PREDICTION OF GENDER EMPLOYING MANDIBULAR MEASUREMENTS: APPLICATION OF CONE BEAM COMPUTERIZED TOMOGRAPHY

Abo Elyazied A. Fouad, [1; 2]* Hussein I. Saudi[3], Shereen Abdel Moula[3], Mohamed Bayome [4,5]

[1]Department of Forensic Medicine and Clinical Toxicology, Faculty of Medicine, Tanta University, Tanta, Egypt.

[2]Division of Forensic Medicine,Department of Biomedical Science, College of Medicine, King Faisal University, Al-Ahsa, Saudi Arabia.

[3]Department of Oral Medicine, Periodontology, Diagnosis and Radiology, Faculty of Dentistry, Tanta University.

[4] Department of Preventive Dentistry, College of Dentistry, King Faisal University, Al-Ahsa, Saudi Arabia.

[5] Departamento de Estudios de Postgrado, Universidad Autónoma del Paraguay,Asuncian, Paraguay.

Corresponding author:

Abo Elyazied A. Fouad MD,*

E-mail address: draboyazid@yahoo.com

Phone: +966580349754

ABSTRACT

The identification of skeletal remains is of fundamental value in medico-legal fields. The skeletal components most often investigated for gender determination are the pelvis and skull, with the mandible especially in cases of destroyed bodies. The purpose of this study was to define the validity of mandibular measures taken through cone beam computerized tomography in sex determination and to establish a formula for such differentiation. The sample consisted of 100 Cone beam computerized tomography (CBCT). The CBCT images were analyzed for five measurements: the distance from the inferior border of the mandibular body to the highest point of the alveolar crest (IBM-HAC), the distance between the inferior margins of the mental foramen to the inferior border of mandibular body (IMMF-IBM), the distance between the superior margins of the mental foramen to the highest point of the alveolar crest (SMMF-HAC), the distance between the superior margins of the mental foramen to the inferior border of the mandible (SMMF-IBM), and volume of mental foramen. (VMF). Data analysis was achieved using SPSS version 22. Forward stepwise binary logistic regression analysis was accomplished to predict the probability of identifying male based on one or more independent variables. The logistic regression for the different varies revealed only the distance between the superior margins of the mental foramen to the inferior border of the mandible (SMMF-IBM), and volume of mental foramen. (VMF) as the significant contributors to the regression model. The logistic regression model was statistically significant and able to 75% of the difference in sex and accurately categorized all cases. Based on the logistic regression model, an equation for prediction of sex was derived. In conclusion, the current study demonstrates the probability of sex determination employing mandibular measurements taken thought CBCT that is proved as a superior tool if compared with the other radiological techniques.

Key Words: Forensic Odontology, Mandible, Gender, Mental forame

I- INTRODUCTION

The distinction in racial groups by analyzing the morphological features of the skeleton is a fundamental aspect in the scope of forensic anthropology (Thiago et al., 2016). Prediction of sex is an important parameters that may employ for precursory identification of missing persons (Annamalai et al., 2012 and Akhilesh et al., 2013). Because of the indestructible characters of craniofacial bones, a high definitive information can be obtained from such non-destroyed skeletal parts, including the mandible (Franklin et al., 2008).

As a role, the anthropologists use the morphological characters of the mandible in the determination of sex. Inclusion of mandibular radiographs as a part of the investigations will increase the accuracy of measurements (Humphrey et al., 1999). The digital panoramic technique may improve the quality of the radiograph with more obtained measurements' accuracy (Cagri et al., 2011).

Worldwide, the morphologic and morphometric sexual dimorphism of the mandible has been investigated in many studies in the United States, China, Japan, and Europe, for so, it is of great significance to link a particular population with their existing skeletal characters (Naroor et al., 2015). Mental foramen is the opening of mandibular canal in the body of mandible. It is fairly well depicted in panoramic radiographs that may show vertical and horizontal difference of location in different racial sets (Wei et al., 2010).

Computed tomography (CT), as a three-dimensional radiographic imaging technique, has been reported to be an effective tool for imaging head and neck structures both clinically as well as in forensic purposes (Rashid and Ali, 2011). Cone-beam computed tomography (CBCT), a more latterly applied variance of CT, has shown various advantages if compared with the panoramic radiography and the conventional CT methods, including improvement of images adequacy, better uniformly resolution of the osseous structures with the expected improvement of findings' interpretations (Lubis and Anfelia 2018). The aim of this study was to focus light at the sexual dimorphism that may be exist between the male and the female gender using anthropometric mandibular measures on Cone beam computerized tomography images, and to set up a formula with prospect predictive estimates.

