

SEX DETERMINATION FROM MANDIBULAR CANINES : A NEW RADIOMETRIC METHOD

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ABSTRACT

Human teeth are the hardest and the most stable and durable tissues in the body. Teeth can be identified even after complete decomposition. They are therefore invaluable for identification of sex and age from fragmentary adult skeleton. The present study aimed to investigate the accuracy with which gender can be differentiated by utilizing computed mandibular canine width measurements. Periapical radiographs for the permanent mandibular canines on both sides were obtained from 60 Egyptian individuals (30 males and 30 females). Their age ranges between 18 and 21 years. The developed radiographs were digitized and analyzed using the Load and Measure Program. Measurements obtained in this study include, maximum mesiodistal crown width (W1), root width at cemento-enamel junction "CEJ" (W2), root width midway between "CEJ" and mid root level (W3), root width at mid root level (W4) and root width midway between mid root level and tooth apex (W5). The statistical analysis of the obtained data showed that, the mean values of right and left canines' measurements were statistically larger in males than females regarding whole variables. The maximum mesiodistal crown width (W1) was the variable with the greatest sex differences in both sides ($d/s=5.135$ for right and 5.474 for the left). The distance between sex means (d/s) was higher in left canine more than the right regarding all variables. In both sides the maximum mesiodistal crown width (W1) showed the higher rate of accuracy (100%). The lowest rate of accuracy was obtained from root width at mid root level (W4), (58.33% for right & 86.34% of left). The mesiodistal crown width (W1) and root width midway between cemento-enamel junction and mid root level (W3) were the most sensitive variables for in both sides (100%). Meanwhile, mesiodistal crown width (W1) and root width at cemento-enamel junction (W2) were found to be the most specific variables in both sides (100%). The present study establishes an accurate method for sex prediction from mandibular canines that depend upon taken computed measurements from different levels and so, it can be applied if canine tooth or even a part of it was subjected to forensic postmortem examination.

Keywords: *Sex Determination, Mandibular Canines, Radiometric.*

INTRODUCTION

Sex determination of skeletal remains is an important part of archaeological and many medicolegal examinations, particularly where the bodies are damaged beyond recognition as in aircraft accidents and other major mass disasters. The methods vary and depend greatly on the available body tissues and their condition. The only method that can give accurate results is the DNA technique but in many cases and for several reasons it cannot be used (Vodanovi et al., 2007; Rozylo et al., 2008).

Determination of sex using skeletal remains presents a great problem to forensic experts especially when only fragments of the body are recovered. Forensic dentists can assist other experts to determine sex of the remains by using teeth and skull (Acharya and Minali, 2009).

Teeth are excellent material for anthropological, genetic and odontologic investigations in both living and dead population and are therefore important in forensic practice. Their ability to survive fire and bacterial decomposition makes them invaluable for identification of sex and age from fragmentary adult skeleton (Khraisat et al., 2007).

Various features of teeth, like morphology, crown size, root length and root

width which show differences between males and females in addition to the sexual dimorphism of the skull help forensic odontologist to identify sex from the human remains (Probhu and Acharya, 2009).

Tooth size standards based on odontometric investigations can be used in age and sex determination as human teeth exhibit sexual dimorphism. Males possess larger tooth crown than females in contemporary human populations that could be attributed to the longer period of amelogenesis for both deciduous and permanent dentitions in males (Acharya and Minali, 2007).

From all human teeth, canines are the least frequently extracted teeth, possibly because of the relatively decreased incidence of caries and periodontal disease. Besides, canines are reported to withstand extreme conditions and have been recovered from human remains even in air disasters and hurricanes (Reddy et al., 2008). In addition, mandibular canines are considered to be the key teeth for sexual dimorphism (Acharya and Minali, 2008). Therefore, canines were chosen in this study to be the material of investigation.

AIM OF THE WORK

The aim of this study is to investigate the accuracy with which gender can be

differentiated by using computed mandibular canine width measurements.

MATERIAL AND METHODS

Subjects :

After obtaining the participation consent of the subjects, periapical radiographs for the permanent mandibular canines on both sides were taken from 60 Egyptian individuals (30 males and 30 females) their age range between 18 and 21 years. This age period was selected because attrition is minimal (Reddy et al., 2008). The study was conducted on the students of Faculties of Dentistry and Medicine, Tanta University.

