Pesquisa Brasileira em Odontopediatria e Clínica Integrada 2024; 24:e220230
https://doi.org/10.1590/pboci.2024.032
ISSN 1519-0501 / eISSN 1983-4632

ORIGINAL ARTICLE

Evaluation of Diagnostic Values of a Gender Discrimination Function, Based on Mandibular Dimorphic Parameters in Iranian Population

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Academic Editor: Yuri Wanderley Cavalcanti

Received: April 15, 2022 / **Review:** May 11, 2023 / **Accepted:** July 17, 2023

How to cite: Rad FO, Shokri A, Javanshir B, Kashi F, Fazilat M. Evaluation of diagnostic value of a gender discrimination function, based on mandibular dimorphic parameters in Iranian population. Pesqui Bras Odontopediatria Clín Integr. 2024; 24:e220230. https://doi.org/10.1590/pboci.2024.032

ABSTRACT
Objective: To evaluate mandibular dimorphic parameters for sex determination by using panoramic radiographs and comparing the results with another equation. **Material and Methods:** In this analytical-descriptive study, the mandible variables, including the ramus height, the coronoid height, the mental height, and the distance between the right and left condyle, were measured in 326 panoramic radiographs. The discriminant function of the statistical method has previously been used to evaluate the diagnostic value of sex. The level of significance was considered 0.05. **Results:** The detection function obtained was statistically significant in quantitative correlation ($p<0.001$) with 99% agreement. Moreover, good sensitivity (81.72%), specify (80.25%), and moderate to good predictive values (PPV: 62.29 and NPV:91.6) were found. Among the mandibular parameters, chin height, ramus height, coronoid height, and distance between two condyles showed the highest gender dimorphism. **Conclusion:** Chin height, and ramus height have the most quality in gender dimorphism. A unique gender discrimination function has been obtained from the results.

Keywords: Forensic Dentistry; Diagnostic Imaging; Sex Determination by Skeleton.

Introduction

One of the main issues in forensic anthropology is human identification, mainly in the form of human remains [1], which is not always efficiently and correctly performed, especially in cases of massive disasters such as explosions, warfare, and aircraft crashes due to skeletal fragmentation [2].

Three basic criteria should guide choosing the skeletal elements being valuable indicators of sex determination: 1) their morphology should show anatomic or physiologic sex differences, 2) they should be able to withstand the rigors of skeletonizing and fossilization, and 3) they should be easily recognizable traits through time and across paleo species [3,4].

In adult skeletons, sex determination is usually the preliminary step of the identification process as subsequent approaches for age and stature evaluation, which are sex-dependent in most ethnicities [5]. Tooth and bone are critical tools for personal identification due to their high resistance to decomposition and degradation [6].

The skull is considered the second most dimorphic portion to identify sex, with an accuracy of up to 92%, following the pelvis. Among them, the mandible is the strongest, largest, and most dimorphic bone. Mandibular dimorphism is affected by the size and shape of masticatory muscles since the chewing force varies for men and women, making the male's bones more prominent and more robust than the female's [2]. Age, sex, race, and occlusion status affect the morphological characteristics of the mandible. A previous study has shown that mandibular bone remodeling occurs with aging [1].

Panoramic imaging is the most available and widely used extra-oral radiography, and its lower cost, ample coverage, and ease of preparation have made it an excellent choice for the examination of many structures [7]. Panoramic radiography accuracy in providing the angular and linear measurements for the mandibular bone has been reported [8-10]. Several studies have explored and proved the effectiveness of craniometric parameters – obtained from radiographs such as panoramic images- amongst various population affinities [11,12].

Considering the importance of the subject and the lack of research in the Iranian population, the main authors had previously conducted a study assessing sexual dimorphism with mandibular parameters including the ramus height, the coronoid height, the mental height, the mandible body height, by using panoramic radiographs [6]. We achieved a discriminative function with high predictability (82.5%) and using fewer measured parameters.

This study aimed to verify the accuracy of the mentioned function in the Iranian population. As a hypothesis, if this function is proven to be accurate, it can be used in forensic medicine for sex identification.

