3D CBCT Analysis of Odontometric Variables for Gender Dimorphism in Saudi Arabian Subpopulation

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Abstract

Background: For assessing the sex of unidentified or skeletonized individuals, the tooth crown diameters are a good and reliable source amongst the other clinical markers.

Aim and Objectives: To check the accuracy and reliability of Mandibular Canine Index (MCI) in sex determination among Saudi subpopulation using 3D Cone Beam Computerized Tomography (CBCT) images. An additional objective is to establish the norm of Standard MCI.

Methodology: A total of 400 CBCT images were studied for the measurements of mesio-distal width (MDW) and inter-canine distance (ICD) of mandibular canines. Then, the observed and Standard MCI were calculated that was statistically determined by receiver operating characteristic (ROC) analysis.

Results: Left canine showed greater sexual dimorphism. The Standard MCI was calculated as 0.239 (right mandibular canine) and 0.241 (left mandibular canine). The ability to determine gender correctly using Standard MCI (right mandibular canine) method was estimated to be 49% among males and 46.5% among females. The accuracy of the method, when applied to the combined data, was 47.8%.

Conclusion: MCI and the variables that allow MCI quantification were shown to distinguish the groups, in terms of average, suggesting the possibility that canine-related measurements may be used for sex discrimination.

Keywords: *Canine; CBCT; Odontometric.*

Introduction

Forensic odontology plays a vital role in the recognition of victim of mass disasters.[1] Odontometric features used for sex identification are sometimes dependent on the gender wise comparison of tooth dimensions.[2] Among all the teeth, mandibular canines are better-known to show the greatest sexual dimorphism, and so it is assigned as the 'key teeth' in human identification.[3]

Odontometric analysis using direct measuring ways has been done using hand-held digital calipers, 2D digital model, graphical illustration to record dimensions on dental casts, digital impression model, 3D CBCT model, and laser scanned model.[4] 3D CBCT has made it possible to conduct odontometric measurements in three-dimension and providing a lot of precise and consistent tools.[5] It conjointly offers additional advantages like availability of images created, decrease in storage expenses and the facility to gauge the pictures by refined software. All these options strengthen the credibility and reliability of 3D CBCT method for the odontometric morphometry.[4]

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Despite conducting thorough literature review, no study could be found that has tested this methodology among Saudi population. Hence, the current study was conducted with an aim to examine the accuracy and reliability of MCI in sex determination among Saudi population by in vivo 3D CBCT. An additional objective of this study was to ascertain the norm of Standard MCI.

Material and Method

This cross-sectional study of secondary data was conducted between the periods of May 2017 to July 2019. Sample size was assessed using nMaster software (version 2, CMC, Vellore). Anticipating, a 60% accuracy of Standard MCI method for predicting gender in the study population, an absolute precision of 5% and a 95% Confidence interval, a sample size of 369 was found to be sufficient. This sample size was rounded off as 400 with equal proportion of males and females.

The data source was CBCT volumetric data from the archives of the College of Dentistry, Jouf University and samples were selected using simple random technique. Odontometric morphometry was analyzed and recorded in 400 3D CBCT volumetric data mandibular arches. The inclusion criteria were i) age-group of 17-35 years; ii) presence and complete eruption of all morphologically normal permanent teeth with exception of third molars; and iii) high quality CBCT that have proper density and contrast with sharp outlines. The exclusion criteria were i) severe crowding; ii) excessive spacing; and iii) interproximal caries or restoration.

Studied parameters

MDW: measured as the maximum distance between the contact points of mandibular canines on the approximate surfaces of the tooth crown.[6] (**Figure 1)**

ICD: measured between the contact points of mandibular canines.[7] (**Figure 2)**

Procedure

The selected 400 CBCT images were analyzed using software OnDemand 3D. The readings obtained from measurement MDW and ICD were subjected to mathematical operations to calculate the observed MCI. The formula used to determine canine index was-

Observed MCI = MDW of mandibular canines/ICD.

Standard MCI = (mean male MCI − Standard deviation [SD]) + (mean female MCI+SD)/2.