The inclusion criteria for selection of the study sample were, healthy state of gingiva and periodontium, caries free teeth, absence of anterior teeth spacing and absence of dental wear and tear (attrition, abrasion, erosion) (Shafer et al., 2009).

Radiographs were collected and developed automatically under standardized time and temperature. The developed radiographs were digitized using a full page, full color Umax scanner with a transparency adapter. The images were saved in bitmap formats for further processing.

The "Load and measure" program was

developed in Visual Basic Language specially for the present research. A specially developed green filter background was added to enhance the visualization of the tooth apex, cemento enamel junction and tooth outlines.

As illustrated in figure 1, the saved images were analyzed for; maximum mesiodistal crown width (W1), root width at cemento enamel junction "CEJ" (W2), root width midway between "CEJ" and mid root level (W3), root width at mid root level (W4) and root width midway between mid root level and tooth apex (W5).

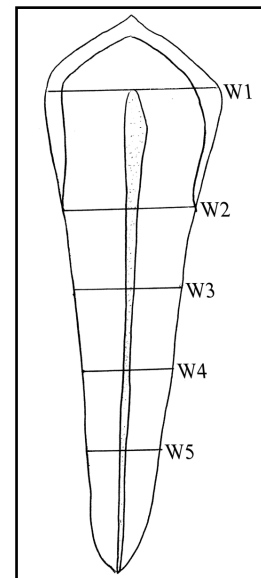


Figure (1): Diagram showing the measurements taken from the radiographs for each tooth. (W1); maximum mesiodistal crown width. (W2); root width at cemento enamel junction "CEJ". (W3); root width midway between "CEJ" and mid root level. (W4); root width at mid root level. (W5); root width midway between mid root level and tooth apex.

The software was based on a simple equation for measuring the distance between any two points: $A = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$ where A = distance, x^1, y^1 is the coordinates for the first point and x^2, y^2 are the coordinates for the second point.

The data obtained were statistically analyzed by using the SPSS program (version 11). The student's t test determined the mean and standard deviation (SD) for each variable in both sexes was performed. The t and p values were estimated. The level of significance was 0.05.

The distance between sex means (d/s) was determined from the ratio of the mean difference and the mean standard deviation. The formula used was the following: $d/s = (x_m - x_f) / \sqrt{(n_m s_m^2 + n_f s_f^2) / (n_m + n_f)}$

Where; x_m, x_f = means; n_m, n_f = examined samples; s_m^2, s_f^2 = variance.

The distance between sex means (d/s) is the ability of each variable to distinguish between male and female samples and to show how well, each variable will be more correlated to sex at both sides (Rosner, 2006).

According to Flash and Wu, 2003, The Receiver Operating Characteristic (ROC) curve is a method that could test the efficiency of sex determination from each variable and also detect the rate of false posi-

tive and false negative measurements as a result of the possible overlap between some male and females measurements with a very close similarity. The curve was employed in the study and each variable was analyzed in relation to the following:-

- 1- The cut off value (sectional point); which is a definite value that minimizes the number of false positive and false negative measurements.
- 2- Sensitivity; which is the percentage in which the curve can detect the true positive rate.
- 3- Specificity; which is the percentage in which the curve can detect the false positive rate.
- 4- Accuracy; which is the percentage in which the curve can detect true positive and false positive rates.

RESULTS

Males showed higher mean values than females regarding all variables (figures 2 and 3). The descriptive statistics are depicted in tables 1 and 2 showing that, mean values of both canines are significantly larger in males than females and the mesiodistal crown width (W1) is the measurement with the greatest sex differences in both sides (d/s = 5.153 for right canine and 5.474 for the left), to be followed by the root width at cemento-enamel junction (W2), (d/s = 2.090 for right and 2.264 for the left). Root width midway

between mid root level and tooth apex (W5), was the measurement with the lowest sex differences in both sides (0.785 for right canine and 0.960 for the left). Tables 1 and 2 also revealed that, the distance between sex mean (d/s) was higher in left canine more than right one regarding all variables.