II- PATIENTS AND METHODS

This work was conducted on one hundred Cone beam computerized tomography images of 100 Saudi Arabia patients (54 males and 46 females), their ages ranged from 20-55 years. They were attending at four private dental care academies in the Eastern Provence, Saudi Arabia from the period from January 2017 to Jun 2018. The patients underwent a dental Cone beam computerized tomography examination as a part of their treatment. The approval of the local ethics committee of our institute was obtained after fulfillment of the ethical aspect. Written informed consent was gained from each patient for using his/ her personal or imaging data after obvious clarification for the purpose as well as the anticipated scientific interests of the study. Moreover, the absolute confidentiality of the information was promoted.

The inclusion criteria for selection of the study sample were; Presence of all teeth in the region of measurements. Minimal or absent alveolar crest resorption in the examined regions. No artefacts in CBCT images. Exclusion criteria were; less than 10 years of age because of invisibility of mental foramen due to mixed dentition, distortion of images, Presence of artifacts, as well as non-visualization of the mental foramen. The study materials were divided into three sets of less than 25 years (42 patient), 25 – 50 years (33 patient) and above 50 years (25 patient).

The cone beam images were imported to the Simplant program Ver. 17.01 (Dentsply Implants 3500 Hasselt Belgium). The 3D view was selected and magnified using the Zoom" tool then the "Measure distance" tool was selected from the tools menu. As previous studies demonstrated that, the mental foramens had almost symmetrical position on both sides **(Junior et al. 2009 and Afkhami et al., 2013),** the next measurements were taken on the right side of the mandible in actual 1:1 size in millimeters without magnification. (Figures 1)

A: Mandibular height, the distance from the inferior border of the mandibular body to the highest point of the alveolar crest (IBM-HAC).

B: The distance between the inferior margins of the mental foramen to the inferior border of mandibular body. (IMMF-IBM)

C: The distance between the superior margins of the mental foramen to the highest point of the alveolar crest (SMMF-HAC).

D: The distance between the superior margins of the mental foramen to the inferior border of the mandible (SMMF-IBM).

E: Volume of mental foramen (VMF): The bone graft tool was selected and activated to fill the empty space of the mental foramen, and then the graft volume was converted into three-dimensional object. More clarification of the three- dimensional object was done by selecting the properties option from the panel to display the width, height, and depth of the mental foramen in millimeters and the volume in cubic centimeters in the second panel (figures 2).

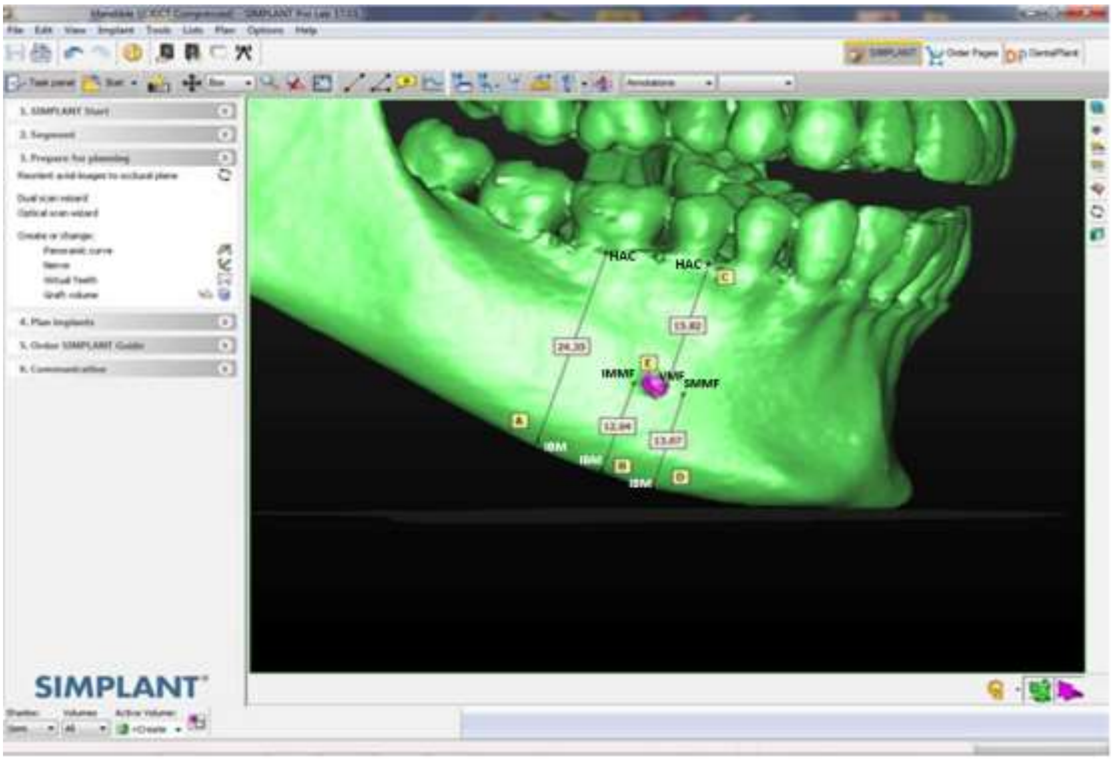

Figure (1): Cone beam image showing the measurements related right mandibular side; **A :(IBM-HAC)**: Mandibular height, the distance from the inferior border of the mandibular body to the highest point of the alveolar crest. **B :(IMMF-IBM)**: The distance between the inferior margins of the mental foramen to the inferior border of mandibular body. **C: (SMMF-HAC)**: The distance between the superior margins of the mental foramen to the highest point of the alveolar crest. **D: (SMMF-IBM)**: The distance between the superior margins of the mental foramen to the inferior border of the mandible. **E: (VMF)**: Volume of mental foramen.

