

# Sex determination by radiographic localization of the inferior alveolar canal using cone-beam computed tomography in an Egyptian population

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## ABSTRACT

**Purpose:** The purpose of this study was to evaluate possible differences in the location of the inferior alveolar canal in male and female Egyptians.

**Materials and Methods:** This cross-sectional retrospective study involved the evaluation of 210 CBCT scans of Egyptian individuals (18-70 years old). The inferior alveolar canal was localized by measuring 8 linear dimensions: 2 for the vertical localization of the mental foramen (superior and inferior to the mental foramen), 4 at the first molar bifurcation for the vertical and horizontal localization of the inferior alveolar canal (superior, inferior, buccal, and lingual to the inferior alveolar canal), and 2 for the horizontal localization of the mandibular foramen (anterior and posterior to the mandibular foramen). The measurements were statistically analyzed via comparative analysis, stepwise logistic regression, and receiver operating characteristic (ROC) curve analysis.

**Results:** Six of the 8 measured distances differed to a statistically significant extent between the sexes. Regression analysis suggested a logistic function with a concordance index of 84%. The diagnostic accuracy capabilities of the linear measurements as sex predictors were calculated using ROC analysis, and the 6 best predictors for sex determination were selected and ranked from highest to lowest predictive power. Moreover, combining these 6 predictors increased the predictive power to 84%.

**Conclusion:** The location of the inferior alveolar canal in the Egyptian population varies significantly by sex; accordingly, this anatomic landmark could be used as a reliable indicator of sexual dimorphism. (*Imaging Sci Dent* 2020; 50: 117-24)

**KEY WORDS:** Sex Determination Analysis; Cone-Beam Computed Tomography; Mandible

## Introduction

Forensic odontology, a promising new area of forensic medicine, involves - among other uses - the application of dental sciences in the identification of deceased individuals.<sup>1</sup> Sex determination is a subdivision of forensic odontology that plays an indispensable role in human identification, especially when information related to the deceased individual is unavailable.<sup>2</sup>

The inferior alveolar canal, an intrabony canal in the

mandible that contains a neurovascular bundle, originates in the mandibular foramen on the medial surface of the ascending mandibular ramus. From there, it runs obliquely downward and forward in the ramus and then travels horizontally forward and ends at the mental foramen.<sup>3</sup> Previous sexual dimorphism studies on dry mandibles, cadavers, and radiographic images have indicated that the course of the inferior alveolar canal varies with sex.<sup>4-6</sup>

Radiographic imaging is remarkably useful as an aid for sex determination, as it can provide a variety of morphological information noninvasively.<sup>1</sup> In particular, cone-beam computed tomography (CBCT) has proven to be a useful modality for forensic tasks, offering several advantages that include good resolution for skeletal imaging, relatively low cost, and simplicity.<sup>7</sup>

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Many previous studies have examined sexual dimorphism using anthropometric measurements from CBCT images.<sup>2,6,8</sup> The fact that different populations have distinct morphologic and morphometric manifestations of sexual dimorphism makes it essential to study population-specific characteristics. Unfortunately, to date, only limited studies have been published regarding the use of mandibular measurements in sex assessment in Egyptians.<sup>9,10</sup> Based on this information, the current study aimed to examine possible differences in the location of the inferior alveolar canal between male and female Egyptian adults.

## Materials and Methods

The sample size was calculated using the nQuery statistical package (nQuery Advisor, Los Angeles, CA, USA). A statistical power analysis was conducted based on a previous study by de Oliveira Gamba et al.<sup>8</sup> In the detection of a difference in means of 1.05 (the difference between males and females, with means  $\pm$  standard deviations of  $15.7 \pm 1.9$  and  $14.7 \pm 2.0$ , respectively), using the *t*-test with a 2-sided significance level of 0.05 and a power of 80%, a total sample size of 110 participants (55 of each sex) was required. To allow for 25% loss, the sample size was increased to 136 (68 participants of each sex). The sample size was raised further to 210 (120 female and 90 male participants), as increasing the sample size can increase the power of the study and decrease the degree of uncertainty.<sup>11</sup>