Employing the ROC curve to study each variable independently revealed that, the accuracy of all measurements ranged from 58.33 % to 100% in right canine and from 86.34% to 100% in left one. The highest accuracy for sex prediction in both sides was obtained from the mesiodistal crown width (W1), (100% in both sides) followed by root width midway between cemento-enamel junction and mid root level (W3), (91.0 % in right canine and 91.67 % in the left), (tables 3 and 4).

Table 3 and 4 also revealed that, the mesiodistal crown width (W1) and root width midway between cemento-enamel junction and mid root level (W3) were the most sensitive variables in both sides (100% in both sides). Meanwhile, the mesiodistal crown width (W1) and root width at cemento-enamel junction (W2) were found to be the most specific variables in both sides (100% in both sides).

Examples for radiographs included in this study before and after application of

the green filter were represented in figures 4 and 5. Males showed higher measurements than females in all levels from W1 down to W5.

DISCUSSION

Sex determination is one of the important aspects of forensic sciences. Teeth being the central component of the masticatory apparatus of the skull are good sources of material for civil and medicolegal identification (Prathibha et al., 2009). The degree to which teeth resist bacterial decomposition, fire and fractures makes them valuable tools for forensic investigation and research (Acharya, 2008).

The present study aims to investigate the accuracy with which gender can be differentiated by using computed mandibular canines width measurements. The tested individuals were well matched for the age as there was no difference in age between males and females.

The present study establishes the existence of definite statistically significant sexual differences between males and females regarding mandibular canine measurements. It is consistent with Hashim and Murshid (1993), who conducted a study on Saudi males and females whose age ranged between 13 and 20 years. They found that, only

the canines in both jaws exhibited a significant sexual difference while the other teeth did not. In another study on Saudian Arabian Sample of 503 school children by AL-Rifaiy et al. (1997), it was reported that, the mean values for left and right maxillary and mandibular canine mesio-distal width was less for females than for males but with no statistically significant differences.

The results of this study go hand in hand with the results of Mughal et al. (2010) in their study on 200 students from Punjab Province of Pakistan whose age ranged between 18 and 25 years. They performed their study on the lower canines using the ratio between the maximum crown width and canine arch width resulting in a mandibular canine index which was significantly higher in males than females. Probhu and Acharya (2009), studied 384 females and 382 males of the south Indian population to detect sex differences in their lower canines. They concluded the significant differences of males' canines' dimensions if compared to these of the females'.

The differences between canines' measurements in both sexes were reported to be due to the influence of the Y chromosome which affects the size of teeth by controlling the thickness of dentine, whereas the X chromosome is considered to be the chromosome responsible only for

the thickness of enamel (Boaz and Gupta, 2009).

Throughout the literature, most of the studies agree with the results obtained in this study regarding the larger size of male teeth if compared with that of females. However, reversed dimorphism; where the females showed larger teeth than males was found in the studies carried out by Acharya and Minali (2007), on mandibular second premolar in Nepalese population and by Yuen et al. (1999), in a longitudinal study on mandibular and maxillary first and second premolars among Chinese population.

Unexpectedly, the efficacy of mandibular canines for sex prediction, which was proven in this work, had been denied by other studies. Lund and Monstard (1999), in their study on Swedish population reported low percentage of dimorphism obtained from mandibular canines if compared with maxillary canines. Prathibha et al. (2009) studied 50 males and 49 females belonging to Karnataka, India, and concluded that, no significant sex differences were obtained from mandibular teeth including the canines on both sides.

There can be a complex interaction between a variety of genetic and environmental factors that might be responsible for the variation in the magnitude of dimorphism among population. According

to Acharya and Minali (2009), teeth have behaved in many ways through the course of evolution, ranging from reduction of the entire dentition to reduction of one group of teeth in relation to other and this may be responsible for the low degree of morphism in some populations.

Different human populations may show different expression of sexual dimorphism. In some populations, this dimorphism may be greatly developed than in others. For so, any measurements of teeth unaccompanied by information about age, race and sex should be taken with great caution. It must be well born in mind that, studies which found no sexual difference in teeth size in some populations, do not necessarily contradict those which found such difference in others (Mughal et al., 2010).

