

ORIGINAL ARTICLE

Sex Estimation by Discriminant Function Analysis using the Anatomical Location of the Mental Foramen in the Indian Population of Malaysia

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ABSTRACT

Introduction: Gender determination is an inevitable part of forensic odontology. The mandible, being the strongest bone in the human body, persists well-preserved for extended periods, making its morphological features valuable for gender identification. Among mandibular features, the anatomical position of the mental foramen has shown promising results for gender determination. However, very little research has been conducted in Malaysia among the Indian population. This study aims to correlate mental foramen position with gender among Indian-origin Malaysians and derive a discriminant equation. **Methods:** This retrospective cross-sectional study analyzed 140 digital panoramic radiographs of Malaysian individuals of Indian ethnicity, equally representing both genders (70 males, 70 females). Radiographs were acquired using Planmeca ProMax® 3D system and analyzed using Romexis® software. Two measurements were recorded bilaterally: distance from superior border of mental foramen to lower mandibular border (S-L) and from inferior border of mental foramen to lower mandibular border (I-L). Discriminant function analysis was performed to develop a gender prediction equation. **Results:** Significant differences were found between males and females for all parameters ($p < 0.05$), with males showing greater distances. Mean S-L distances were 14.93 ± 1.84 mm (right) and 14.97 ± 1.79 mm (left) for males versus 13.23 ± 1.68 mm (right) and 13.17 ± 1.44 mm (left) for females. The discriminant equation: $Z = -8.456 + 0.185(\text{Left S-L}) + 0.531(\text{Right S-L}) + 0.316(\text{Left I-L}) - 0.455(\text{Right I-L})$ achieved 72.85% classification accuracy. **Conclusion:** Mental foramen position exhibits sexual dimorphism and can be effectively utilized for gender determination in the Indian population of Malaysia with reasonable accuracy. *Malaysian Journal of Medicine and Health Sciences* (2025) 21(SUPP13):21-25. doi:10.47836/mjmhscs.21.s13.4

Keywords: Mental foramen, Sexual dimorphism, Discriminant function analysis, Forensic odontology, Gender determination

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fields of activity as described by Avon: civil, criminal, and research (3).

INTRODUCTION

The anthropological field encompasses various parameters to understand the existence of variability among humans that could be of significant value in forensics (1). The word forensic is derived from a Latin word, which means “to the forum”. Forensic odontology (FO), or forensic dentistry, is that branch of forensic medicine that, in the interest of justice, deals with the proper handling and examination of dental evidence and also with proper evaluation and presentation of the dental findings (2). This field comprises three major

Gender determination has been an inevitable part of forensic odontology, and understanding sexual dimorphism based on various parameters, including studies on morphological characteristics of bone, has been a perennial topic of research interest (4-6). The mandible, being the strongest bone in the human body, has the ability to persist in a well-preserved state for a long duration of time. Thus, utilizing the morphological features of the mandible to determine the gender of an individual can be useful in various situations (2, 4).

Among various morphoscopic and morphometric features of the mandible, studies on understanding sexual dimorphism based on the position of the mental

foramen have shown promising results and numerous studies have been conducted across the world to determine gender based on the anatomical position of the mental foramen (7-11). Very little research has been done in Malaysia to estimate gender based on the position of the mental foramen. Malaysia comprises people from different ethnic origins, among whom the three main ethnic groups are the Malay, Chinese, and Indian populations. Morphological variations in mental foramen may be attributed to the racial differences. In their research, Alias et al. demonstrated that there was no difference in all the parameters relating to the anatomical position of the mental foramen among three races: Malays, Chinese, and Indians (12). According to the study by Ngeow et al., the most common location for the mental foramen among the Malay population was in line with the longitudinal axis of the second premolar's longitudinal axis (13). George et al., in their study, demonstrated a statistically significant difference based on discriminant analysis among the Chinese female and male populations, indicating that the distance from the superior border of the mental foramen to the lower border of the mandible exhibits sexual dimorphism and is a reliable tool for gender determination (14).

There was no research focusing on determining such variation among Malaysians of Indian origin. Thus, the present study aims to correlate the anatomical position of the mental foramen and gender among the Indian-origin Malaysians visiting the Faculty of Dentistry, Manipal University College Malaysia. An equation for gender determination is derived using discriminant function analysis by analyzing the measurements between the superior border of the mental foramen to the lower border of the mandible (SL) and the inferior border of the mental foramen to the lower border (I-L) of the mandible.

