Original Article

Gender Determination Using Digital Lateral Cephalograms: A Discriminant Function Analysis

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Abstract

Introduction: Gender determination can help establishing a biological profile of the human body remains. Since the pelvic and skull remains are the most unyielding parts of human skeleton, identifying the dead bodies from these two parts would be very useful. After coaxial bone, the skull is the most gender-discriminated portion of the human skeleton. Since no determination study have been reported in Iranian population, present study aimed to determine gender by measuring 12 craniomandibular parameters and provide specific discriminant function scores in a selected population in Mashhad, Iran. **Methods:** a total of 202 digital lateral cephalograms of healthy adults, (101 males and 101 females) in the age range of 18 to 50 years were selected. 14 cephalometric points were utilized, which enabled tracing of 11 linear measurements and an angle. All cephalometric points and measurements were traced by onyxceph® version 2.6 software. **Results:** Based on the analyses, among the chosen parameters, facial height (N-Me), mandibular ramus height (AR-Go), mandibular plane (Me-Go), frontal sinus width (FsWd) contributed the most for sexual dimorphism. The discrimination accuracy was 87.6% (84.2% in males and 91.1% in females). All the linear measurements were significantly larger in males except for angular variable which showed no significant difference between the two genders.

Conclusion: According to the present findings, cephalometric craniomandibular parameters could be utilized to discriminate the gender of human remains using discriminant function analysis (DFA) in the selected Iranian population.

Keywords: Sex determination, Discriminant function analysis, Lateral cephalometry.

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Introduction

Several studies demonstrated that human remains identification is one of the most crucial aims in the forensic medicine and fingerprint, dental, anthropological, genetic or radiological examination, cheiloscopy, and so forth are used to construct the human biological profile (1-8). According to a study in the field, as the soft tissues of the corps disappear, the human remains could be identified only by skeletal examination (5). Thus, the most important factor helping to determine the gender of the remains is the presence of prominences in bones (9). Two techniques to help human identification has been described by using data assembled by skeletal examination; the first method, which is not completely verified by scientists, is the use of morphological and visual techniques and the second method is the measurement techniques. However, the more accurate results would be obtained when the two methods are combined (10, 11). Based on other studies, metric examinations are quantitative and current researchers are using this method more and more with direct measurements and biostatic advances (12, 13). However, several factors could provide dissimilar results in different populations; for instance, different environmental factors in different geographical areas and bio-differences (2, 9). Therefore, skeletal sex studies should be conducted in different ethnic and racial populations (14).

In addition, talus, humerus, femur, scapula, and methacarpal bones can be utilized in anthropology and forensic identification (15). So far, studies of pelvic bone have been widely used for gender indentification. However, weakness and fragility, complex shape, and detachment of its components makes its difficult to find an intact pelvic bone; consequently, using the skull would be more practical in this respect (12, 16-18).

Also, some studies have demonstrated that teeth, especially mandibular canines, due to strong anatomical structures, can be very helpful in forensics (19-22)

Studies on the sex determination by scalp or mandibular bones

It is widely accepted that the mandibular bone is one of the strongest and most diverse bones after the skull and pelvic bone ; therefore, it could be very helpful in identifying human remains (2). However, most previous studies have focused on the cranial features and a few have used craniomandibular parameters (23).

Using the skull radiographs

According to some studies, radiographic identification is a great tool in this area. Therefore, pre-mortem radiographs taken clinically and post-mortem radiographs are required for identification(1-12, 24). Skull radiographs can be helpful in differentiating gender in 80 to 100% of cases (2, 23). As a result, radiography is a simple and cost-effective way to determine sex in comparison to other methods such as histology and biochemistry (25). In addition, lateral and anterior posterior cephalometric radiographs of the skull are very helpful due to the large number of points for comparison (2, 23).

Poongodi et al. and Bhardwaj et al. studied sex determination and achieved good results using panoramic images (25, 26). Moreover, Uthman AT et al. determined the sex of unknown corpses using spiral CT images of the frontal sinuses and other skull measurements (1).