After institutional ethical clearance, a sample of 210 CBCT scans (120 from females and 90 from males; age, 18-70 years) was retrieved from the archival database (with the records registered between December 2017 and December 2018) of the Department of Oral and Maxillofacial Radiology of the Faculty of Dentistry at Cairo University. The CBCT images were acquired using a Planmeca Pro-max 3D Mid (Planmeca, Helsinki, Finland) machine with the following protocol: a peak kilovoltage of 90 kVp, a current of 10 mA, a voxel size of 0.4 mm, and a field of view of 160 mm  $\times$  200 mm. According to the manufacturer's instructions, all images were obtained with the patient in a standing upright position, with the head adjusted using the machine's head support aids and with the use of system light localizers to ensure that the midsagittal plane was vertically oriented and the occlusal plane was perfectly horizontal. Only scans that included the full extension of the mandible, had no evidence of bone fractures or pathological lesions, and showed at least the premolars and first molars were selected. Moreover, only scans with normal alveolar bone height or mild bone loss ( $< 3$  mm from the

cementoenamel junction) were accepted.

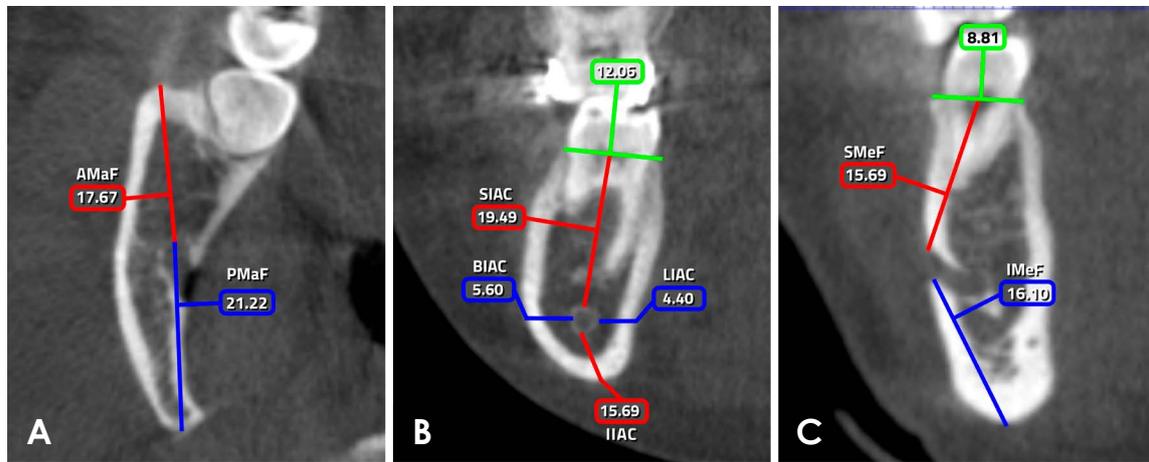
The Planmeca Romexis software viewer version 4.6.2.R (Planmeca) was used for the reconstruction and measurement of the included scans using a personal laptop (LENOVO IdeaPad 320, 15.6-inch screen, 1920  $\times$  1080 pixels, LENOVO, Beijing, China). The measurements were made on different coronal and axial orthogonal planes of the scan after selecting the smallest slice thickness (0.4 mm). The assessment of the location of the inferior alveolar canal was guided by the same 8 linear measurements and their abbreviations originally suggested by Angel et al.,<sup>6</sup> with some minor modifications.

For horizontal localization of the mandibular foramen, 2 measurements were taken on the first CBCT axial image that showed the maximum width of the mandibular foramen (Fig. 1A). First, the distance from the most anterior point of the mandibular foramen to the most anterior part of the mandibular ramus was measured and recorded as the anterior mandibular foramen (AMaF). Then, the distance from the most anterior point of the mandibular foramen to the most posterior part of the ramus was measured and recorded as the posterior mandibular foramen (PMaF).