The Standard MCI value aided as a cut-off point to differentiate males from females. Individuals with the observed MCI values≤Standard MCI value were categorized as females; otherwise, they were grouped as males.

Measurement of error: The readings were repeated at two weeks interval to evaluate the systemic and random errors for 50 CBCT images that were randomly selected. Two-sample *t*-test was used for calculating systemic errors for each pair of analyses. All test and retest measurements presented an intra-class correlation of value greater than 0.91 that is acceptable as per Stirrup (1993).[8] Outcomes form these variables showed that there were no random errors. All pairs of measurements showed a p-value>0.1, suggesting that there was no systemic bias in these analyses as stated by Houston (1983).[9]

Statistical analysis

Descriptive analysis of MDW and ICD were presented as means and SD. Predictive accuracy was assessed in terms of percentage. The accuracy of the Standard MCI, to correctly identify the gender, was statistically determined by ROC analysis. Sensitivity and specificity of a diagnostic test can be interpreted by ROC curve that is created by plotting the true positive rate against the false positive rate at various threshold settings. The area under curve (AUC) determines the accuracy of the test. An AUC value of 1.0 indicates the perfect test. If the AUC is 0.9-1.0, it shows excellent test. An AUC value of 0.8-0.9 indicates a good test, whereas an AUC value of 0.7-0.8 depicts a fairly reliable test. The AUC value<0.5 indicate an unreliable test.

Results

The descriptive statistics for MDW, ICD and MCI are summarized in **Table 1**.

1. ***MD dimensions:*** The mean right and left MD canine dimensions among females were 6.41±0.46mm and 6.48±0.44mm respectively, while among males, the values were significantly higher. This difference was found to be statistically significant (p<0.05).

2. ***ICD:*** The mean ICD among males was significantly greater than among females.

3. ***MCI:*** The MCI were found to be higher among

females as compared to males, which was statistically insignificant.

4. ***Sidewise comparisons:*** Left canine exhibited greater sexual dimorphism when compared to right canine.

5. ***Standard MCI:*** Generally, the Standard MCI is obtained using the right mandibular canine MD dimension. But to check the suitability of left mandibular canine for sex determination, the Standard MCI using the left mandibular canine was also determined. The calculated Standard MCI was calculated as 0.239 (right mandibular canine) and 0.241 (left mandibular canine). The ability to determine sex correctly using Standard MCI (right mandibular canine) method was estimated to be 49% among males and 46.5% among females. The accuracy of the method, when applied to the combined data, was 47.8%. While, when Standard MCI (left mandibular canine) was used as cut-off value, 44.5% males and 48.5% females were correctly predicted. The overall accuracy of this Standard MCI (left mandibular canine) was calculated as 46.5%. **(Table 2)**

The AUC (for MCI calculated from right mandibular canine) has a value of 0.481 and 0.519 for males and females respectively. The AUC (for MCI calculated from left mandibular canine) has a value of 0.486 and 0.514 for males and females respectively **(Figure 3a-d).** It can be interpreted that this MCI method was not a reliable method for prediction of gender in the Saudi subpopulation.

Discriminant analysis was utilized to conduct a multivariate analysis of variance test of the hypothesis that males and females would differ significantly on a linear combination of five variables, *viz,* MDW of right canine, MDW of left canine, ICD, right and left MCI. The overall Chi-square test was significant (Wilks λ=0.696, Chi-square=143.56, df=5, Canonical correlation 0.552, $p<0.001$). Re-classification of cases based on the new canonical variables was highly successful: 72.3% of the cases were correctly reclassified into their original categories. **(Table 3)**