MATERIALS AND METHODS

This retrospective cross-sectional study was conducted at the Department of Oral Medicine and Radiology, Faculty of Dentistry, Manipal University College Malaysia (MUCM), with the objective of evaluating the correlation between the anatomical position of the mental foramen and gender in Malaysian individuals of Indian ethnicity. Ethical approval was obtained from the Institutional Ethics Committee (MUCM/ Research and Ethics Committee – 006/2023), and all procedures adhered to the principles outlined in the Declaration of Helsinki. Informed consent had been previously obtained from all patients at the time of radiographic imaging for diagnostic and treatment purposes.

All digital panoramic radiographs were acquired using a single imaging system: Planmeca ProMax® 3D (Planmeca Oy, Helsinki, Finland) under standardized exposure settings optimized for diagnostic clarity. The images were originally captured for clinical purposes and

archived in the institutional database. As the Planmeca system integrates seamlessly with Romexis® Imaging Software (Version 3.0.1.R), the digital images retained consistent image quality, magnification parameters, and acquisition metadata across all cases. Romexis® software automatically reads and applies the embedded magnification and geometric correction factors specific to each image, thereby ensuring spatially accurate linear measurements without the need for manual calibration. This integration of device and software has been shown to reduce measurement variability and improve reproducibility in morphometric studies (15,16).

The archived panoramic radiographs were independently screened by a senior oral and maxillofacial radiologist for image integrity. To enhance anatomical landmark identification and measurement reliability, only those images that demonstrated optimal diagnostic quality representing adequate contrast, sharpness, absence of artefacts, and full visibility of anatomical landmarks including the mental foramen were included in the study (17,18).

Radiographs were included if the patient was of Indian ethnic origin and aged 20 years or older, with bilateral visibility of the mental foramen, a fully dentulous mandibular premolar region, and no evidence of distortion or radiographic artefacts that could compromise anatomical interpretation. Radiographs were excluded if they exhibited partial or complete edentulism, pathological lesions (e.g., cysts, tumors, or periapical pathology) in the region of interest, congenital craniofacial anomalies, poor resolution, or overlapping structures obscuring the mental foramen.

The final dataset comprised 140 radiographs, equally representing both genders. These were stratified into two cohorts while maintaining gender balance: an original sample of 112 radiographs and a test sample of 28, the latter selected using a computer-generated randomization protocol to eliminate selection bias.

Each radiograph was analyzed in Romexis® software, utilizing its in-built calibrated measurement tools. The mental foramen was identified bilaterally, and two horizontal tangents were drawn: one along its superior border and another along its inferior border. From these reference lines, vertical perpendiculars were extended to the lower border of the mandible. The vertical distances from the superior border of the mental foramen to the lower border of the mandible (S-L), and from the inferior border of the mental foramen to the lower border of the mandible (I-L), were measured and recorded on both sides (Fig.1).

To reduce measurement bias and inter-observer variability, a dual-observer protocol was employed. Two trained investigators, blinded to each other's findings and to patient demographics, independently



Figure 1: Digital radiograph showing the distance between the superior border and inferior border of the mental foramen to the lower border of the mandible marked with tangential lines.

performed each measurement three times per side. The average of the three measurements was calculated for each investigator, and the final value used for analysis was the mean of the two observers' results. The superior border of the mental foramen on the right side was consistently used as the primary anatomical reference to standardize comparison.

RESULTS

Table I illustrates the mean and standard deviation (SD) of the lengths between the lower border of the mandible and the superior and inferior borders of the mental foramen on the right and left sides of the Indian ethnicities. The independent t-test was the statistical test used, and the p-value and degrees of freedom were included.

In the Indian population, with males exhibiting greater distances between the mental foramen and the lower border of the mandible than females. A gender distinction in the mental foramen's proximity from the mandibular lower border is thus implied by the overall pattern.

Table II shows the overall summary of discriminant function analysis of the Indian population. The dependent variables in determining sex have a moderate association, according to the canonical correlation of 0.526, and the (Rc) indicates that gender discrimination accounts for 27.6% of the entirety; however, other factors additionally play an important part. The statistically significant but limited ability for discrimination between groups is illustrated by the Wilk's Lambda (0.723, p-value -0.001) falling fairly close to one.