For vertical and horizontal localization of the inferior alveolar canal, 4 measurements were taken on the CBCT coronal cuts at the region of the first molar bifurcation (Fig. 1B). The first measurement was the distance from the most superior point of the inferior alveolar canal to the midpoint of the alveolar ridge crest, which was recorded as the superior inferior alveolar canal (SIAC). The second was the distance from the most inferior point of the inferior alveolar canal to the lowest point of the inferior border of the mandible, termed the inferior inferior alveolar canal (IIAC). Next was the distance from the most lingual point of the inferior alveolar canal to the mandibular lingual cortical plate, which was recorded as the lingual inferior alveolar canal (LIAC), and the last measurement was the distance from the most buccal point of the inferior alveolar canal to the mandibular buccal cortical plate, defined as the buccal inferior alveolar canal (BIAC).

For vertical localization of the mental foramen, 2 measurements were taken on the coronal cut on which the mental foramen was widest (Fig. 1C). The first was the distance from the most superior point of the mental foramen to the midpoint of the alveolar ridge crest, recorded as the superior mental foramen (SMeF), and the second was the distance from the most inferior point of the mental foramen to the lowest point of the inferior border of the mandible, termed the inferior mental foramen (IMeF).

All measurements were performed by an observer with



**Fig. 1.** Inferior alveolar canal localization on 3 different cone-beam computed tomographic (CBCT) images. A. A cropped axial CBCT cut shows the measurements of the anterior mandibular foramen (AMaF) and the posterior mandibular foramen (PMaF). B. A cropped coronal CBCT cut shows the measurements of the superior inferior alveolar canal (SIAC), inferior inferior alveolar canal (IIAC), buccal inferior alveolar canal (BIAC), and lingual inferior alveolar canal (LIAC). C. A cropped coronal CBCT cut shows the measurements of the superior mental foramen (SMeF) and the inferior mental foramen (IMeF).

> 8 years of experience in oral and maxillofacial radiology. To assess reliability, 63 scans (32 of female and 31 of male participants, representing 30% of the total sample) were evaluated twice by the first observer separated by a 2-week interval and once by a second observer, who had > 15 years of experience in oral and maxillofacial radiology.

Prior to image analysis, the personal data on all scans were concealed and coded, and a reference sheet (consisting of each scan code with its associated personal data) was completed and placed in a sealed envelope by a colleague who was not involved in the image assessment procedures. Each observer evaluated the scans separately and was blinded to the results of the other observer.

All measurements were described in terms of mean, median, standard deviation, and range using R statistical package version 3.5.2 (R Foundation for Statistical Computing, Vienna, Austria) software. Intraclass correlation coefficients (ICC) were calculated to determine the intraobserver and interobserver levels of agreement. The level of agreement was specified according to the following coefficient ranges: 0.00 to 0.30, lack of agreement; 0.31 to 0.50, weak agreement; 0.51 to 0.70, moderate agreement; 0.71 to 0.90, strong agreement; and 0.91 to 1.00, very strong agreement.

To assess the normality of the data, the Shapiro-Wilk test was applied to choose the proper test for the correlation and comparative analyses. Data that were not normally distributed required use of the non-parametric Mann-Whitney *U* test, while normally distributed data required use of the parametric Student *t*-test to assess the differences between

males and females regarding the 8 linear measurements under study. A logistic regression model was built using the stepwise method to determine which predictors were useful in classifying male and female mandibles, and the concordance index was calculated. To evaluate the diagnostic capabilities of the predictors, an optimal cut-off value for each predictor was calculated according to the Youden index method.<sup>12</sup> The sensitivity, specificity, positive and negative predictive values, and accuracy were also calculated for each predictor. The receiver operating characteristic (ROC) curve and area under the curve (AUC) were plotted, and the AUCs were compared using the DeLong test to determine whether the indicators exhibited statistically significant differences in diagnostic accuracy. A *P* value < 0.05 was considered to indicate statistical significance.

