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SEX DETERMINATION BY MORPHOMETRIC ANALYSIS OF THE MENTAL FORAMEN FROM DIGITAL PANORAMIC RADIOGRAPHY

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ABSTRACT

Aim: to assess the mental foramen as a landmark for sex determination through morphometric analysis done on digital panoramic images.

Materials and methods: 100 digital panoramic images of dentulous and partially edentulous Egyptian patients (50 males and 50 females) of age over 18 years old were included in the present study. Morphometric analysis of the mental foramen was conducted on all images concerning one side of the images. The measurements of the distances from the superior border of the mental foramen to the alveolar crest of the mandible (D1), from the superior border of the mental foramen to the inferior border of the mandible (D2), from the inferior border of the mental foramen to the inferior border of the mandible (D3), from the mesial border of the mental foramen to the distal border of the mental foramen (D4) and from the superior border of the mental foramen to the inferior border of the mental foramen (D5) were performed on each digital panoramic image. The data obtained were subjected to statistical analysis and discriminant function analysis was used to estimate the efficiency of each variable for sex determination.

Results: Both (D2) and (D3) were significantly higher in males than in females and they showed the greatest contribution as predictors for sex determination. The cutting score was zero, therefore, discriminant scores greater than zero were classified as male and less than zero (negative scores) were classified as female. Accordingly, 70 % of the cases of the cross-validated group were classified correctly.

Conclusion: Both (D2) and (D3) exhibit sexual dimorphism and can be used in sex determination.

KEYWORDS: Forensic, sex determination, morphometric, mental foramen, panoramic radiography

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INTRODUCTION

Human identification is a basic pillar for civilization and is of great significance to the social life and the need for such identification is for various reasons [1,2]. It is of a great importance in homicides, mass deaths due to nature disasters, wars, terrorist attacks, and traffic accidents. It is also highly required by laws and social rules for legal issues and of emotional significance as it helps grief resolution by family and friends [1-4]. Forensic analysis plays a significant role in human identification [5] and it has been performed on living subjects to determine values and measurements that help in identification in mass fatalities[6]. The process of identification starts by sex determination [3,7] as this step is the most important in the biological profile during the forensic identification[1,2,8,9]. Forensic determination of the sex depends mainly on variation in anatomic and skeletal characteristics that can be used to differentiate between males and females [3].

Almost every bone exhibits sexual dimorphism, especially the pelvis and skull, which are considered to be the most dimorphic elements of the skeleton and most important for sex determination [2-5,7,8,10,11], however in mass disasters when these bones are not available [3-5,8], the mandible plays a significant role in sex determination [5,8]. The mandible is the most dimorphic part of the skull and is considered one of the strongest and most indestructible bones of the body and can remain well preserved than any other bone [2-4,8,10].

The mandible has few anatomical structures that show sexual dimorphism, among which is the mental foramen. The mental foramen is considered a stable landmark on radiographs with its location remains almost the same despite the alveolar bone resorption as it shows a stable relation with the inferior border of the mandible throughout life. Hence, the mental foramen has been considered of a high degree of accuracy and validity as an indicator for sex determination [2,6,8,10-13].

Radiography is an essential mean that is to be used in forensic analysis. Being a non-destructive technique, it is considered to be of an important role in forensic analysis to discover the hidden data, which cannot be provided by means of physical examination. Such method is considered the simplest and cheapest for sex determination among other methods used in forensics such as histological and biochemical methods [1,9,10,14,15].

Panoramic radiography can be used in forensic analysis with the help of portable units. It requires less time and provides an extra-oral examination for the dental arches. It provides the ability to view the whole body of the mandible and can offer information about the localization of anatomic structures vertically and horizontally. Hence it is considered the most preferred radiographic diagnostic modality for depicting the mental foramen as it allows for a more accurate location of the mental foramen in both horizontal and vertical dimensions [5,9,10,14].

Therefore, this study was aimed to assess the mental foramen as a landmark for sex determination through morphometric analysis done on digital panoramic images.

MATERIALS AND METHODS

This study included 100 digital panoramic images that related to dentulous and partially edentulous Egyptian patients of known sex (50 males and 50 females) with ages greater than 18 years old. All panoramic radiographic images included in this study were performed as part of an essential dental care, or for patients requiring diagnosis for the purpose of receiving dental management. Since the present study was conducted using digital panoramic images stored in the system, ethical clearance was not applicable.