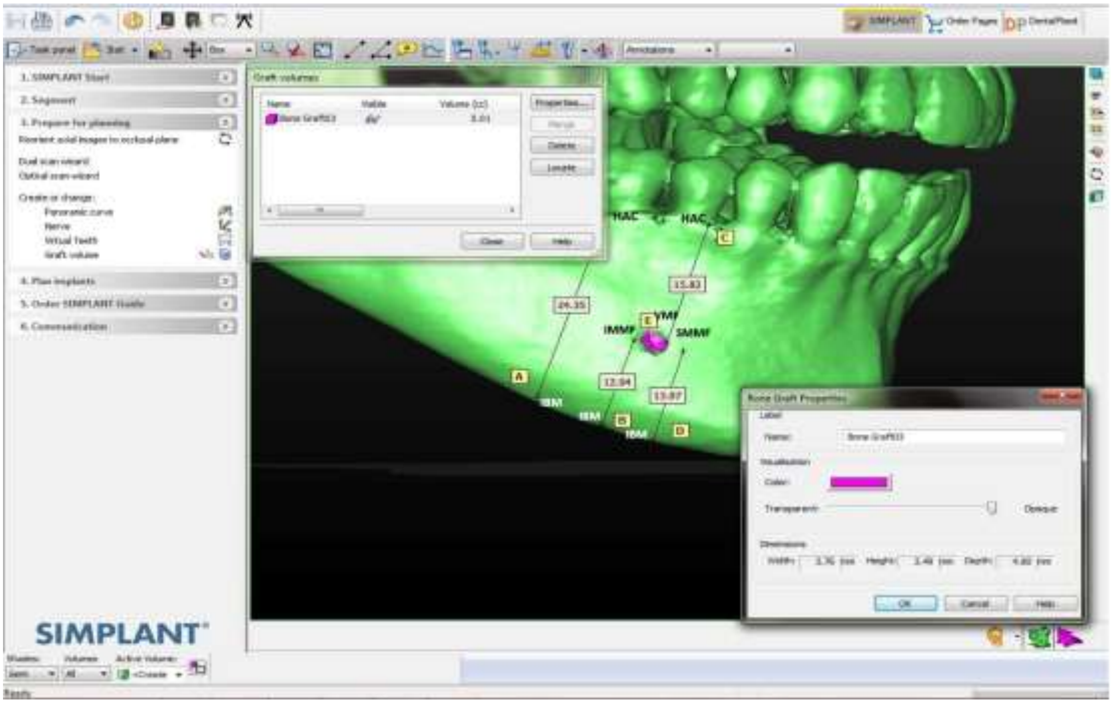

Figure (2): Cone beam image showing the measurements related right mandibular side; **A :(IBM-HAC)**: Mandibular height, the distance from the inferior border of the mandibular body to the highest point of the alveolar crest. **B :(IMMF-IBM)**: The distance between the inferior margins of the mental foramen to the inferior border of mandibular body. **C: (SMMF-HAC)**: The distance between the superior margins of the mental foramen to the highest point of the alveolar crest. **D: (SMMF-IBM)**: The distance between the superior margins of the mental foramen to the inferior border of the mandible. **E: (VMF)**: Volume of mental foramen, employing the bone graft tool from Simplant program Ver. 17.01.

Statistical analysis:

Data analysis was carried out using IBM SPSS statistics version 22. Numerical variables were checked for normality by Shapiro-Wilk test. All numerical variables were found to follow a normal distribution; therefore, values were summarized as mean ± standard deviation and Independent-samples T test was implemented for comparison between men and women. For qualitative data, Pearson's Chi -square test was employed to examine the association among sex and age groups. Multiple regression analysis was done to examine the effect of predictors (age and sex) on the outcome (mandibular measurements). Forward stepwise binary logistic regression was carried out to foretell the probability of identifying male based on one or more independent variables (age and mandibular measurements). Significance was considered at $p < 0.05$ for interpretation of results of tests **(**William et al., 2015).

III- RESULTS

The distribution of age and sex of the study participants is depicted in figure (3) showing that the percentage of men was slightly higher than the women in all age groups, with no statistical significance ($p > 0.05$). Table (1) compares the five studied measurements between the male and female participants. Men had a significantly higher mean mandibular height (IBM-HAC), SMMF-IBM, and VMF, than women ($p < 0.001$). On the contrary, there was no significant difference between the means of IMMF-IBM and SMMF-HAC of men and women.