The results of the present work revealed that, the distance between sex means (d/s) was higher in left canine more than the right one and hence, left canine is more correlated to sex than the right. These results agree with those of Mughal et al. (2010), in their study on 60 Indian males and females. They reported a greater sex differences in the measurements of left mandibular canine taken either intraorally or on casts. On the other hand, Lysell and Myrberg (1982), in their study on 530 boys and 580 girls from Sweden, reported that, the right mandibular

canine showed maximum sexual dimorphism if compared with the left one.

The finding that, teeth on one side are more correlated to sex more than the other side is not clearly understood but it may be due to genetic variability allowing complete growth of teeth on both sides at different times (Prathibha et al., 2009).

In this study, the mesiodistal crown width (W1) and the root width midway between cemento enamel junction and mid root level (W3) were found to be the most sensitive variables in both sides with the highest rate of accuracy. The most specific variables in both sides were the mesiodistal crown width (W1) and root width at cemento enamel junction (W2).

It is notable that, mesiodistal crown width (W1) is of utmost importance if compared with the other measurements obtained from the root. This finding is of uncertain explanation, it may be due to more variations in crown measurements than those of root among individuals. Affection of the crown, which is the external portion of the tooth, by external factors more than the root, may be another explanation.

From the results of this study it is clear that, root width at mid root level (W4) and root width midway between mid root level and tooth apex (W5) were the variables

with less accuracy, sensitivity and specificity. This finding may be due to reduction of tooth size in the root portion, a finding that may necessitate studying of the overall root length and surface area in further researches for more explanation.

Referencewise, studies concerning mandibular canines as a sex predictor were relying only on measurements of canine crown width and the mandibular intercanine arch width. In the study herein, canine width measurements were taken at different crown and root levels employing the "Load and Measure, Visual Basic Program" for a better accuracy in measurements. The results of this work do not necessitate the presence of intact entire mouth structures for sex prediction and so, may be applied where a canine tooth only or even a part of it was subjected to forensic postmortem examination.

To the best of our knowledge, no previous studies have used canine width measurements from different levels for sex pre-

diction, so the results of this work regarding this aspect could not be compared. The need for more than one sex predictors from teeth may arise in case of partial destruction of teeth to a degree that their crown cannot be examined. In this situation, the examiner may depend only on root measurements obtained from radiographs.

In conclusion, this study confirms the reliability of sex prediction from the mandibular canines and the reported results may be considered a valid support for investigations involving teeth as predictors for sex. The establishment of an Egyptian data base obtained from dental morphometric measurements using intra-oral periapical radiographs will support this study and render an easy and reliable method for prediction of sex among Egyptians.

ACKNOWLEDGMENT

The authors would like to thank all the individuals who willingly participated in the study.

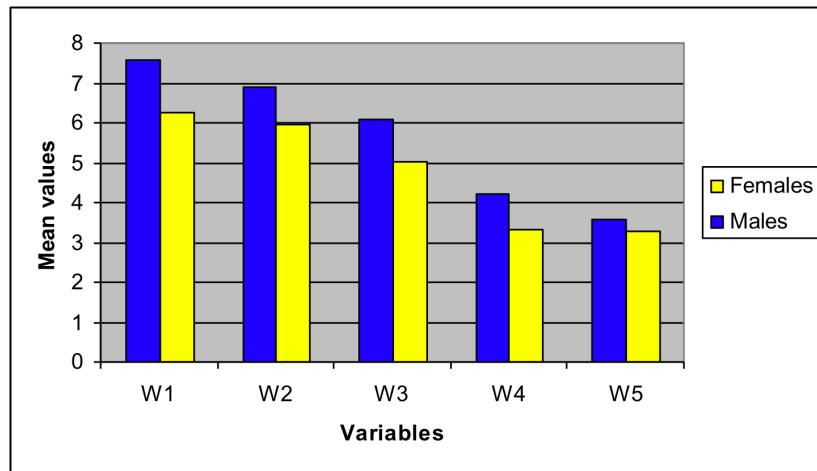


Figure (2): Bar chart of mean values of different right canine measurements in males and females.