Studies done by lateral cephalograms and posterolateral radiographs

Naikmasur VG et al. conducted a study on the Tibetan immigrants and the South Indian population. They concluded that among the 11 selected cephalometric landmarks, Bizygomatic width, Ramus height, and face depth were the most important factors in sexual dimorphism (2). Moreover, Patil KR et al.'s study aimed to obtain a discriminant function for sex determination and estimation of the height and size of individuals using lateral cranial cephalometric radiographs in a homogeneous population in India. The researchers found that the discriminant function obtained from the 10 cephalometric variables correctly led to the sex determination in 99% of cases (23).

In another study, Naikmasur et al. (2010) studied lateral cephalometric and PA images and concluded that among the 11 selected cephalometric landmarks, Bizygomatic width, Ramus height, and facial depth had the most important role in sexual dimorphism (2). Finally, Patil and Mody investigated 150 lateral cephalograms and concluded that differential analysis using 10 cephalometric variables had 99% validity in sex determination (23).

Materials and Methods

This study evaluated digital lateral cephalograms of patients referred to one of the private maxillofacial Radiology Clinics (Mashhad, Iran) for their therapeutic purposes. Therefore, a total of 202 lateral cephalograms was selected for the study. 101 radiographic samples were taken from females and 101 from males aged between 18 to 50 years. Since the purpose of this study was to determine gender in forensic medicine, and in most cases it is not possible to estimate the age of a skeleton or body that does not have a recognizable gender age grouping was not performed.

Radiographs with clear cephalometric landmarks and the head in the NHP status when taking the image were selected for the study. Exclusion criteria were any visible skeletal abnormalities in the radiographic images. These patients also had no symptoms such as skeletal abnormalities, previous orthognathic surgery, and trauma in their lateral cephalometric radiographs. Finally, samples with bilateral frontal sinus aplasia were excluded.

It should be mentioned that this study did not consider skeletal classification because the indices associated with mandible and maxilla were used separately. Therefore, all patients were participated in the study. All digital lateral cephalograms were made by Planmeca EC 2003 in one clinic.

Several craniomandibular variables were measured as suggested by Iscan and Steyn (27). This objective procedure was performed by a student under the supervision of an orthodontist and a radiologist with onyxceph®2.6 software that is a dental imaging software with a precision of one-tenth of a mm. OnyxCeph is an image processing software that examines the visual purposes of VTO treatment (visualized treatment objective) (Figure 1). There are some pre-designed analyses in this software, which are practical especially in orthodontics and surgery. Since our study required analysis other than those available in the software, it was necessary to prepare the analysis specific to our study. There is a scaled ruler in the cephalogram image that is used for calibration. At first we entered 10 mm on the cephalogram ruler and then we selected 10 mm in the calibration option in the software menu.

Linear indices in millimeters (mm) and angles in degrees (°) were shown at the right bottom of the screen. Variable measurements were performed by a calibrated operator, and the values were entered in the Microsoft Excel after completing the measurement of all 202 cephalometers. The age and sex of radiographs were clear.

Therefore, 14 cephalometric points were identified on the radiographs and consequently 11 longitudinal and 1 angular indices were obtained (Tables I) and (Tables II). Finally, the line between the two images was taken into account in cases where the binary image was created. (Figure 2)

PASW18 statistical software was used to perform data discrimination, mean comparison of linear indices, and discriminant function analysis. The significance level was also considered to be 5%.