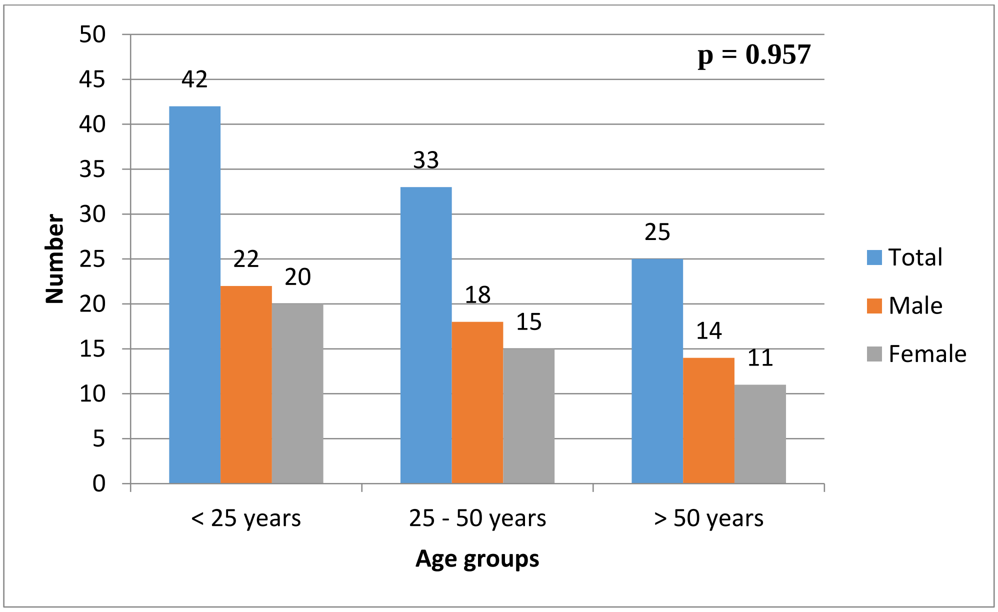

Figure (3): Bar chart showing distribution of age and sex in the study participants (n = 100; 54 males& 46 females)

Table (1): Statistical comparison of the studied measurements between men and women in the different age groups by Student's -Test

n = 100		Mandibular height (mm)		IMMF-IBM (mm)		SMMF-HAC (mm)		SMMF-IBM (mm)		VMF (mm3)	
		Sex		Sex		Sex		Sex		Sex	
		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Total	n	54	46	54	46	54	46	54	46	54	46
	Minimum	22.13	15.11	11.34	11.33	10.99	11.10	12.11	9.23	22.00	14.00
	Maximum	24.99	17.34	14.85	14.81	13.80	13.60	14.10	10.90	24.00	16.00
	Mean	23.93	16.45	13.35	13.25	12.61	12.54	13.35	10.24	23.30	14.89
	SD	0.63	0.67	0.77	0.69	0.62	0.55	0.41	0.43	0.72	0.71
	t	57.541		0.723		0.589		37.120		58.814	
	p	<0.001*		0.471		0.557		<0.001*		<0.001*	
< 25 years	n	22	20	22	20	22	20	22	20	22	20
	Minimum	23.45	16.34	12.99	12.98	12.31	12.11	12.98	9.80	22.00	14.00
	Maximum	24.99	17.34	14.85	14.81	13.80	13.57	14.10	10.90	24.00	16.00
	Mean	24.26	16.89	13.79	13.54	12.96	12.80	13.57	10.44	23.09	14.90
	SD	0.40	0.30	0.41	0.43	0.43	0.39	0.42	0.33	0.81	0.79
	t	67.114		1.882		1.248		26.614		33.128	
	p	<0.001*		p > 0.05		0.219		<0.001*		<0.001*	
25 - 50 years	n	18	15	18	15	18	15	18	15	18	15
	Minimum	23.20	16.11	12.56	12.45	12.00	11.99	13.10	9.23	23.00	14.00
	Maximum	24.90	17.30	14.84	14.32	13.40	13.20	13.99	10.90	24.00	16.00
	Mean	23.94	16.58	13.44	13.33	12.57	12.48	13.28	10.25	23.61	15.07
	SD	0.47	0.41	0.46	0.45	0.43	0.39	0.21	0.46	0.50	0.70
	t	47.506		0.722		0.627		24.894		40.641	
	p	<0.001*		0.476		0.535		<0.001*		<0.001*	
> 50 years	n	14	11	14	11	14	11	14	11	14	11
	Minimum	22.13	15.11	11.34	11.33	10.99	11.10	12.11	9.45	22.00	14.00
	Maximum	24.45	15.90	14.23	14.20	13.20	13.60	13.59	10.21	24.00	15.00
	Mean	23.40	15.45	12.56	12.60	12.12	12.15	13.08	9.88	23.21	14.64
	SD	0.75	0.35	0.94	0.92	0.76	0.74	0.41	0.28	0.70	0.50
	t	32.386		-0.106		0.124		21.993		34.220	
	p	<0.001*		0.916		0.902		<0.001*		<0.001*	

IMMF: Inferior margin of mental foramen; IBM: Inferior border of mandible; SMMF: Superior margin of mental foramen; HAC: Highest point of alveolar crest; VMF: Volume of mental foramen; n: Number of patients =100 (54 males&46 females); SD: Standard Deviation; t: Student's T- test; * significant at p <0.05.;*highly significant at p<0.001; NS=Non-significant (p> 0.05).