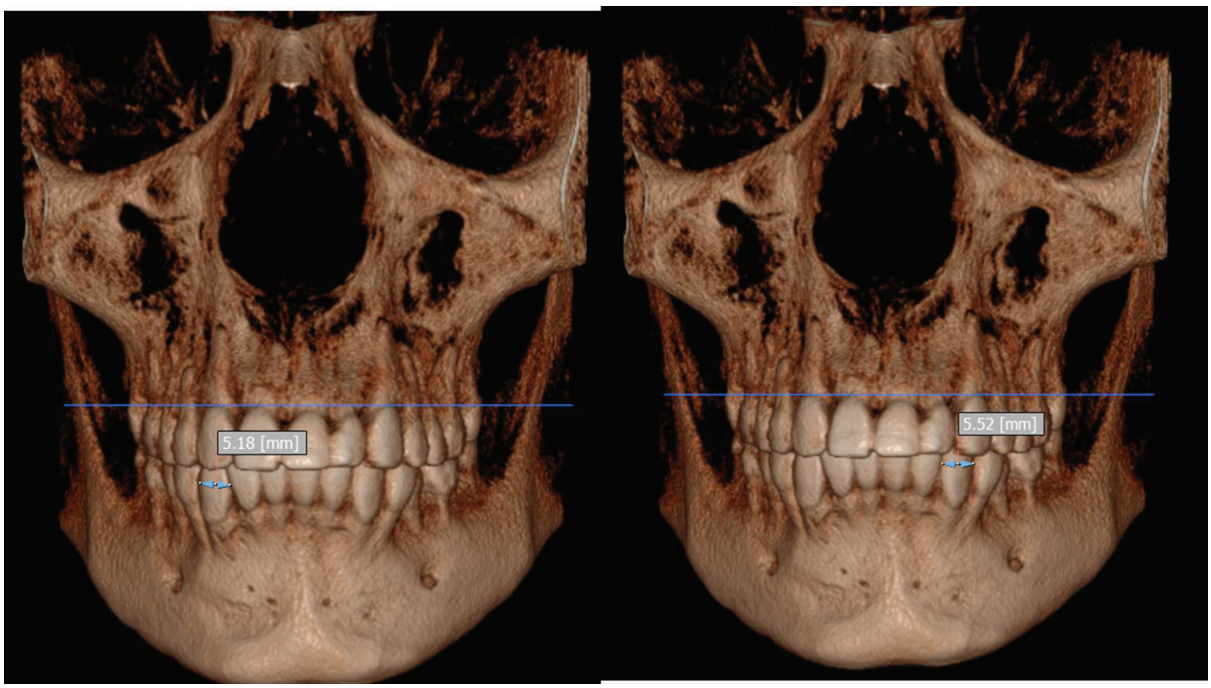

Figure 1. MDW of right and left mandibular canines

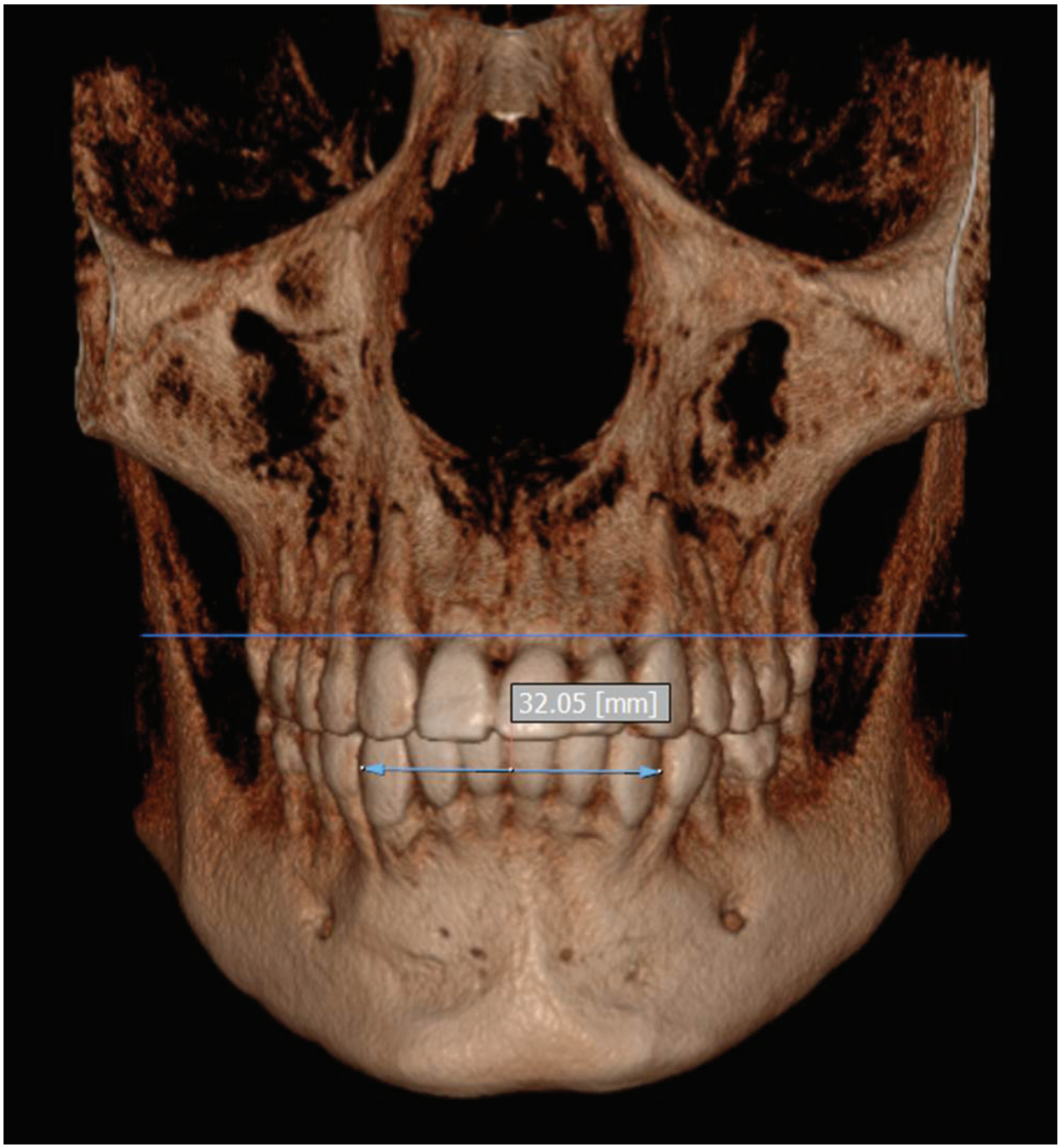

Figure 2. Measurement of ICD

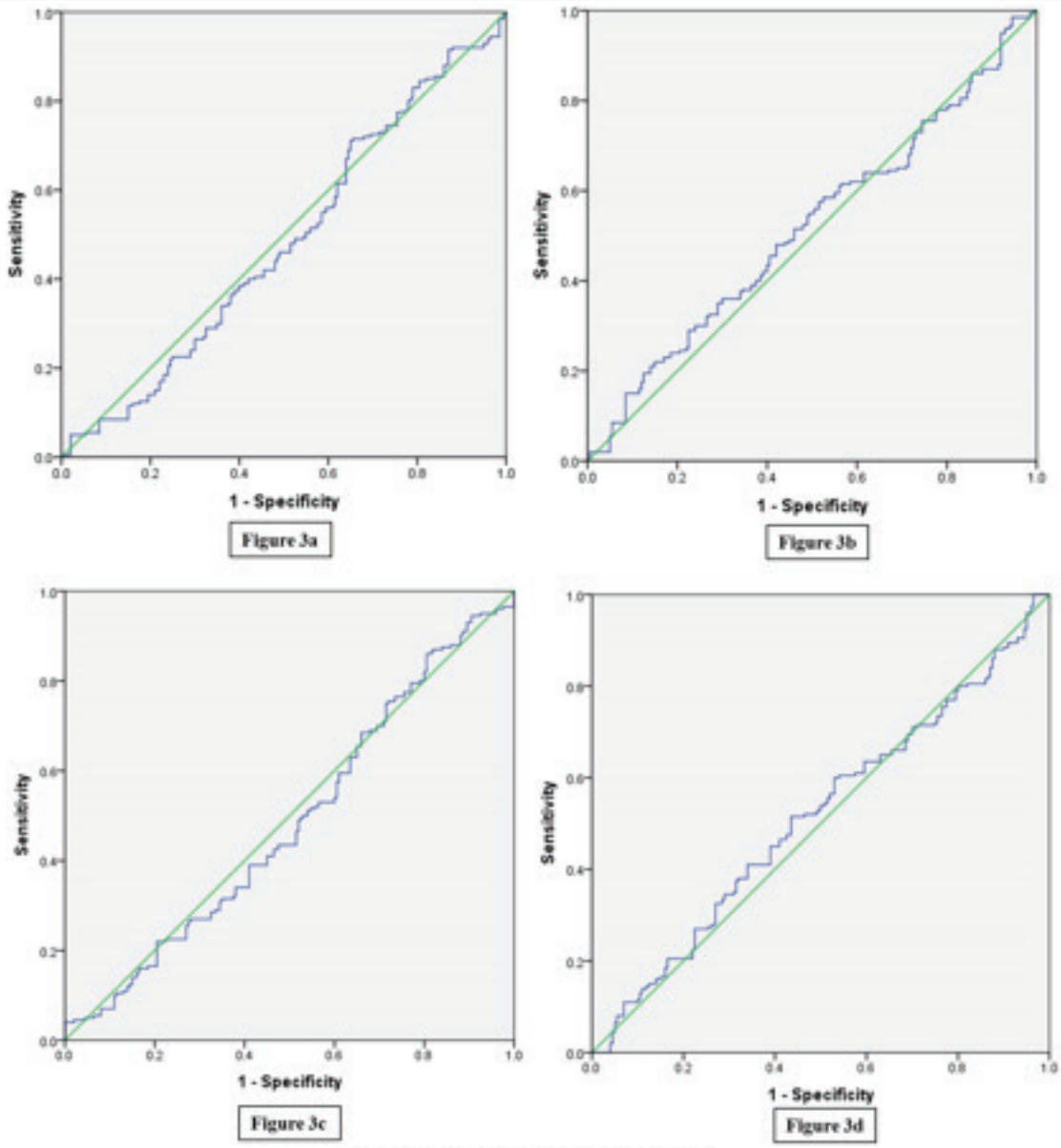

Figure 3. ROC curve depicting

a. MCI (as calculated from MDW of right mandibular canine) among males

b. MCI (as calculated from MDW of right mandibular canine) among females

c. MCI (as calculated from MDW of left mandibular canine) among males

d. MCI (as calculated from MDW of left mandibular canine) among females

Table 1: Gender-wise comparison of right & left canine MDW, ICD & MCI values

Parameter	Gender	N	Mean	SD	't' value	'p' value
Lt Canine MDW (mm)	Males	200	6.99	0.49	10.94	<0.0001*
	Females	200	6.48	0.44		