Material and Methods

Study Design and Sample

In this observational study, 326 digital panoramic radiographs were chosen by simple random sampling from the archive of a private maxillofacial radiology clinic up to 2020. The inclusion criteria were proper quality of radiography in patients with complete dentitions and ages between 20 and 55 years. Radiographies of the patients losing more than one tooth in each quadrant, any bone lesions, fracture, history of surgery, deformed mandible, erosion, malocclusion, anomalies of temporomandibular joint (TMJ), as well as radiographs with positioning errors, were excluded.

Data Collection

Radiographs were acquired using the Cranex D panoramic system (Soredex Inc., Tuusula, Finland) with the KVp = 66, mA = 10, t =14.3 ms. Selected mandibular parameters were:

1. Coronoid height (the distance between the coronion and the lower wall of the bone [2]);
2. Chin height (the distance between the menton and the alveolar crest [8]);
3. Ramus height (the distance between the highest and the lowest posterior point of the ramus [8]);
4. The distance between the condyle of both sides (the direct distance between the most lateral points on both condyles [8]).

These parameters were measured using a digital ruler between each pair of mentioned correlated points, as shown in Figure 1. We utilized Scanora Software, ver. 5.2.1 (Soredex, Tuusula, Finland) and a 12.6-inch LED monitor for observation.

All images were once evaluated by a unique dental student, then a maxillofacial radiologist under surveillance on a 17-inch 32-bit monitor (Sync Master 740 N, Samsung Electronics Co., Suwon, South Korea) with 1280 ×1024 pixels resolution in a semi-dark room.

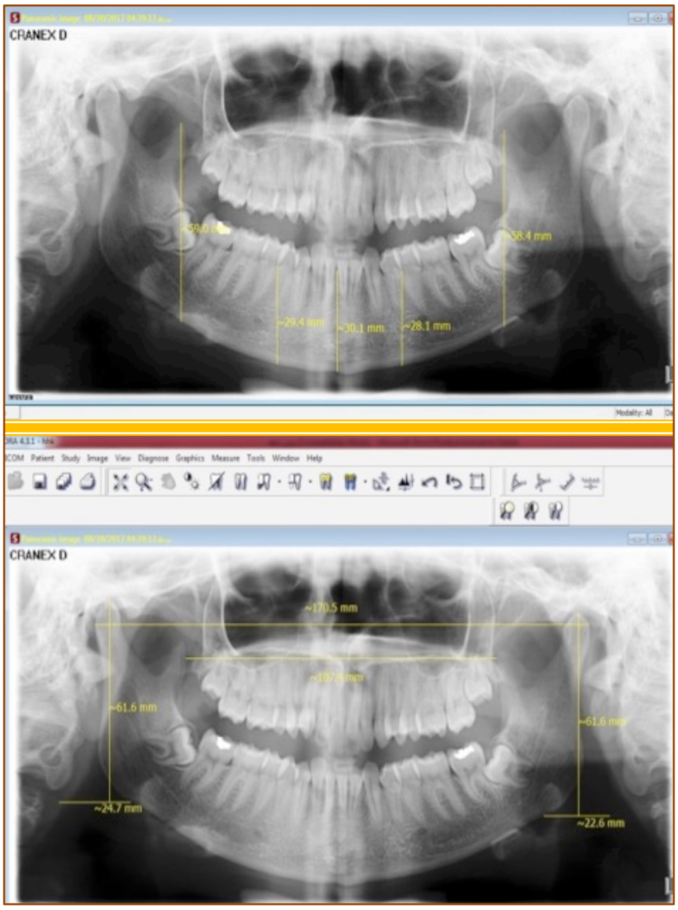

Figure 1. The measurements of parameters using tools of digital panoramic radiography software.

In a previous study, the existence of an equation, such as the consequent one, between these parameters has been proven [6]: $Z = -23.748 + 0.111X1 + 0.128X2 + 0.042X3 + 0.070X4$; Where X1 = the height of the right ramus; X2 = chin height; X3 = the distance between condyles of both sides; and X4 = height of right coronoid. So the correlation between the parameters in this study has been aimed to be investigated.