The differences in mean mandibular height (IBM-HAC) between men and women, also between the three age groups showed slight decrease with increase of age, with the highest mean value at the age group "less than 25 years" (24.99 and 16.89 mm in male and female, respectively) . This difference reached the lowest value in age group "above 50 years" (23.40 and 15.45 mm of male and female, respectively). Similar changes were noticed with mean value of SMMF-IBM, which was 13.57 and 10.44 in male and female participants aged less than 25 years; then reached 13.08 and 9.88 in male and female who were above 50 years. However, the mean VMF was slightly higher in both male and female participants who aged 25 to 50 years than those aged less than 25 or above 50 years old. (Figures 4-6).

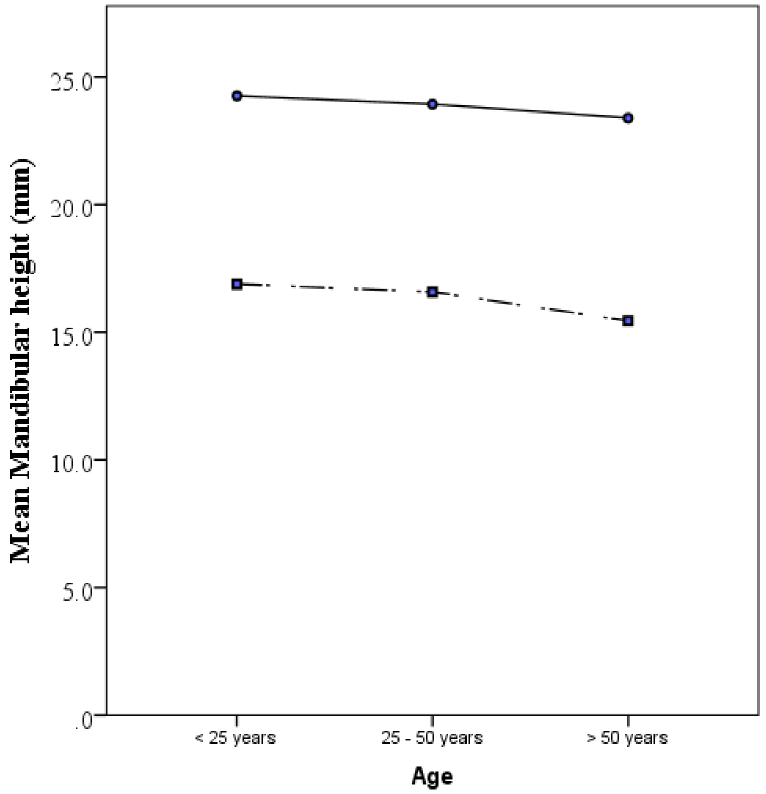

Figure (4): Comparison of mean mandibular height in men (continuous line) and women (interrupted line) among the three age groups

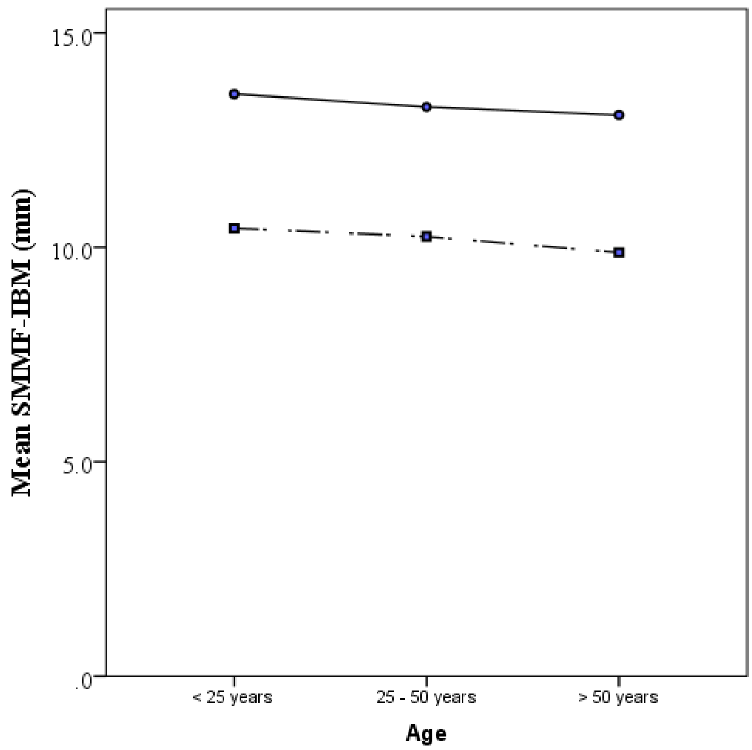

Figure (5): Comparison of mean superior margin of mental foramen - inferior border of mandible (SMMF-IBM) in men (continuous line) and women (interrupted line) among the three age groups.