Table I: Landmarks and their definitions

Indicator point	Definition
Nasion (N)	The anterior point of the intersection between the nasal and frontal bone. Nasion is known as the point of contact between the face and the cranium.
Anterior nasal spine (ANS)	The anterior point is of the maxilla and arises from the anterior extension of the palate.
Posterior nasal spine (PNS)	It is a single point that shows the posterior border of the hard palate in the midline and is at the posterior junction of the palate bones.
Menton (Me)	The lowest point in the lowest edge of the symphysis.
Infradental (Id)	The most anterior point of the alveolar process of mandibular bone.
Articular (Ar)	Junction of the posterior edge of mandibular ramus and the posterior surface of the basal portion of occipital bone.
Gonion (Go)	Located at the junction of the posterior edge of the ramus and the inferior edge at the mandibular angle. It is geometrically obtained by drawing a bisector between the posterior ramus and inferior plane of mandible.
V1	Uppermost point of frontal sinus.
V2	Lowermost point of frontal sinus.
W1	The left point located on the line perpendicular to v1-v2.
W2	The right point located on the line perpendicular to v1-v2.
Sella (s)	It is at the center of Sala Torsica (pituitary gland).
Condylion (condyl)	The rearmost and uppermost point of the condyle.
Gnathion (Gn)	The most inferior and anterior point on the mandibular symphysis.

Table II: Linear and Longitudinal Variables and Their Definitions

Variables	Definitions
Linear	
N-ANS plan	Anterior-superior facial height
N-Me plan	Anterior facial height
ANS-Me plan	Anterior-inferior facial height
Id-Me plan	Mandibular symphysis height
Ar-Go plan	Mandibular ramus height
Me-Go plan	Mandibular plan
FsHT	Frontal sinus height
FsWd	Frontal sinus width
S-N horizontal plan	The guiding plan of the anterior cranial base, which arises from the connection of the S point to Na.
Condyl-Gn plan	A line connects condylion and gnathion
ANS-PNS(pal) palatal plan	It is obtained by connecting ANS and PNS.
Angular	
Saddle angle (SNAr)	The angle between the anterior and posterior base of the skull.

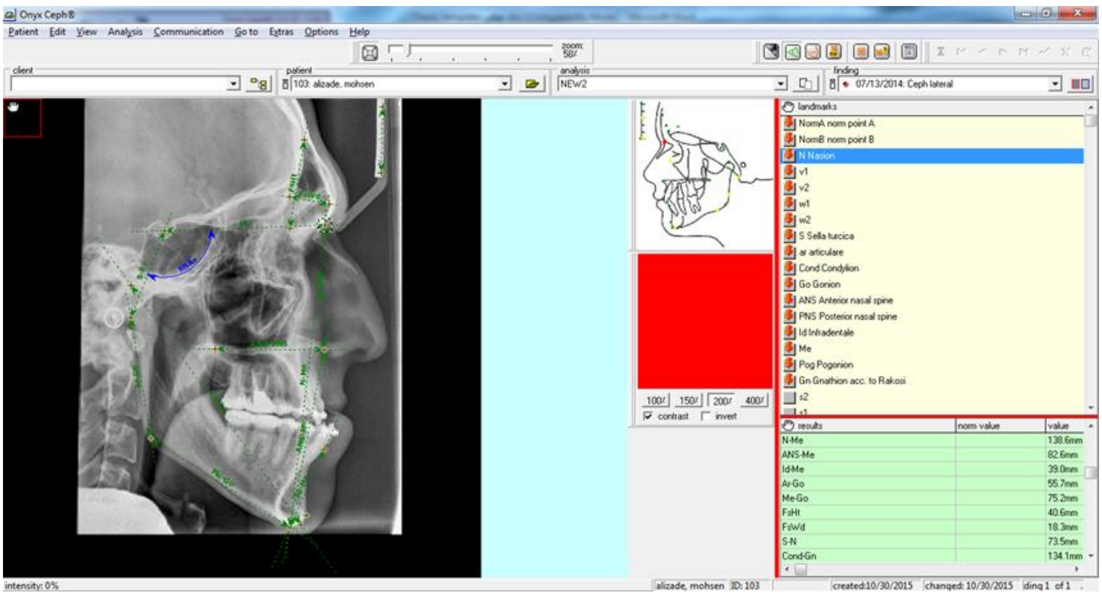

Figure 1: Overview of Onyx Ceph software.