Compared to Left I-L (0.471) and Left S-L (0.301), the standardized coefficients of Right S-L (0.939) and Right I-L (0.789) among the dependent variables exhibit a significant contribution to the discriminant function. The male group centroids (0.615) and female group centroids (-0.615) show that the two groups are symmetrically separated. Regarding the predictor variables, the discriminant function shows an adequate capacity for distinguishing between males and females because the centroids are not too close to zero. In order

Table I: Descriptive Statistics

Ethnicity	Variable	Male	Female	T (df)	P value
		Mean (SD)	Mean (SD)		
Indian	Right S-L	14.93 (1.84)	13.23 (1.68)	5.69 (138)	0.00
	Left S-L	14.97 (1.79)	13.17 (1.44)	6.53 (138)	0.00
	Right I-L	12.15 (1.78)	11.17 (1.68)	3.33 (138)	0.001
	Left I-L	12.30 (1.58)	10.92 (1.38)	5.48 (138)	0.00

Table II: Summary of canonical discriminant functions of original Indian sample

Variable	Unstandardized coefficient	Standardized coefficient	Structure matrix correlation
Left S-L	0.185	0.301	0.899
Right S-L	0.531	0.939	0.784
Left I-L	0.316	0.471	0.754
Right I-L	-0.455	-0.789	0.458
a (constant)	-8.456		
Group centroid (male)	0.615		
Group centroid (female)	-0.615		
Canonical correlation	0.526		
Wilks' lambda	0.723		<0.001

to determine if the separation is robust enough for practical applications classification demands, additional investigations might be essential, such as investigating accuracy in classification or including other variables. Thus, the discriminant equation for the Indian population is $Z = -8.456 + 0.185 (\text{Left S-L}) + 0.531 (\text{Right S-L}) + 0.316 (\text{Left I-L}) - 0.455 (\text{Right I-L})$.

Table III presents the classification accuracy for the Indian population. Following cross-validation, efficiency slightly decreased (71.42%), but the first grouped situations appropriately identified 72.85% of patients. Although considerably less accurate, the classification accuracy is still robust.

Table III: Percentage of correct classification in original grouped cases, cross-validated grouped cases of the Indian population.

	Male		Female		Accuracy	
	No. of cases	No. (correctly classified) (%)	No. of cases	No. (correctly classified) (%)	Total No. of cases	%
Original grouped cases	70	50	70	52	102/140	72.85
Cross-validated grouped cases	70	48	70	52	100/140	71.42

DISCUSSION

Identification of a person in forensics depends significantly on variables such as age, sex, and race. Since bones may approximate age, sex, and race, they are regarded as an essential tool for identifying skeletal remains (12).

The current study offers new knowledge on the location of the mental foramen and its Indian-ethnic Malaysian populace. A funnel-like aperture in the mandibular lateral surface at the end of the mental canal is known as the mental foramen. The radiographic landmarks of the mental foramen are visible on the majority of standardized panoramic radiographs; nevertheless, their appearance varies without affecting the radiographic quality (13).

The data showed that the mean value of the distance between the superior border of the mental foramen to the lower border of the mandible (SL) and the inferior border of the mental foramen to the lower border (I-L) of the mandible was higher among the males. These results were in accordance with the study conducted by Alias et al., George et al., and Gupta et al. (12, 14, 19).

The results demonstrated that there was a significant difference in the position of the mental foramen among the male and female populations in terms of the superior border to the lower border and the inferior border to the lower border, both on the right and left sides of the mandible, with a p-value being less than 0.05. This marks the importance of employing the position of the mental foramen in gender determination. In a study conducted by Alias et al., among the Malaysian population, they found a significant difference in the distance between the lower border of the mandible and the lower margin of the mental foramen among the males and females (12).

The discriminant function analysis for the Indian population reveals a moderate relationship between the variables used and gender classification. The standardized coefficients of Right S-L (0.939) and Right I-L (0.789) among the dependent variables show a significant contribution to the discriminant function in comparison to Left I-L (0.471) and Left S-L (0.301).

The classification results in the Indian population indicate that the model performs reasonably well in distinguishing between males and females. The original grouped cases showed an overall accuracy of 72.85%, with 50 out of 70 males and 52 out of 70 females correctly classified. After cross-validation, which provides a more realistic estimate of the model's performance on new data, the accuracy slightly decreased to 71.42%, with 48 males and 52 females accurately identified. This small drop in accuracy suggests that the model is relatively stable and maintains consistent performance.

In the study conducted by George et al. , for the Chinese population of Malaysia, a discriminant equation based on the anatomical position of the mental foramen for gender estimation showed accuracy of 85.7% (14).

CONCLUSION

The present study analyzed the less explored zone of utilizing the mental foramen position in gender determination among the Indian population of Malaysia. The precise statistical analysis done is the key feature of the present study. One of the primary outcomes of the study is the discriminant equation that was constructed using the variables among the male and female populations of Indian ethnic origin in Malaysia.

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