Data Analysis

IBM SPSS Statistics Software, version 21 (IBM Corp., Armonk, NY, USA) was used for data analysis. The canonical correlation coefficient was used to determine the relationship between each variable and the sex variable. Also, statistical methods of discriminant function and canonical regression were used to assess the predictability of mandibular parameters for sex determination. In addition, the diagnostic indices (sensitivity, specificity, Positive Likelihood Ratio [LR+], Positive Predictive Value [PPV], Negative Predictive Value [NPV], Negative Likelihood Ratio [LR-]) were calculated. The significance level of the tests in this study was considered as 0.05 ($p<0.05$).

Ethical Clearance

This study was approved by the Committee of the School of Dentistry, Guilan University Sciences (GUMS), Rasht, Iran (Code: IR.GUMS.REC.1398.01.

Results

A total of 326 digital panoramic radiographs were collected, and coronoid height, chin height, ramus height, and intercondylar distance were measured on both sides. Two hundred thirty-three radiographs (71.5%) belonged to the females, and 93 radiographs (28.5%) to the males between 20 and 54 years (the mean age: 28.5 ± 7.9). There was no significant difference according to the age of patients ($p=0.329$).

In the present study, all mandibular parameters had significant differences between men and women ($p<0.001$). Measurements of men were higher than women in all of the parameters.Coronoid height, chin height, ramus height, and intercondylar distance were considered diagnostic (discriminative) for gender by using Wilk's lambda. Moreover, according to the Canonical discriminant function coefficient done on the parameters, the order of capability of parameters was chin height, ramus height, coronoid height, and intercondylar distance. The average of canonical correlation coefficients was 0.6 (Table 1).

Table 1. Canonical discriminant function coefficients of mandibular dimorphic parameters.

Discriminative Parameter	CCC	Eigenvalue	Wilks' Lambda	Chi-Square	df	Sig.	Box'M	p-value
Chin Height	0.736	0.563a	0.640	143.904	4	<0.001	12.32	0.278
Ramus Height	0.667							
Coronoid Height	0.633							
Intercondylar Distance	0.508							

CCC: Canonical Correlation Coefficient.

Based on the acquired data, the sex discriminant function can be obtained by the following equation. The canonical correlation coefficient in the present study is 0.6, meaning that values above 0.6 represent the male gender. Based on the acquired data, the sex discriminant function can be obtained by the following equation:

$$Z = -20.714 + 0.08X_1 + 0.148X_2 + 0.037X_3 + 0.059X_4$$

According to the measured dimorphic parameters, the total accuracy in our model was 80.7%. Cohen's Kappa coefficient of the two functions was 0.567±0.048, which is statistically significant and indicates good agreement ($p<0.001$). Moreover, the Interclass Correlation Coefficient (ICC) and Pearson regression coefficient (r) were 0.994 and 0.995, respectively ($p<0.001$). This also shows good to excellent quantitively agreement between two functions.

The diagnostic indices (sensitivity, specificity, NPV, PPV) are shown in Table 2. The results showed good sensitivity (81.72%), specificity (80.25%), and moderate to good predictive values (PPV: 62.29% and NPV: 91.6%).

Table 2. The diagnostic indices of dimorphic parameters in both genders.

Frequency	Sex	Predicted Group		Total	Sensitivity	Specificity	PPV	NPV
		Male	Female					
N	M	76	17	93	81/72	80/25	62/29	91/6
	F	46	187	233	80/25	81/72	91/6	62/62
%	M	81/7	18/3	100/0				
	F	19/7	80/3	100/0				

PPV: Positive Predictive Value; NPV: Negative Predictive Value; 80.7% of original grouped cases correctly classified (accuracy); Kappa = 0.567±0.048; p<0.001.

According to the linear regression (Figure 2), 99% of the results could be predictable in the present function (r^2=0.99).