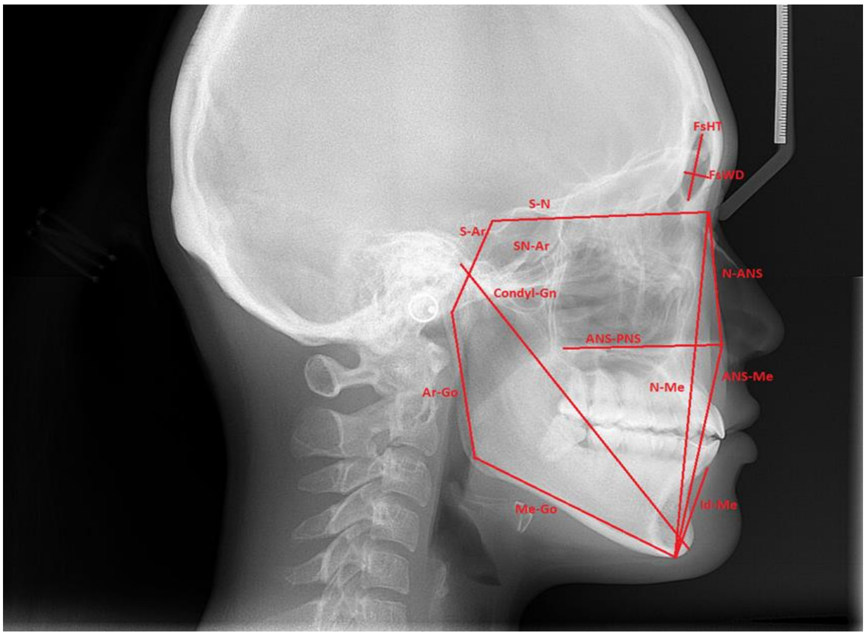

Figure 2: Craniomandibular variables measured in this study.

Results

The mean and standard deviation of the patients' age was 24.03 ±5.20 and the minimum and maximum age was 18 and 50 years, respectively. (Table III)

The mean and standard deviation of the patients' age was 24.03 ±5.20 (were 22.98±4.12 for males and 24.68 ±5.70 for females) and the minimum and maximum age was 18 and 50 years, respectively. (Table III)

Table IV lists the results of tracing based on the gender, which included 11 linear variables and one angular variable. Moreover, independent t-test was used to compare the presence or absence of significant differences between the mean of the variables in each group ($p < 0.001$) (Table IV).

According to the Table IV, it could be concluded that the mean of all studied variables except for SNAr was higher in the male than female and Cond-Gn and N-Me were the most determinant linear variables.

Differential analysis equations by incorporating all independent variables into the model

Differential analysis equation

According to Table V, coefficients and constant values of the differential analysis equation were used to obtain the discriminant score.

The equation is as follows.

Table V: Coefficients and constant values of the differential analysis equation to obtain the discriminant score.

D= -19.626+0.07(N-Me)+0.106(Ar-Go)+0.066(Me-Go)+0.161(FsWd)

If the value obtained from the equation was greater than zero , it was more likely to be male and if the value was lower than zero it was more likely to be female. Also, the closer the value was to +1.14, the more likely it was to be male and the closer the value was to -1.14, the more likely it was to be female.

The other concept in differential analysis is centroid. Centroids are the mean discriminant values for each group. The centroid table is used to base the cutting point for classifying the samples. If the two groups have equal numbers, the best sectioning point is the mean of the two centroid values. (Table VI)

According to the above table, the sectioning point value is zero. This means that if the discriminant score of a person is positive, that person is likely to be male, and if negative, she is more likely to be female. In 85.1% of cases the male gender was detected correctly and in 89.1% of cases the female gender was correctly identified. (Table VII)

Table III: Descriptive findings of the age of the patients by sex

Gender	Mean	N	SD	Minimum	Maximum
Male	22.98	61	4.121	18	35
Female	24.68	99	5.700	18	50
Total	24.03	160	5.207	18	50

Table IV: Descriptive statistical findings and t-value of cephalometric variables by sex.