## Results

Very strong levels of intraobserver and interobserver agreement were found (with ICCs ranging from 0.93 to 0.1), indicating high reliability and reproducibility for all evaluated measurements (Tables 1 and 2).

The mean values of all posterior measurements (SMeF, IMeF, SIAC, IIAC, BIAC, LIAC, AMaF, and PMaF) were higher in males than females. Additionally, all of the linear measurements except BIAC and IIAC showed statistically significant differences between males and females, with the largest differences found (from highest to lowest) in IMeF, SIAC, IIAC, AMaF, and PMaF and the smallest difference found in SMeF (Table 3).

**Table 1.** Intraobserver reliability as indicated by intraclass correlation coefficients (ICCs) with 95% confidence intervals (CIs) and *P* values

Intraobserver agreement	ICC*	95% CI	<i>P</i>	Level of agreement
Anterior mandibular foramen	0.96	0.93-0.97	<0.05	Very strong
Posterior mandibular foramen	0.99	0.99-1.00	<0.05	Very strong
Superior mental foramen	0.99	0.99-1.00	<0.05	Very strong
Inferior mental foramen	0.99	0.98-0.99	<0.05	Very strong
Superior inferior alveolar canal	0.99	0.98-0.99	<0.05	Very strong
Inferior inferior alveolar canal	0.99	0.98-0.99	<0.05	Very strong
Buccal inferior alveolar canal	0.97	0.95-0.98	<0.05	Very strong
Lingual inferior alveolar canal	0.99	0.99-1.00	<0.05	Very strong

**Table 2.** Interobserver reliability as indicated by intraclass correlation coefficients (ICCs) with 95% confidence intervals (CIs) and *P* values

Interobserver agreement	ICC*	95% CI	<i>P</i>	Level of agreement
Anterior mandibular foramen	0.97	0.95-0.98	<0.05	Very strong
Posterior mandibular foramen	0.99	0.98-0.99	<0.05	Very strong
Superior mental foramen	0.99	0.99-1.00	<0.05	Very strong
Inferior mental foramen	0.98	0.97-0.99	<0.05	Very strong
Superior inferior alveolar canal	0.99	0.99-1.00	<0.05	Very strong
Inferior inferior alveolar canal	0.99	0.99-0.99	<0.05	Very strong
Buccal inferior alveolar canal	0.96	0.93-0.97	<0.05	Very strong
Lingual inferior alveolar canal	0.99	0.99-1.00	<0.05	Very strong

**Table 3.** Descriptive data of all studied linear measurements according to sex

Measurement		Mean $\pm$ SD	Median	Range
Anterior mandibular foramen	Males	16.8 $\pm$ 2.2	16.7	11.8-22.5
	Females	15.8 $\pm$ 2.0	16.0	11.2-20.5
Posterior mandibular foramen	Males	17.8 $\pm$ 2.3	17.8	11.9-23.4
	Females	16.8 $\pm$ 1.9	16.8	10.8-23.4
Superior mental foramen	Males	15.6 $\pm$ 2.8	14.9	9-25.2
	Females	14.6 $\pm$ 1.9	14.7	9.2-19.6
Inferior mental foramen	Males	16.3 $\pm$ 2.2	16.2	10.6-28.5
	Females	14.5 $\pm$ 1.6	14.4	9.9-19.2
Superior inferior alveolar canal	Males	19.1 $\pm$ 2.9	19.3	11.3-25.2
	Females	17.2 $\pm$ 3.0	17.4	9.9-23.8
Inferior inferior alveolar canal	Males	9.4 $\pm$ 2.1	9.7	4.8-14.2
	Females	7.8 $\pm$ 1.9	7.6	2.4-15.6
Buccal inferior alveolar canal	Males	5.8 $\pm$ 1.7	5.6	2-10
	Females	5.5 $\pm$ 1.5	5.4	2-9.2
Lingual inferior alveolar canal	Males	4.6 $\pm$ 1.7	4.4	1.6-9.8
	Females	4.4 $\pm$ 1.6	4.0	1.6-8.8

SD: standard deviation

Screening tests were conducted to determine which variables to include in a logistic regression model for sexual differentiation, and 6 linear mandibular measurements were included in the final model: IMeF, SIAC, IIAC, LIAC, AMaF, and PMaF.