Rt Canine MDW (mm)	Males	200	6.89	0.52	9.88	<0.0001*
	Females	200	6.41	0.46		
ICD (mm)	Males	200	29.07	2.49	10.01	<0.0001*
	Females	200	26.81	1.99		
MCI (using Rt canine MDW)	Males	200	0.24	0.02	-0.82	0.414
	Females	200	0.24	0.02		
MCI (using Lt canine MDW)	Males	200	0.24	0.02	-0.39	0.695
	Females	200	0.24	0.02		

N= Number of participants

**Statistically significant*

Table 2: Predictive accuracy

MCI	Standard MCI	Males		Females		Total	
		N	%age	N	%age	N	%age
Rt mandibular canine	0.239	98	49	93	46.5%	191	47.8%
Lt mandibular canine	0.241	89	44.5	97	48.5%	186	46.5%

Table 3: Discriminant function analysis for sex prediction

Variables	Raw coefficients	Standardised coefficients	Factor structure matrix	Group centroids
MDW Rt Mandibular canine	14.84	7.29	0.75	0.660 -0.660
MDW Lt Mandibular canine	-14.52	-6.83	0.83	
MCI - Rt Mandibular canine	-433.42	-8.89	-0.06	
MCI - Lt Mandibular canine	460.17	9.33	-0.03	
ICD	0.54	1.22	0.76	
Constant	-23.79			

Classification Resultsa,c

			Gender 1	Predicted Group Membership			Total
				2			
Original	Count		Male	143	57		200
		Female	45		155	200	
	%		Male	71.5	28.5		100
		Female	22.5		77.5	100	
Cross-validatedb	Count		Male	135	65		200
		Female	46		154	200	
	%		Male	67.5	32.5		100
		Female	23.0		77.0	100	

a. 74.5% of original grouped cases correctly classified.

b. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.

c. 72.3% of cross-validated grouped cases correctly classified.