Parameters	Gender	N	Mean	SD	Std. Error Mean	t	P-value
N-ANS	Male	101	50.6511	4.71474	.46913	6.755	<.001
	Female	101	46.5144	3.95580	.39362		
N-Me	Male	101	121.6481	7.25082	.72148	10.519	<.001
	Female	101	111.8784	5.87816	.58490		
ANS-Me	Male	101	71.8135	5.80670	.57779	6.795	<.001
	Female	101	66.5843	5.10858	.50832		
Id-Me	Male	101	33.7589	2.68212	.26688	8.371	<.001
	Female	101	30.7007	2.50717	.24947		
Ar-Go	Male	101	48.4123	4.88795	.48637	9.378	<.001
	Female	101	42.0024	4.82655	.48026		
Me-Go	Male	101	74.1946	4.78757	.47638	8.112	<.001
	Female	101	68.6281	4.96372	.49391		
FsHt	Male	101	28.7406	5.90622	.58769	4.594	<.001
	Female	101	24.8845	6.02359	.59937		
FsWd	Male	101	13.3925	3.04056	.30255	8.927	<.001
	Female	101	10.0229	2.26801	.22568		
S-N	Male	101	70.0996	3.14621	.31306	8.499	<.001
	Female	101	66.5057	2.85687	.28427		
Cond-Gn	Male	101	118.9933	6.96046	.69259	11.498	<.001
	Female	101	108.5441	5.91381	.58845		
ANS-PNS	Male	101	48.8425	3.28738	.32711	5.570	<.001
	Female	101	46.4138	2.89749	.28831		
SNAr	Male	101	121.0178	6.27053	.62394	-1.324	.187
	Female	101	122.1262	5.60771	.55799		

Table V: Coefficients and constant values of the differential analysis equation to obtain the discriminant score.

Canonical Discriminant Function Coefficients	
	Function
	1
N-Me	.070
Ar-Go	.106
Me-Go	.066
FsWd	.161
(Constant)	-19.626

Unstandardized coefficients

Table VI: Centroid values associated with either sex

Functions at Group Centroids	
Gender	Function
	1
Male	1.140
Female	-1.140

Unstandardized canonical discriminant functions evaluated at group means

Table VII: Predictive findings of the group membership based on discriminant analysis.

Female	Male	Female	Male		
15(14.9%)	86(85.1%)	15(14.9%)	86(85.1%)	101	Male
91(90.8%)	10(9.9%)	90(89.1%)	10(9.9%)	101	Female

Discussion

As stated in a previous study, the most important step in identifying an adult is to determine gender, which makes it easier to identify age and height (30). It is notable that gender determination by skull has been the subject of many morphological and craniometric examinations. Since morphological studies are subjective and have high inter-observer variability, their results may not be very reliable, but craniometric studies are more objective and their results could be reproduced (2, 14). Therefore, craniometric studies of the human skeleton are of great importance in anthropological and forensic studies due to their high resistance to degradation processes after death. Moreover, these studies can be performed directly on the skeletal bones or by comparing pre- and post-mortem radiographs (1). To the investigators' knowledge, only one craniometric study of gender determination by frontal sinus evaluation in CT images has been performed in Mashhad, Iran (31). The present study investigated 202 digital lateral cephalograms belonging to patients in the age range of 18 to 50 years. Since craniofacial growth is complete and hormones have completed the bone changes at the age of 18, minimum age to be included in the study was set accordingly (30). Moreover, the maximum age was 50 years because research has shown that craniomandibular parameters changed during the aging process (2). At first, the landmarks were initially identified in the radiographs and then the variables included 11 linear and one angular variable were measured by onyxceph®2.6 software. Finally, the results entered the Microsoft Excel. In order to analyze datas, Discriminant Function Analysis was used in two ways so that it included all independent variables in the model. Therefore, the discriminant analysis technique provided a relatively simple and objective method for predicting gender in a valid and computable way; for this reason, it is widely used in the contemporary craniometric studies. To date, differential analysis for gender determination has not been studied in this way the Iranian population of Mashhad city, and since differences between the two genders in a particular race were not similar to another population, the discriminant analysis technique should be individually applied to each population for obtaining the standard and correct results (23). According to the results of independent t-test, there was a statistically significant difference in all linear variables and mean value was higher in males than females ($P<0.05$). However, for the SNAr angular variable, there was no significant difference between the males and females, indicating that most of the maxilla and mandibular variables were different in both genders. This was supported by the findings of most previous observations of craniometric studies, in which the men's skull was larger than the women's (2, 10, 14, 15, 23).