When likelihood analysis was applied to those 6 variables, the following logistic function was formulated:

$$\text{Logit: } 17.58 - 0.38 \text{ IMeF} - 0.18 \text{ SIAC} + 0.33 \text{ LIAC} - 0.39 \text{ IIAC} - 0.22 \text{ AMaF} - 0.15 \text{ PMaF}$$

A negative logit indicates a male anatomic mandibular landmark, while a positive logit indicates a female landmark. Combining the 6 variables yielded a concordance index of 84%.

The results of the evaluation of diagnostic accuracy using cut-off values for the 6 parameters revealed that the highest accuracy was associated with IIAC (73%), followed by IMeF (72%); SIAC, IMeF, and PMaF followed at the same accuracy level (65%), while LIAC was associated with the lowest accuracy (60%). Additionally, when the 6 predictors were combined, the accuracy rate for the identification of female and male mandibles increased to 78% (Table 4).

The diagnostic accuracy of the studied linear measurements as sex predictors was tested using ROC curves and AUC. The results revealed that that the best predictors for sex determination (ranked from highest to lowest predictive power) were ImeF, IIAC, SIAC, AmaF, PmaF, and LIAC. Moreover, combining the 6 predictors increased the predictive power to 84% (Table 4 and Fig. 2).

### Discussion

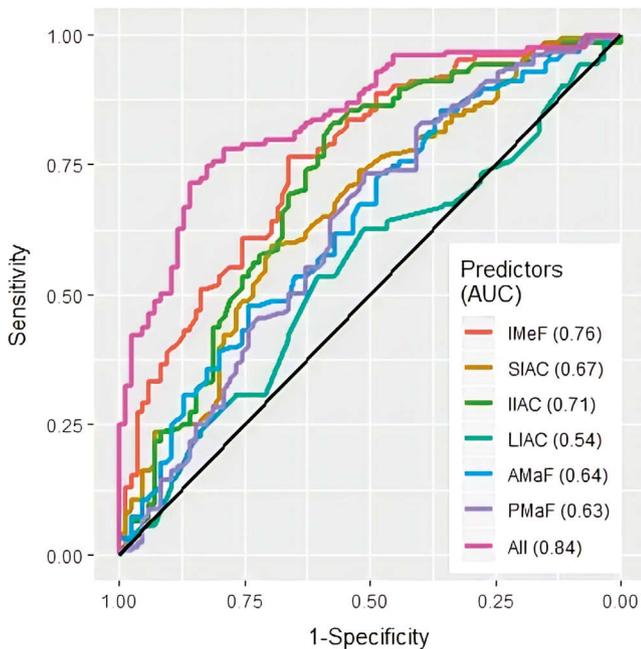
Sex determination is a method used to facilitate human identification and can be accomplished by studying osseous structures such as the human pelvis, the skull foramina, and bones. The accuracy rate of sex determination has been reported as 100% from a skeleton, 98% from both the pelvis and the skull, 95% from the pelvis alone or both the pelvis and the long bones, 90%-95% from both the skull and the long bones, and 80%-90% from the long bones alone.<sup>2,13</sup>

As an internal mandibular anatomic landmark, the mandibular canal exhibits important anatomic variations between individuals, and its position has been demonstrated to differ by sex and age. Based on the uniqueness of this anatomic landmark, the authors of the current study were motivated to assess its location throughout its course and to investigate correlations between its position and the individual's sex in a sample of the Egyptian population.<sup>2,8,14</sup>