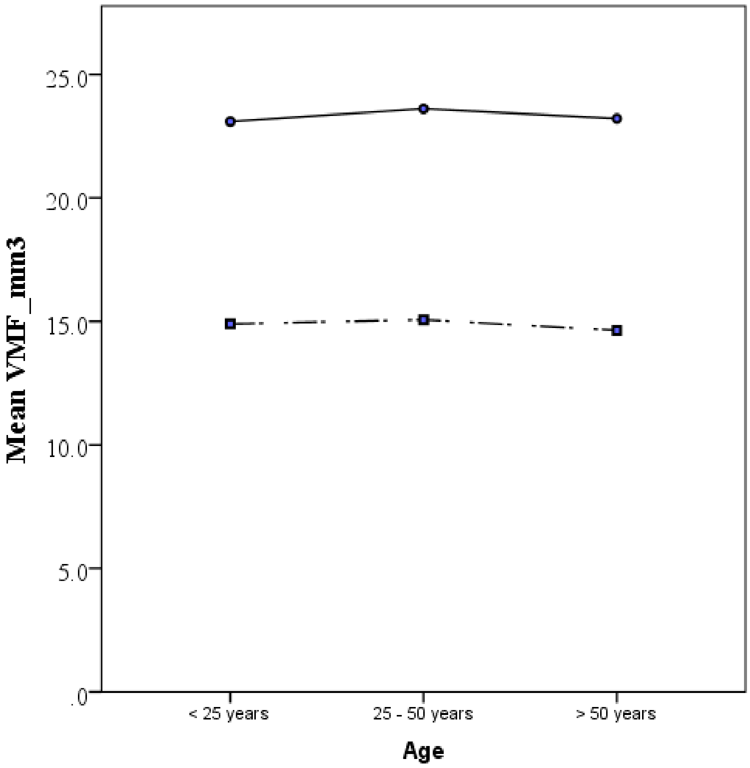

Figure (6): Comparison of mean volume of mental foramen (VMF) in men (continuous line) and women (interrupted line) among the three age groups.

Employing a multiple regression analysis to evaluate the effect of sex and age on the five studied measurements revealed that, increase in age was found to be significantly associated with a decrease in mandibular height (IBM-HAC), IMMF-IBM and SMMF-HAC, and SMMF-IBM ($p < 0.001$, when adjusted for sex). However, increased age was not associated with a significant change in VMF ($p > 0.05$, when adjusted for sex). Studying the effect of sex on the mandibular measurements revealed a significant effect on mandibular height (IBM-HAC), SMMF-IBM, and VMF ($p < 0.001$, when adjusted for age). Sex was not associated with significant changes in IMMF-IBM and SMMF-HAC ($p = 0.279$ and 0.393 respectively, when adjusted for age), (table 2).

Table (2): Multiple regression analysis to evaluate the effect of sex and age on the five studied measurements:

Model		Unstandardized Coefficients		t	p	95.0% CI for B	
		B	Std. Error			Lower Bound	Upper Bound
Mandibular height (mm)	**Age**	-0.540	0.060	-8.975	<0.001*	-0.660	-0.421
	Sex	-7.510	0.097	-77.683	<0.001*	-7.702	-7.318
IMMF-IBM (mm)	**Age**	-0.527	0.075	-6.995	<0.001*	-0.676	-0.377
	Sex	-0.132	0.121	-1.089	0.279	-0.372	0.108
SMMF-HAC (mm)	**Age**	-0.376	0.064	-5.913	<0.001*	-0.502	-0.249
	Sex	-0.088	0.102	-.858	0.393	-0.290	0.115
SMMF-IBM (mm)	**Age**	-0.260	0.045	-5.749	<0.001*	-0.350	-0.170
	Sex	-3.116	0.073	-42.913	<0.001*	-3.260	-2.972
VMF (mm3)	**Age**	0.006	0.089	0.068	0.946	-0.171	0.184
	Sex	-8.405	0.144	-58.487	<0.001*	-8.690	-8.119

IMMF: Inferior margin of mental foramen; IBM: Inferior border of mandible; SMMF: Superior margin of mental foramen; HAC: Highest point of alveolar crest; VMF: Volume of mental foramen; B: Unstandardized coefficients; CI: Confidence Interval; t=t test, * significant at $p < 0.05$.*Highly significant at $p < 0.001$.