All panoramic images were digital and made by the same panoramic machine (Planmeca Proline XC with Dimax 3 X-ray system, PLANMECA OY, Helsinki, Finland) with exposure parameters 60-80 kVp, 4-12 mA and 2.5-18 sec. according to patient's age and size. Measurements were done using Planmeca Romexis® for windows version 3.8.3 (COPYRIGHT PLANMECA).

Inclusion criteria

- Digital panoramic images of both dentulous and partially edentulous patients with age older than 18 years old
- High quality images with no visible errors where the mental foramen, the alveolar crest and the inferior border of the mandible were clearly visible
- Evidence of resorption in the mandibular arch should be minimum or absent, especially in the premolar and first molar region

Exclusion criteria

- Digital panoramic images with positioning errors which could cause distortions of the dimensions
- Presence of congenital anomalies or hereditary facial asymmetries
- Digital panoramic images of patients who are completely edentulous
- Patients with history of surgeries involving the mandible and those with orthognathic surgeries
- Presence of oral pathologies or periodontal lesions, affecting the mandible that could affect the interpretation of panoramic images at the area of interest of the present study.

There is no statistical significant difference between the locations of the mental foramen on both sides of the mandible [5,9,12,14,16- 20], so the distances from any side can be used. The measurements were done on one side of the mandible image as follows:

Tangents were drawn to the superior (T1) and inferior borders (T2) of the mental foramen, and a perpendicular (P) was drawn from these tangents to the alveolar crest and to a tangent to the inferior border of the mandible (T3). Other tangents were drawn to the mesial and distal borders of the mental foramen (T4 and T5) parallel to the perpendicular (P). The following measurements were taken:

- D1: the vertical distance from the superior border of the mental foramen to the alveolar crest of the mandible.
- D2: the vertical distance from the superior border of the mental foramen to the inferior border of the mandible
- D3: the vertical distance from the inferior border of the mental foramen to the inferior border of the mandible
- D4: the horizontal distance from the mesial border of the mental foramen to the distal border of the mental foramen (Horizontal dimension)
- D5: the vertical distance from the superior border of the mental foramen to the inferior border of the mental foramen (Vertical dimension)

The perpendicular, the tangents and the measurements conducted on the digital panoramic image are shown on (Figure 1).

Statistical analysis

The data were tabulated using Microsoft excel and statistically analyzed using SPSS 20.0 statistical package. Discriminant function analysis was used to estimate the efficiency of each variable for sex determination. The canonical correlation, Wilk's lambda, canonical discriminant

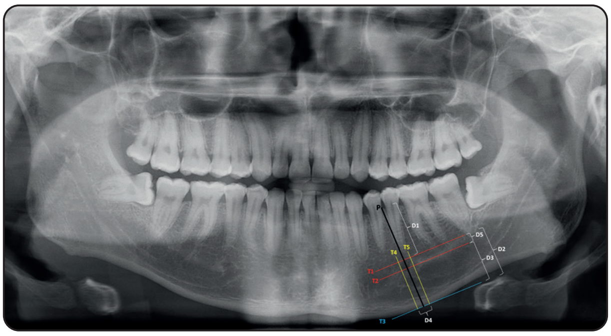

Fig. (1): The perpendicular (P), the tangents (T1, T2, T3, T4 and T5) and the measurements (D1, D2, D3, D4 and D5) as conducted on one side of the digital panoramic image function coefficients including standardized and unstandardized coefficient, structure matrix correlation, and group centroids were calculated. The following discriminant equation was used to calculate the discriminant score (Z):

$$Z = C + W1X1 + W2X2 + W3X3 \ldots\ldots\ldots + WiXi$$

where:

Z = discriminant score, C = constant W = discriminant coefficient for the independent variable, X = Independent variable, i = number of predictor variables. The cutting score will be used to classify the sex and it was calculated by using the following formula; $Z_{CS} = (Z_M + Z_F)/2$ where Z_{CS} is optimal cutting score for equal group size, Z_M is centroid for male and Z_F is centroid for female. When Z_{CS} was more than the cutting score, it was classified as male and when Z_{CS} score was less than the cutting score, it was classified as female. The level of significance was set at 0.05. Moreover, the percentage of correct classification for each sex and accuracy were calculated for both original and cross validated groups