According to the results of analysis, N-Me, Ar-Go, Me-Go, and FsWd played a crucial role in generating the differential analysis equation. In their study, Veyre-Goulet et al. found that the frontal and skull base were the most differentiated areas of the skull between the two sexes, although the frontal area was more helpful in determining sex and FsWd. (Sinus width) and FsHt (sinus height) were also included (14). In addition, Asmaa T. Uthman et al. (2010) studied the frontal sinuses in spiral CT scan images and found that no two images were alike and even the frontal sinuses of identical twins were different; therefore, they could be compared to fingerprint in this respect. Consequently, it is of high importance to measure the frontal sinus for sex determination (1). In another study, Kanchan R. Patil et al. studied the lateral cephalometers and concluded that FsHt and N-ANS were less helpful in determining sex in comparison to other variables. In this study, N-Me was identified as the most valid variable in sex determination (23). As in our study, ANS-Me and Id-Me were among the variables that had a little effect on the gender determination. Furthermore, Venkatesh G. Naikmasur et al. (2010) demonstrated that lower facial height (ANS-Me) and symphyseal height (Id-Me) had the smallest difference between the sexes in the Tibetan population (2). Moreover, among the parameters found in the mandible in this study, Ramus height (Ar-Go) was one of the strongest determinants of sex determination in both Tibetan and Indian populations. Similarly, Ar-Go in our study played a key role in the equation and gender determination, but unlike Naikmasur's study, N-Me and Me-Go were found to be effective in our study (2). However, the present study showed that N-ANS did not play an important role in sex determination that is similar to Kanchan R. Patil's (2005) study, in which this variable did not contribute to sex determination. According to Hongmei Dong's (2015) study, the maximum mandibular ramus height (Condyl-Go) was the only indicator that did not have the greatest impact on sex determination. This result is consistent with our study's finding (32). Fernando Toledo de Oliveira et al. (2015) also studied the maximum remus length in lateral cephalometers. This variable was only different between males and females at age of 16 to 20 years and was higher in males; however, overall analysis in this study showed that Ramus Length was not appropriate for sex differentiation (33). Finally, Wankhede et al.'s (2015) study directly measured various indices in the mandibular bones, including Gonion condylar height, but according to the discriminant analysis, this variable did not play a significant role in determining gender, and the projection length of the corpus of mandible had the greatest effect (34).

Conclusion

Based on the present study findings, gender was correctly diagnosed in 87.6% of cases (84.2% in males and 91.1% in females). FsWd, Me-Go, N-Me, and Ar-Go were the most valid variables and the gender was correctly diagnosed in 87.6% of cases only by measuring these variables. Moreover, the mean of all linear variables was higher in the males.

In addition, SNAr, the angular variable was greater in females but this difference was not significant. Therefore, it could be concluded that the measurement of craniomandibular parameters in the Iranian population of Mashhad city would play an important role in the sex determination of human remains with unknown identity.

Conflict of interest

The authors declare that they have no conflict of interest**.**

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