The results of a forward stepwise binary logistic regression predicting sex were illustrated in (table 3). The measurements included in the analysis were those significantly different between the male and female participants. After carrying out the logistic regression for mandibular height (IBM-HAC), SMMF-IBM, and VMF, only SMMF-IBM, and VMF - in addition to age group - were significantly contributing to the regression model, while mandibular height (IBM-HAC) was excluded. The logistic regression model was statistically significant, $\chi^2 = 138.629$, $p < 0.001$. The model clarified 75% (Cox & Snell R^2) of the difference in sex and accurately categorized all cases. Based on the logistic regression model, an equation for prediction of sex was derived:

Logit (p) = -143.56 + (5.17 × SMMF- IBM) + (4168.1 × VMF) + (1.547 × age)

Where age is coded as 1 if less than 25; 2 if between 25 and 50; and 3 if above 50 years.

Logit (p) can be transformed into P (probability of being male) by the following formula: $p = \frac{1}{1+e^{-\text{logit (p)}}}$

Table (3): Forward stepwise binary logistic regression predicting sex based on the studied measurements:

Chi square test		**Cox & Snell R Square**	**Percentage accuracy in classification**	**Variables**	**Coefficients**	
X^2	p				**B**	**Exp (B) (Odds ratio)**
138.629	<0.001*	0.750	100.0%	Age	1.547	4.698
				SMMF- IBM	5.172	176.262
				VMF	4168.097	
				Constant	-143.562	0.000

IBM: Inferior border of mandible; SMMF: Superior margin of mental foramen; VMF: Volume of mental foramen. X^2 Chi square test; Cox & Snell R Square.

IV- DISCUSSION

In the present work, men had significantly higher mean mandibular height (IBM-HAC), than women (p < 0.001). These differences were observed when studying the total study sample, as well as in all age groups and these results were in accordance with other studies conducted on dentulous and edentulous persons that concluded the significantly greater maxillary and mandibular measurements in men than women. (Ortman et al., 1989; De Baat et al., 1993 and Moni et al., 2014).

As proved in this research, the mean values of SMMF-IBM were significantly higher in males than females in all age groups. Previous studies on other races reported similar results (Mahima et al., 2009) and (Chandra et al.,2013) in India, (Afkhami et al., 2013) in Iran, (Catovie et al., 2002) in Croatia, (Thomas et al., 2004) in Australia, and (EL gazzar et al., 2012) in Egypt. Also in this study, the mean values of IMMF-IBM and SMMF-IBM in both sexes were smaller than reported in previous Indian studies (Rajani and Srivastav 2010 &Sankar et al., 2011).

As illustrated in the current results, Men had significantly higher mean VMF than women (p < 0.001).This goes in accordance with a previously published report for studying the average sizes of long and short axes of mental foramina of both sexes using dried adult human mandibles (Rajani and Srivastav 2010). On the other hand, another study from Sri Lanka denied any significant difference in shape and position of the mental foramina in both sexes (Prabodha and Nanayakkara 2006).

In our existing study, the mean VMF was slightly higher in both male and female participants who aged 25 to 50 years than those aged less than 25 years old. This could be explained by the various changes occurring in bone with age in the form of obvious raise in cortical porousness and increase resorption rate of canals of Havers (Vodanovic et al., 2006; Ngeow et al., 2010 and Mahnaz & Mitra, 2016).

Our results demonstrate that there was no considerable difference among the means of IMMF-IBM and SMMF-HAC of men and women and these results go hand in hand with: Indian study (Moni et al., 2014), and Iranian study (Haraji and Boostani,2013). On the contrary, other studies from Egypt (EL gazzar et al., 2016), India (Sankar et al, 2011), and Brazil (Amorim et al, 2008) proved a significant difference among the means of IMMF-IBM and SMMF-HAC. These observed differences may be attributed to different methodology such as measurements on dry skull, photographs or radiographs (Yi-Ping et al., 2010).

In this work, Increase in age was found to be significantly associated with a decrease in the studied mandibular measurements when adjusted for sex. These results coincide with those of Singleton et al. (2006) and Yi-Ping et al. (2010), who stated that the decrease of the height of mandibular residual ridge correlates with the decrease of the mandibular bone density and the age. Also with Jonasson and Rythén, (2016), who reported a significant high difference between males and females in midline and mental foramen areas. In addition, Franklin et al., (2008), in their study on South Africans Population, concluded about the continuous reduction in bone height with age due to multiple systemic and local factors , this reduction is greater in females.

The significant influence of sex on the analyzed measurements with the higher values observed in males may be attributed to the higher rate of bone growth of craniofacial dimensions in males under effects of sex hormones. In addition, There is considerable differences in mental foramen position between the two sexes (Rashid and Ali, 2011; Lubis and Anfelia, 2018 and Naveen et al., 2018). Moreover, mandibular dimorphism is influenced by the strength of mastication muscles (Humphrey et al., 1999; Greenstein and Tarnow, 2006).