Discussion

The present study was carried out on CBCT data of 400 patients using the In-Vivo Dental program and the digital models obtained out of 3D onDemand software. The uniqueness of the current study lies upon the following statements: (1) 400 CBCT data; (2) assessment of odontometric morphometry by new approach; and (3) first time in Arabian subpopulation using this novel method.

There is no consensus on the suitability of the MCI in sex determination, as different authors have stated different conclusions. In an Indian sample, Duraiswamy *et al.* (2009)[10] claimed 72.0% accuracy rate, while Silva *et al.* (2016)[11] mentioned a 54.2% accuracy rate in a Portuguese population. A higher accuracy rate was reported by Yadav *et al.* (2002)[12] but a much lower accuracy was stated by Muller *et al.* (2001)[13]. Variations can, obviously, exist in population disparities.

The present study established that the MD dimension of mandibular canines exhibited statistically significant sex variation. No statistically significant differences were found between right and left mandibular canines in both sexes suggesting that the canine measurement on any side of the jaw can also be used for the other side. This finding is in harmony with the study done by Shahid *et al.* (2015).[14] Also a significant difference in ICD was detected between the sexes with male subjects exhibiting larger ICD. Although this finding is consistent with previous reports on the canine index but these measurements were done by digital caliper on plaster model.[15]

The percentage sexual dimorphisms were also calculated by using Garn and Lewis formula.[16] The present study found a definite statistically significant sexual dimorphism in mandibular canines, which is consistent with previous studies.[17,18] The left mandibular canine exhibited greater dimorphism as compared to right. Thus, usage of left mandibular canine for sex determination of an individual will give more precise results. This finding is found to be in accordance with many previous studies showing the values of sexual dimorphism in this range only. Few studies had found a higher degree of sexual dimorphism in canine dimensions while few others had found a lower magnitude of sexual dimorphism. This observation is of definite significance and the discrepancy can be explained based upon the fact that tooth morphology is known to be influenced by environmental, cultural, and racial factors.[19]

Nonetheless, MCI did not show any statistically significant sexual variation in the present study population. This finding was contradictory to many previous studies.[11,18] Many recent similar studies on Nepalese and Indian origin population also could not found gender variation in MCI.[20,21] In addition, discriminant analysis of MCI revealed poor ability to differentiate the sexes. This finding could be attributed to MCI being measured as a relative value- it is estimated as a ratio of two absolute measurements and does not reproduce sex differences that exist in the absolute measurements per se.[22] Acharya *et al.*(2011)[23] in his study have also questioned the reliability of ICD for sex assessment considering the fact that males have larger jaw dimensions with a more predilection for bilobate and square shaped chin in contrast to pointed ones in females. Moreover, MCI relies on ICD, which can be modified by orthodontic treatment or periodontal disease that can result into pathological migration of canines to different positions and despite being very resistant to hazard, teeth particularly a single rooted tooth, can be displaced from its location peri- or post-mortem. In such conditions, methods that rely on having the two mandibular canines in their alveoli cannot be used.[24]

The ROC curve analyses reported poor discriminative ability values for both right and left MCI, and therefore did not support the use of dental variables for sex estimation.

Conclusion

i. CBCT provides a valuable tool in record and data management for odontometric morphometry assessment obtained directly from the digital image;

ii. MCI and the variables that allow MCI quantification were shown to distinguish the groups, in terms of average, suggesting the possibility that canine-related measurements may be used for sex discrimination; and

iii. The MCI proposed in other population sample was not found to be a reliable tool in sex determination in the present Saudi Arabian sample, and therefore its application should be confined.

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Conflict of Interest- Nil.

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