**Table 4.** Sensitivity, specificity, positive predictive value, and negative predictive value of the 6 linear measurements selected for sex prediction at optimal cut-offs

	Cut-off	Sensitivity	Specificity	Positive predictive value	Negative predictive value	Accuracy	AUC	95% CI	P
Inferior mental foramen	<15.45	0.76	0.66	0.76	0.66	0.72	0.76	0.69-0.83	<0.05
Superior inferior alveolar canal	<18.4	0.74	0.52	0.69	0.58	0.65	0.67	0.59-0.74	<0.05
Inferior inferior alveolar canal	<9.28	0.85	0.55	0.73	0.72	0.73	0.71	0.64-0.79	<0.05
Lingual inferior alveolar canal	<4.02	1.00	0.02	0.59	1.00	0.60	0.54	0.47-0.62	0.14
Anterior mandibular foramen	<15.68	0.85	0.36	0.66	0.63	0.65	0.64	0.56-0.72	<0.05
Posterior mandibular foramen	<17.72	0.82	0.41	0.66	0.61	0.65	0.63	0.55-0.71	<0.05
All	-	0.78	0.79	0.84	0.72	0.78	0.84	0.79-0.89	<0.05

AUC: area under the receiver operating characteristic curve, CI: confidence interval



**Fig. 2.** Receiver operating characteristic curves of the predictors that are included, both individually and combined, in the final logistic regression model: the inferior mental foramen (IMeF), inferior inferior alveolar canal (IIAC), superior inferior alveolar canal (SIAC), anterior mandibular foramen (AMaF), posterior mandibular foramen (PMaF), and lingual inferior alveolar canal (LIAC). AUC: area under the receiver operating characteristic curve.

CBCT is a groundbreaking 3-dimensional imaging modality that yields outstanding images, which can be studied in an integrated, interactive manner and can contribute to the accuracy of multiple diagnostic tasks in the maxillofacial region. Currently, CBCT scans are widely used in forensic studies for the analysis of different landmarks for the purpose of sex determination.<sup>15,16</sup>

In the present study, the measurements were guided by Angel et al.<sup>6</sup> with some minor modifications to allow for additional standardization. Angel et al.<sup>6</sup> measured both the SIAC and the SMeF up to the occlusal surface of the corresponding tooth. Similarly, de Oliveira Gamba et al.<sup>8</sup> and Gopal and Sundaram<sup>13</sup> measured the SIAC from the superior aspect of the inferior alveolar canal to the occlusal aspect of the mandibular first molar. We found that the tooth crown should not be included in this measurement, as its omission avoids any variation resulting from changes in the crown height such as overeruption, attrition, caries, or poor restorations; when only the bone dimension is assessed, the methodology can be applied even to cases in which teeth are missing, broken, or decayed. In contrast, Uppal et al.<sup>2</sup> and de Oliveira Gamba et al.<sup>8</sup> measured the SMeF from the mental foramen to the lingual margin of the alveolar crest,

while we chose to measure it from the mental foramen to the midpoint of the alveolar ridge crest.

The means of all the assessed measurements were higher in male than in female participants, similar to the results obtained by Uppal et al.<sup>2</sup> The higher mean values in males than in females can be attributed to a sex-based difference in the degree of bone growth in the adult phase. Bone growth is controlled by several factors, including sex hormones and muscular tension. Sex hormones such as estrogen and progesterone can influence the speed of bone growth, contributing to the development of sex-based differences in the craniofacial morphology. Bone growth is more rapid in males, resulting in craniofacial dimensions that are 5% to 9% larger than those in females.<sup>17,18</sup> However, some authors consider this difference to be mainly due to the longer puberty period in males and the correspondingly longer duration of bone growth, which in turn affects bone size. Muscular tension is another factor known to induce bone formation, and because men have stronger masticatory muscles than women, the mandible is generally more developed in males.<sup>19,20</sup>

However, de Oliveira Gamba et al.<sup>8</sup> found that the mean values of all measurements were higher in males except for AMaF and BIAC, which were higher in females. Another dissimilarity with the results of the present report was found in a study conducted by Gopal and Sundaram,<sup>13</sup> who found that the mean values of all measurements were higher in males except for that of AMaF, which was higher in females. The variations between the results of these studies and the present study could be attributed to the different ethnic origins of the studied populations and the differences in standardization protocols employed for the measurements.

