Michel *et al.* [12] calculated volumetric measurements from CT images and found an accuracy of 72.5% based on the total volume of the sinus. This is in accordance with our findings. But our study differs from that study by using CBCT images instead of CT and calculating the left and right sinus volume measurements separately.

The frontal sinus can be affected by pathology such as acute or chronic inflammations, endocrine dysplasias, osteitis and trauma. We had ruled out these possibilities by including only individuals with a healthy frontal sinus in the study. In case of pathology, the method presented in this study cannot be used. The use of this analysis is further limited by age due to fact that only individuals over the age of twenty were included. One problem inherent in a study of this kind is the sample homogeneity. The assumption is that each of the two groups of individuals is composed of subjects from a rather homogeneous familiar origin. It was not possible to prove that this was true.

In conclusion, frontal sinus volume measurements of right side were found applicable for gender determination with a reasonable accuracy in Dutch and Turkish samples. The assessment of frontal sinus as a gender indicator could make a potential contribution in addition to other gender assessment methods in forensic studies especially when only relatively small portions of the skeleton are available for study.

Conflict of interest

The authors declare that they have no conflict of interest.

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