The measurements obtained from the current study were more comparable to those of direct measurement investigated by Apinhasmit et al., (2006) on 106 Thai adult skulls. In addition, many investigators had reported the results of CT scans as more precise than plain radiographs to reveal mental foramen (Ngeow et al., 2010& Alessandro et al., 2017). According to Alessandro et al., (2017), digital distances taken on CBCT images may conduct dependable results when compared to measurements gained through a digital caliper.

V- CONCLUSION

From the five studied measurements, men had significantly higher mean mandibular height (IBM-HAC), SMMF-IBM, and VMF, than women. Contrariwise, there was no significant difference between the means of IMMF-IBM and SMMF-HAC of men and women. Logistic regression revealed SMMF-IBM, and VMF, in addition to age group, as significant contributors to the regression model. The logistic regression model was statistically significant to clarify 75% of sex difference with an accurate categorization of all cases. Based on the logistic regression model, an equation for prediction of sex was created that could be used for prediction of sex in forensic odontology.

VI- RECOMMENDATIONS

It is a scientific request to expand the study of forensic odontology in Arabic countries and to provide the scientific fields for training among different sectors of the forensic professionals. The advantages of CBCT in the field of forensic odontology should be highlighted in both forensic and police circles. Conducting further inclusive studies on larger scales may improve the accuracy of the results. In addition, Studies considering group specific standards are increasingly asked as the surrounding environment and occupation may affect the skeleton and subsequently bones measurements.

Acknowledgment

The authors are very grateful to all patients who participate in this study. A warm expression of thanks is due to the administrative and medical affairs of the involved dental care academies.

Disclosure statement

There are no conflicts of interest.

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التنبؤ بالجنس باستخدام قياسات الفك السفلي: استخدام الأشعة المقطعية المخروطية

***أبو اليزيد أحمد فؤاد[1]-- حسين سعودي[2] – شيرين عبد المولى[2] – محمد بيومي[3]**
[1]قسم الطب الشرعي والسموم الإكلينيكية-كلية الطب-جامعة طنطا.
[1]شعبه الطب الشرعي-قسم العلوم الطبية الحيوية-كلية الطب-جامعة الملك فيصل –الإحساء-المملكة العربية السعودية.
[2]قسم طب الفم واللثة والتشخيص والأشعة-قسم بيولوجيا الفم-كلية طب الأسنان-جامعة طنطا.
[3]قسم طب الأسنان الوقائي-كلية طب الأسنان -جامعة الملك فيصل –الإحساء-المملكة العربية السعودية .
[3]قسم الدراسات العليا-جامعة باراجواي المستقلة-أسونشيان -باراجواي.

يمثل التعرف على بقايا الهيكل العظمي أهمية أساسية في مجال الطب الشرعي. ومن المعروف أن عظام الحوض والجمجمة والفك السفلى هي أكثر العظام استخداماً لمعرفة الجنس خصوصاً في حالات تحطم أجزاء الجسم. وقد أجريت الدراسة بغرض تحديد مدى صحة القياسات المأخوذة من الفك السفلي باستخدام الأشعة المقطعية المخروطية في تحديد الجنس وأيضاً لوضع صيغة لهذا التحديد وشملت عينة البحث 100 صورة أشعة مقطعية مخروطية وتم تحليل الصور لخمس قياسات وهي: المسافة من الحد السفلي لجسم الفك السفلي إلى أعلى نقطة في العرف السنخي، المسافة بين الحد السفلي للثقبة الذقنية إلى الحد السفلي لجسم الفك السفلي، المسافة بين الحد العلوي للثقبة الذقنية إلى أعلى نقطة في العرف السنخي، المسافة بين الحد العلوى للثقبة الذقنية إلى الحد السفلي لجسم الفك السفلي، بالإضافة إلى حجم الثقبة الذقنية. وقد تم إجراء تحليل البيانات باستخدام البرنامج الإحصائي وقد أظهر تحليل الانحدار الثنائي التدريجي التنبؤي باحتمالية التعرف على الجنس باستخدام واحد أو أكثر من المتغيرات المستقلة. كما أن للمسافة بين الحد العلوي للثقبة الذقنية إلى الحد السفلي لجسم الفك السفلي بالإضافة إلى حجم الثقبة الذقنية أهمية إحصائية في التحليل الانحداري الثنائي التدريجي التنبؤي والذي سجل دلالة إحصائية قادرة على تحديد الجنس في 75 ٪ من الحالات مع تصنفيها بدقة. وبالاستناد إلى التحليل الانحداري الثنائي التدريجي التنبؤي تم اشتقاق معادلة للتنبؤ بالجنس، وقد أظهرت الدراسة الحالية أن جنس الفك السفلي البشري يمكن تقديره من خلال استخدام قياسات مأخوذة باستخدام الأشعة المقطعية المخروطية والتي لها مميزات عديدة إذا ما قورنت بتقنيات الأشعة الأخرى.