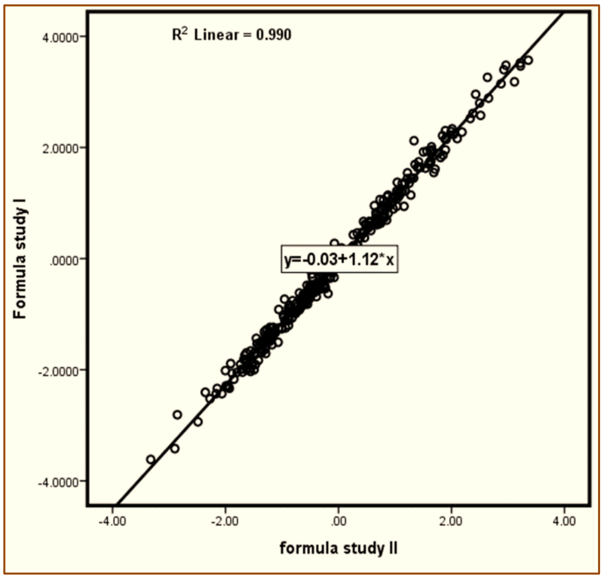

Figure 2. Linear regression model of discriminative functions of the present study and the study of Ostovar Rad et al. [6].

Finally, the Bland-Altman plot was utilized to reveal the agreement between the two studies, shown in Figure 3. In this plot, the difference between the two models was between -0.36 and 0.44, containing zero, which means the difference is not statistically significant (p>0.05).

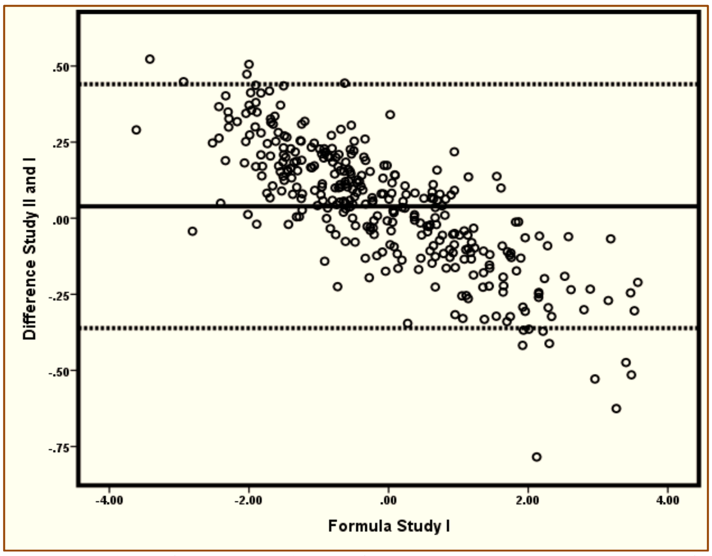

Figure 3. The Bland-Altman Plot of the correlation between the discriminative function of the present study and the study of Ostovar Rad et al. [6].

Discussion

Determining the identity of human skeletal remains is essential in forensic medical sciences. The skull and pelvic bones are best known for their success in sex classification, and more recently, teeth have also been considered a helpful adjunct in this context [13,14]. Mandible bone is the skull's most dimorphic, large, and strong bone, and it is resistant to decomposition and disintegration. Thus, it can be a valuable tool for this purpose [2]. Additionally, mandibular anatomical landmarks are standardized, distinguishable, and easy to locate [15].

Dental radiographs are essential tools in forensic anthropology [16]. Panoramic radiography is the most available extraoral imaging system. Because of lower cost, lower dose, and broader field of view, it is one of the best options for sex determination [17].

Despite the importance of investigation throughout different populations, there are few studies conducted on the Iranian population. One belongs to Ostovar Rad et al. [6], which utilized mandibular dimorphic parameters in 524 patients and achieved a discriminative function with 82.5% accuracy using minimal parameters. In the present study, we aimed to determine the accuracy of the mentioned function in a similar population. As mentioned in methodology, there has been some equations between mandibular parameters in different studies. In a previous study [6], an equation between the same parameters as this study has been obtained.

In the present study, 326 radiographs (93 men, 233 women) between 20 and 55 years old were chosen, and the four most dimorphic parameters in the survey of Ostovar Rad et al. [6] were selected: chin height, ramus height, coronoid height and intercondylar distance on both sides. The gender difference was balanced by increasing the sample size previously estimated for males and females.

The order of the parameters in the present study was chin height, ramus height, coronoid height, and intercondylar distance respectively; However, the order in the study of Ostovar Rad et al. [6] was the ramus height, chin height, intercondylar distance and coronoid height, respectively. In spite of these differences, the present study has proved the discriminative function of Ostovar Rad et al. [6], shows 99% accuracy in sex determination.