RESULTS

The mean and standard deviation for each of the measurements and associated univariate F ratios for both sexes are shown in (Table 1). It is evident that all measurements were larger in males compared to females, except for the (D1). Mean values of the measurements in males and females are shown in

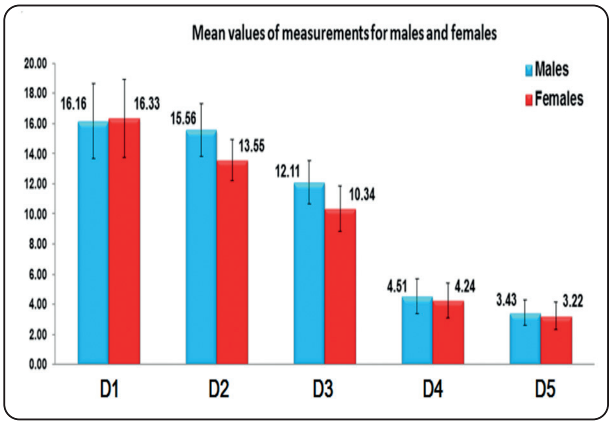

Fig. (2): Mean values of the measurements conducted on the digital panoramic images in males and females

(Figure 2).

For the discriminant function, the unstandardized and standardized coefficients, structure matrix and group centroids were used (Table 2). Standardized discriminant function coefficients indicate the relative importance of each variable in predicting sex; (D3) was found to have the greatest contribution while (D2) was the next in importance as a predictor. The remaining three predictors (D1, D4 and D5) had considerably lower effect in prediction. Unstandardized discriminant function coefficients are used to construct the actual prediction equation in order to calculate the discriminant scores. To calculate this, each variable is multiplied with its unstandardized coefficient and the results are then added together to the constant **(Z = -9.834 +**

TABLE (1): Descriptive statistics and comparisons of mean values of the measurements in both groups

Variables	Males		Females		Wilks' Lambda	F	P value
	Mean	SD	Mean	SD			
D1	16.16	2.49	16.33	2.61	1.00	0.12	0.73090
D2	15.56	1.74	13.55	1.36	0.70	41.47	0.00000
D3	12.11	1.43	10.34	1.51	0.73	36.57	0.00000
D4	4.51	1.14	4.24	1.16	0.99	1.38	0.24302
D5	3.43	0.85	3.22	0.91	0.99	1.39	0.24142

0.028 (D1) + 0.26(D2) + 0.427(D3) + 0.054(D4)+ 0.172 (D5). The group centroids are the mean values of discriminant score for each group. In the present study, they were 0.663 for the male group, and -0.663 for the female group (Figure 3). The statistical difference between the group centroids was significant. The cutting score was zero, therefore, discriminant scores greater than zero were classified as male and less than zero (negative scores) were classified as female. Accordingly, 73 % of the cases of the original group were classified correctly while 70.0% of cross-validated grouped

TABLE (3): Classification accuracy for the discriminant function

Group			Predicted Group Membership		Total
			Male	Female	
Original	Count	Male	36	14	50
		Female	13	37	50
	%	Male	72.0	28.0	100.0
		Female	26.0	74.0	100.0
Cross-validated[b]	Count	Male	34	16	50
		Female	14	36	50
	%	Male	68.0	32.0	100.0
		Female	28.0	72.0	100.0

TABLE (2): Discriminant function coefficients, structure matrix and group centroids for sex determination from the measurements conducted on the digital panoramic images

Variables	Standardized coefficients	Unstandardized coefficients	Structure matrix	Group centroids	
				Males	Females
D1	.071	.028	-.052	0.663	-0.663
D2	.405	.260	.972		
D3	.627	.427	.913		
D4	.062	.054	.177		
D5	.152	.172	.178		
Constant		-9.834			