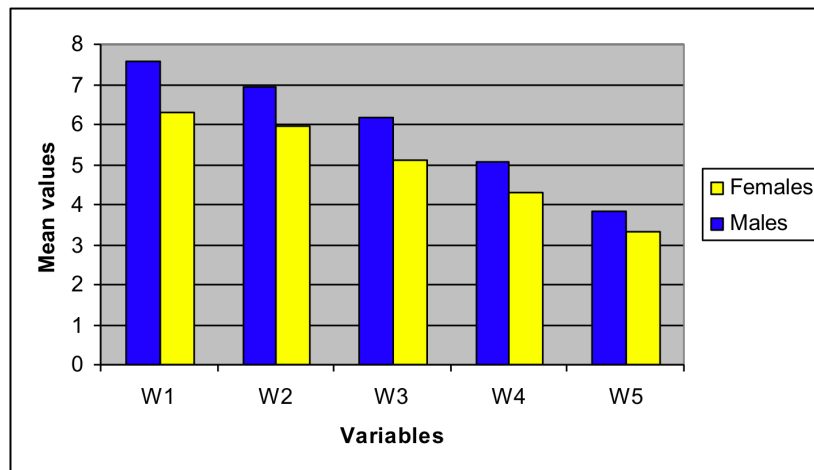


Figure (3): Bar chart of mean values of different left canine measurements in males and females.

Table (1) : Descriptive statistical analysis of right canine measurements.

Variables	Males (30)			Females (30)			t	P	d/s
	Mean	±	SD	Mean	±	SD			
W1	7.5537		0.2277	6.2697		0.2609	10.099	<0.001*	5.135
W2	6.9100		0.6316	5.9467		0.3008	8.090	<0.001*	2.090
W3	6.0990		0.6342	5.0263		0.3588	8.063	<0.001*	2.101
W4	4.2190		0.4902	3.3070		0.5353	5.564	<0.001*	1.490
W5	3.5747		0.2330	3.2603		0.4439	2.967	0.004*	0.785

(W1); maximum mesiodistal crown width. (W2); root width at cemento enamel junction "CEJ".
(W3); root width midway between "CEJ" and mid root level. (W4); root width at mid root level.
(W5); root width midway between mid root level and tooth apex.

Table (2): Descriptive statistical analysis of left canine measurements.

Variables	Males (30)			Females (30)			t	P	d/s
	Mean	±	SD	Mean	±	SD			
W1	7.5623		0.2097	6.3050		0.2623	21.080	<0.001*	5.474
W2	6.9180		0.5279	5.9520		0.2848	8.749	<0.001*	2.264
W3	6.1560		0.5162	5.0927		0.3731	9.143	<0.001*	2.362
W4	5.0800		0.4375	4.3077		0.5448	6.054	<0.001*	1.575
W5	3.8230		0.20711	3.3030		0.4273	3.730	<0.001*	0.960

(W1); maximum mesiodistal crown width. (W2); root width at cemento enamel junction "CEJ".
(W3); root width midway between "CEJ" and mid root level. (W4); root width at mid root level.
(W5); root width midway between mid root level and tooth apex.

Table (3): The cut off values, sensitivity, specificity and accuracy of right canine measurements.

Variables	Cut off	Sensitivity %	Specificity %	Accuracy %
W1	7.015	100	100	100
W2	6.545	80	100	90
W3	5.125	100	80	91
W4	4.745	60	76.7	58.33
W5	3.340	80	70	75

(W1); maximum mesiodistal crown width. (W2); root width at cemento-enamel junction "CEJ".
 (W3); root width midway between "CEJ" and mid root level. (W4); root width at mid root level.
 (W5); root width midway between mid root level and tooth apex.

Table (4): The cut off values, sensitivity, specificity and accuracy of left canine measurements.

Variables	Cut off	Sensitivity %	Specificity %	Accuracy %
W1	6.980	100	100	100
W2	6.565	80	100	90
W3	5.585	100	80	91.67
W4	4.505	100	83.3	86.34
W5	3.360	96.7	83.3	88.67

(W1); maximum mesiodistal crown width. (W2); root width at cemento-enamel junction "CEJ".
 (W3); root width midway between "CEJ" and mid root level. (W4); root width at mid root level.
 (W5); root width midway between mid root level and tooth apex.