Many other previous studies have been conducted in this field. In the present study, chin height is the most dimorphic parameter, while Ostovar Rad et al. [6] found it the second. Previously, only Hazari et al. [18] considered chin height a discriminative parameter.

In the present study, the height of the coronoid, as in the studies by Damera et al. [1], Ostovar Rad et al. [6], and Sairam et al. [7], had sexual dimorphism, and the ramus height in these four studies showed the highest sexual dimorphism. However, in the study of Sambhana et al. [8], coronoid height was the most significant parameter with sexual dimorphism.

The distance between the condyles of both sides was identified as the predictor of sex in the present study and studies by Hazari et al. [18] and Kharoshah et al. [19]. In the study of Karoshah et al. [19], CBCT images were used instead of Panoramic radiography. According to the study by Kharoshah et al. [19], the accuracy of CT scans in sex determination was calculated to be 83.9%, while panoramic accuracy in the present study was obtained to be 82.5%. However, this difference in measurements can be due to differences in race or the anatomical landmarks considered.

Damera et al. [1] (accuracy of 83.5%), More et al. [17] (accuracy of 69%), Bhagwatkar et al. [15] (accuracy of 84%), Sambhana et al. [8] (accuracy of 75.8%), Indira et al. [2] (accuracy of 76%), have also found the ramus and coronoid height useful in sex determination. The present study has confirmed these findings [1,2,8,15,17].

Intercondylar distance has been proved as a dimorphic parameter in the study of Sambhana et al. [8] and Damera et al. [1], with 75.8% and 83.5% accuracy, respectively. This parameter is the fourth rank in the present study.

In all of the previous equations, more parameters were used compared to the present study; therefore, the equation obtained in our research could be considered the most accessible and practical. Moreover, it has the most significant sample size (326 patients) with 82.5% accuracy; in comparison with similar studies such as the study of Damera et al. [1] (80 patients) with 83.8% accuracy, the study of Sambhana et al. [8] (384 patients) with 75.8%, and the study of More et al. [17] (100 patients) with 69% accuracy.

To highlight differences from the work of Ostovar Rad et al. [6], the most significant is the inclusion criteria. Ostovar Rad et al. [6] did not include the patients with more than one tooth missed in each quadrant. The present study included both edentulous and partially dentated patients, although only four were edentulous. However, these findings would confirm the accuracy of the previous function of Ostovar Rad et al. [6] by 99%. According to the presence of just a few edentulous patients in this study, it is essential to investigate this group of patients more in future studies.

On the other hand, all of these studies, in addition to the current study, have used digital panoramic radiography for investigation; therefore, the accuracy of radiographs could have an influence on different results obtained in studies.

Conclusion

This study has obtained a discriminative function using some mandibular and facial measurements for gender diagnosis. Chin height, and ramus height have the most quality in gender dimorphism. A unique gender discrimination function has been obtained from the results.

Authors' Contributions

FOR	https://orcid.org/0000-0002-2618-6056	Conceptualization, Methodology, Validation, Investigation, Supervision and Project Administration.
AS	https://orcid.org/0000-0002-3434-3672	Conceptualization, Validation, Visualization and Supervision.
BJ	https://orcid.org/0000-0002-2137-9115	Conceptualization, Methodology, Investigation and Project Administration.
FK	https://orcid.org/0000-0003-1932-3793	Methodology, Writing - Original Draft, Writing - Review and Editing and Visualization.
MF	https://orcid.org/0009-0003-4333-4246	Investigation, Data Curation and Writing - Original Draft.

All authors declare that they contributed to a critical review of intellectual content and approval of the final version to be published.

Financial Support

None.

Conflict of Interest

The authors declare no conflicts of interest.

Data Availability

The data used to support the findings of this study can be made available upon request to the corresponding author.

Acknowledgments

This study is based on an undergraduate thesis, conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies of the ethics committee of the School of Dentistry, Guilan University Sciences (GUMS), Rasht, Iran. The approval code for this study was: IR.GUMS.REC.1398.013.

We would like to appreciate the Vice Chancellor for Research and Technology of the Guilan University of Medical Sciences for approval of this work.

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