In the current study, 6 linear measurements (AMaF, PMaF, SMeF, IMeF, SIAC, and IIAC) displayed statistically significant differences between sexes, while the differences between males and females in the measurements of BIAC and LIAC were statistically insignificant. Similarly, in a study of Brazilian individuals, de Oliveira Gamba et al.<sup>8</sup> found BIAC to be the only measurement with a statistically insignificant difference between males and females, while the other 7 measurements displayed statistically significant differences. On the contrary, Gopal and Sundaram,<sup>13</sup> in their study of an Indian sample, found that AMaF, PMaF, IIAC, SIAC, and BIAC showed statistically significant differences between sexes, while the differences in LIAC, SMeF, and IMeF were insignificant. Similarly, Uppal et al.<sup>2</sup> found that only 3 measurements (SMeF, SIAC, and IIAC) significantly differed between males and

females. Yet another early study, conducted by Angel et al.<sup>6</sup> on American participants, was the only one in which most of the measured distances showed no significant difference between males and females; indeed, only AMaF and SIAC showed even near-statistically significant differences with very small effects. These studies examined different populations, and variations in genetics, diet, habits, and customs may result in distinct anatomic features.<sup>20,21</sup>

Stepwise logistic regression was performed via variable parameter selection, and the model included IMeF, SIAC, IIAC, LIAC, AMaF, and PMaF measurements. A concordance index of 84% was found when combining the 6 variables. It is worth mentioning that de Oliveira Gamba et al.<sup>8</sup> and Gopal and Sundaram<sup>13</sup> combined only 5 variables (the AMaF, PMaF, SIAC, IIAC, and BIAC) in their models. The results of the study by de Oliveira Gamba et al.<sup>8</sup> revealed an 86.1% concordance index, which is very similar to our results.

The present study was the first to use the ROC curve and AUC to suggest cut-off values and evaluate the diagnostic capability of the 6 studied predictors. Many researchers have confirmed the advantages of the use of the ROC curve in statistical analysis in different research contexts. First, in contrast to the single measures of sensitivity, specificity, and diagnostic accuracy, the AUC derived from this analysis is not affected by the prevalence of one studied group over the other, since it is based on both sensitivity and specificity.<sup>22,23</sup> Second, several diagnostic tasks conducted on the same subjects can be compared simultaneously through ROC, and methods have also been developed to evaluate the covariance between 2 correlated ROC curves. Third, one can easily perceive the sensitivity by visualizing the curve, and fourth, the optimal cut-off value can be determined using ROC curve analysis.<sup>24-26</sup>

One limitation of the current study that could be addressed in future research is that it did not include age estimation as a secondary outcome using the same radiographic localization of the mandibular canal. Furthermore, it is worth mentioning that the present study represents a milestone for sex determination studies concerning the Egyptian population; as such, its results should be included in systematic reviews to facilitate the creation of future definitive clinical guidelines.<sup>27</sup>

In conclusion, the location of the inferior alveolar canal in the Egyptian population varies significantly between sexes; accordingly, this anatomic landmark can be used as a reliable indicator of sexual dimorphism. According to the ROC results, IMeF had the highest individual sex predictive power, followed by IIAC, SIAC, AMaF, PMaF, and fi-

nally LIAC. An even higher predictive power (84%) could be achieved by combining the 6 predictors.

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**Conflicts of Interest:** None

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