Figure (4): The software layout displaying the selected images for left canine radiograph of male aged 20 years before and after application of the green filter. The red lines display the target width (W1-W5) and the tooth apex line. The yellow label shows the width value in pixels for the corresponding lines (each 2.83 pixels form one millimeter) and the scanner to screen magnification error was 7.5 times.



Figure (5): The software layout displaying the selected images for left canine radiograph of female aged 20 years before and after application of the green filter. The red lines display the target width (W1-W5) and the tooth apex line. The yellow label shows the width value in pixels for the corresponding lines (each 2.83 pixels form one millimeter) and the scanner to screen magnification error was 7.5 times.

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تحديد الجنس من أنياب الفك السفلى : طريقة قياسية إشعاعية جديدة.

المشتركون في البحث

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من أقسام الطب الشرعي والسموم الاكلينيكية - كلية الطب - جامعة طنطا

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الأسنان الأدمية هي أكثر أنسجة الجسم صلابة واستقراراً ودواماً ويمكن التعرف عليها حتى عندما يأخذ باقي الجسم في التحلل و لذلك فهي لا تقدر بثمن في تحديد الجنس والعمر من البقايا العظمية لإنسان بالغ. وتهدف الدراسة الحالية إلى تحليل مدى الدقة التي يمكن بها معرفة الجنس باستخدام قياسات عرضية محسوبة من أنياب الفك السفلى في كلتا الناحيتين ، وقد تم أخذ صور إشعاعية لأنياب الفك السفلى الدائمة في الناحيتين من ٦٠ فرد مصري (٣٠ ذكر و ٣٠ أنثى) تتراوح أعمارهم ما بين ٨١ إلى ٢١ عاماً وتم أخذ القياسات التالية: أقصى عرض للتاج وعرض الجذر عند التقاء الجزء الأسمنتي بالمينا وعرض الجذر عند منتصف المسافة بين التقاء الجزء الأسمنتي بالمينا ومستوى نصف الجذر وعرض الجذر عند منتصفه وأخيراً عرض الجذر عند منتصف المسافة من مستوى نصف الجذر وقمة السنّة. وقد أظهر التحليل الإحصائي للبيانات التي تم الحصول عليها أن قيمة قياسات الناب الأيمن والأيسر كانت إحصائياً أكبر في الذكور عنها في الإناث و ذلك على مستوى كل المتغيرات. كما كان أقصى عرض للتاج هو القياس ذو الفارق الأكبر لتحديد الجنس في الناحيتين وكانت قياسات الناب الأيسر ذات فارق أكبر لتحديد الجنس بالمقارنة بقياسات الناب الأيمن. أظهرت الدراسة أيضاً أنه في كلتا الناحيتين كان أقصى عرض للتاج هو القياس الأعلى في معدل الدقة (١٠٠٪) أما القياس الأقل في هذا المعدل فكان مستوى منتصف الجذر ٥٨٫٣٣٪ للناحية اليمنى و ٨٦٫٣٤٪ للناحية اليسرى. أظهرت الدراسة أيضاً أنه في كلتا الناحيتين كان أقصى عرض للتاج وعرض الجذر عند منتصف المسافة بين التقاء الجزء الأسمنتي بالمينا ومستوى نصف الجذر هما المتغيران الأكثر حساسية في الناحيتين (١٠٠٪ لكل قياس). كما أن أقصى عرض للتاج وعرض الجذر عند التقاء الجزء الأسمنتي بالمينا كانا هما أكثر المتغيرات خصوصية (١٠٠٪ لكل قياس في الناحيتين). ولذلك فإن هذه الدراسة تؤسس لطريقة دقيقة للتمييز بالجنس من أنياب الفك السفلى والتي تعتمد على قياسات لمستويات مختلفة لعرض الناب في كلتا الناحيتين ويمكن تطبيقها في حالة خضوع الناب أو جزء منه للفحص الطبي الشرعي.