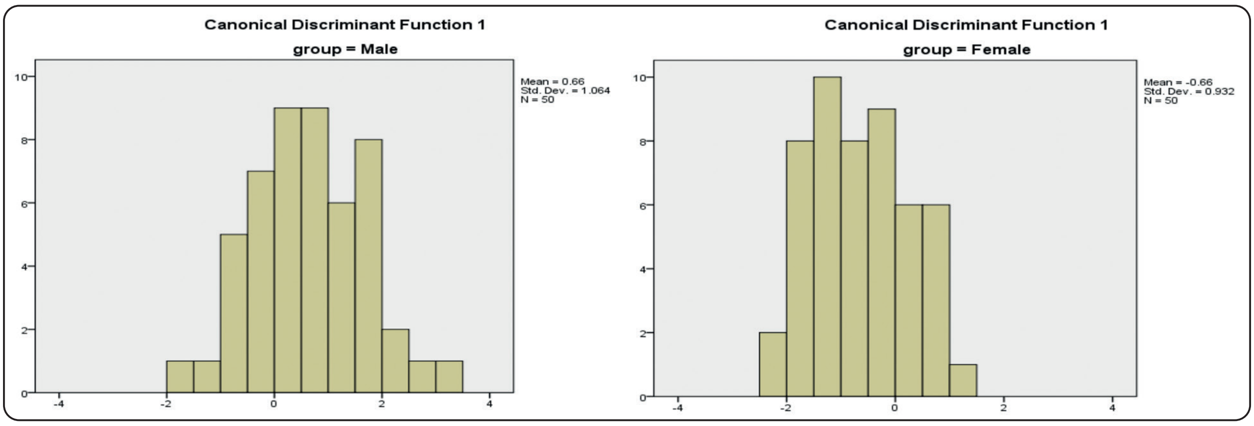

Fig. (3): Group centroids for the male and female groups cases were classified correctly (Table 3).

DISCUSSION

Forensic studies on living subjects play an important role in sex determination [21]. Sex determination is of utmost importance in the forensic analysis involving criminal cases as well as personal identification of missing people and victims of mass deaths [1,2,15] . Forensic dentistry is a branch of dentistry which is involved with human identification through analysis of dental evidences and fragments of jaws [7,15]. Sex determination using just morphological features is subject to error and inaccuracy while identification based on morphometric analysis and measurements of the bone is considered an accurate method [15,22].

Sex determination based on the analysis of the mandibular characteristics has been commonly researched in forensic dentistry [22]. Sex hormones can affect the rate of growth leading to differences in the mandibular morphology between males and females, thus, together with the different forces of mastication between males and females, rendering the mandible of significant sexual dimorphic features [2,3,15]. Among several landmarks of the mandible is the mental foramen that can help in sex determination [1,10]. It is considered a reference point in morphometric analysis due to its stable relation with the inferior border of the mandible, thus rendering it a stable landmark on the mandibular radiographs as reported by several authors [4,5,8-11] Because of the stability of the relation between the inferior border of the mandible and the mental foramen, these landmarks have been used in the present study.

The mental foramen is fairly well projected using panoramic radiography, which allows the ability to view the whole mandibular body, giving an accurate position of the mental foramen in both vertical and horizontal dimensions [8,9]. Malik et al reported that the panoramic radiography is considered to be the most preferable technique for localization of the mental foramen [14]. In addition, Shanmugasundaram and Prasanthi reported that the vertical measurements are clinically applicable on panoramic radiographs while Hu et al mentioned that panoramic radiographs are of better quality when obtained from digital panoramic radiography [22,23]. Moreover, Olasoji et al in their study concluded that there was no significant difference between locating mental foramen on the skull and locating it from panoramic radiographs [24]. Thus, together with its wide availability, the digital panoramic radiography was selected for the analysis in the present study. While regarding age of the patients included in the present study, only those above 18 years old were included, as to assure that the skeletal growth is completed [25].

In the present study, measurements and analysis were done concerning only one side of the mandible of each patient. It was reported by Ghouse et al, Chandra et al, Rani et al and Naroor et al that there was no significant difference between the measurements taken from the right and left sides of the mandible of the subjects involved in their studies [5,9,12,20]. In addition, Apaydin et al and Alias et al were among the authors who conducted the study on only one side of the mandible [3,26].

The highly reliable and easily exhibited aspects of the mental foramen on the panoramic radiographs are the measurements made from the superior and inferior borders of the mental foramen to the inferior border of the mandible [4]. In the present study, the measurements from the superior and inferior borders of the mental foramen to the inferior border of the mandible (D2 and D3) were assessed where the mean values of such measurements are significantly higher in males than in females. These findings are in accordance with similar studies done by Dave and Krishnan, Chandra et al, Malik et al and Shanmugasundaram and Prasanthi who conducted their studies on the same sample size as the present study and their results showed these measurements to be significantly higher in males than in females [8,9,14,22]. On the contrary, Uppal et al reported that the measurement form the inferior border of the mental foramen to the inferior border of the mandible showed no significant difference between males and females [2]. Regarding another variable, the present study showed the measurement form the alveolar crest to the superior border of the mental foramen (D1) to be slightly higher in females than males which is opposite to studies conducted by Uppal et al, and Ghouse et al who reported results with statistically significant higher mean values in males compared to females [2,5]. Moreover, Shaaban et al also reported higher mean values in males but with non-significant difference [10]. Such disagreement of the present result with the other studies may be due to the fact that alveolar ridge resorption, which affects the measurement of the distance between the alveolar crest and the superior border of the mental foramen, is not affected only by the sex, but also it has been attributed to other factors, like age, anatomy of the facial bones, metabolism, oral hygiene, parafunctions, general health condition, and nutrition [27,28].

Both measurements of the horizontal and vertical dimensions (D4 and D5) of the mental foramen were assessed in the present study where the mean values were slightly higher in males than in females with no significant difference. Such findings is in accordance with Bello et al who reported non-significant difference regarding the mean values of the horizontal and vertical dimensions of the mental foramen which were higher in males compared to females [29]. In addition, Oliveira et al reported in their study higher values in males than females with statistical difference that was non-significant regarding the horizontal dimension of the mental foramen but was significant regarding its vertical dimension [30]. Disagreeing with the present results, Zmyslowska-Polakowska et al, who conducted their study using cone beam computed tomography, stated that their study revealed a statistically significant difference between the males and females regarding both the horizontal and vertical dimensions of the mental foramen with the males showing higher mean values [31].

The discriminant function analysis was conducted in the present study. The results showed that the measurement made from the inferior border of the mental foramen to the inferior border of the mandible (D3) has been found to have the greatest contribution as a sex predictor while measurement made from the superior border of the mental foramen to the inferior border of the mandible (D2) is the next in importance as a predictor, rendering them of great sexual dimorphic significance. Similar findings were reported by Chandra et al who stated that the distance from the mental foramen to the inferior border of the mandible shows sexual dimorphism [9]. Moreover, Thakare et al, reported that the mean values in their study showed significant difference in terms of sex, regarding measurements from the superior and inferior borders of the mental foramen to the inferior border of the mandible [21]. On the other hand, the remaining three predictors in the present study; the measurement from the alveolar crest to the superior border of the mental foramen (D1), as well as the horizontal and vertical dimensions (D4 and D5) of the mental foramen, showed considerably lower effect in prediction and thus do not exhibit sexual dimorphism according to the present study. Such present finding is disagreeing with that of Naroor et al who reported that the distance between the alveolar crest to the superior border of the mental foramen can be used for sex determination [20]. Moreover, studies conducted by Uppal et al as well as Ghouse et al reported that the distance from the alveolar crest to the superior border of the mental foramen can be used for differentiating males form females [2,5].

The discriminant equation derived from the results of the present study showed accuracy of 70%

regarding the cross validated group which is similar to accuracy related to the cross validated group of Renjith et al who attained accuracy of 76.8% in their study concerning sex estimation using anatomical location of the mental foramen[11]. Other studies also used the discriminant function analysis of the measurements conducted on the skull [32,33] or involving the mandible [34-37].

Mandibular dimorphism has been interpreted in the literature as being related to the differences between the male and female sex hormones and musculoskeletal development [2, 15,38]. Also there is a tendency of the skulls of males to be dolichocephalic with an oval shape, while in females the skulls tend to be brachycephalic, meaning that there are more rounded, broad, and short. With such shape variations, the vertical height of males' skulls tends to be higher, thus showing greater vertical distance between the mental foramen and the inferior border of the mandible than in females [13].

CONCLUSION

Digital panoramic radiography can be considered a useful radiographic tool for sex determination from the skeletal remains because of its efficiency for performing the proposed measurements which is of great importance in forensic analysis in situations where the full skeleton of a victim is not available. A discriminant equation was derived in the present study based on the variables of the male and female sexes of the patients involved in this study through morphometric analysis of the mental foramen, where such equation showed accuracy of 70% regarding the cross validated group. Based on our results, there was a significant difference between males and females regarding the distance from inferior border of the mandible to superior and inferior borders of the mental foramen (D2 and D3), thus it is possible to conclude that such distances exhibit sexual dimorphism and can be used in sex determination.

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