Original Article

The Role of Three Dimensional Computed Tomography in Age Estimation from Mandible of a Sample of Libyan Population in Tripoli

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ABSTRACT

Age estimation is fundamental in forensic examinations, either in legal conditions that including living people or to identify skeletal remains. The mandible gives better growth than the other facial bones and presents morphological alterations that relate to size and remodeling during human growth. Previous studies have reported the use of facial reconstruction by three dimensional computed tomography (3D-CT) for individual identification. The aim of this study was to investigate role of 3D-CT in age estimation from mandible of a sample of Libyan Population in Tripoli. This study was conducted in National Cancer Institute, Tripoli, Libya on 200 adults for 6 months (from the beginning of January to the end of June, 2020). All subjects were subjected to 3D-CT scan to assess seven mandibular parameters which were gonial angle, ramus length, minimal ramus breadth, coronoid height, gonion-gnathion length, bicondylar breadth and bigonial length. The results showed significant positive correlation between gonial angle, gonion-gnathion length and age. While, there was significant negative correlation between ramus length, bigonial length and age either in total, male and female samples. By simple linear regression equations, age can be estimated from mandibular parameters proven to be statistically significant with highest R^2 (coefficient of determination) were gonial angle and ramus length either in total, male and female samples. Additionally, there were no significant differences between actual age and estimated age by gonial angle and ramus length either in total, male and female samples. It can be concluded that age can be estimated from mandibular metric parameters measured by 3D-CT with high degree of accuracy.

Key words: Mandibular metric parameters, Three-dimensional computed tomography, Age.

I. INTRODUCTION

The accurate identification of human remains is essential in forensic investigations and anthropological work, mainly during criminal cases and in the identification of accident or natural disaster victims (Indira, 2012).

Age estimation is an important method of human identification either in living or dead corpses. As a result of the increase in immigration, age estimation of living people have greater significance, because foreigners with invalid original documents need estimation of actual age during criminal or civil investigations. Additionally, in cases of unaccompanied minors, age estimation is primarily essential for adoption or immutability purposes (Cunha et al., 2009).

De Oliveira et al. (2014) stated that the mandible is an appropriate indicator of an individual's age. The mandible gives better growth than the other facial bones and presents morphological changes that relate to size and remodeling during human growth. Accordingly, various researches have been performed using different manibular metric measurements for age determination (Rai et al., 2008, Leversha et al., 2015 and Pelin et al., 2018)

Furthermore, Abu-Taleb and El Beshlawy (2015) performed a study on 191 panoramic images (105 males and 86 females) of Egyptian patients aged (6-70) years old, and used five mandibular ramus linear measurements (upper ramus breadth, lower ramus breadth, projective height, condylar ramus height and coronoid ramus height). They concluded regression equation for age estimation in the whole studied sample was: (Age=-32.306+8.481 Coronoid height) that yields no significance on comparing actual and estimated ages.

Actually, there is a growing interest in anthropological researches linked to radiographic or X-ray based methods because they include living individuals. Therefore, recently, computed tomography (CT) has become a common modality to identify human remains and make a biological profile. As a result of lack of contemporary population collections and the ethical difficulties related to the use of maceration techniques, scholars have begun to use recent techniques to gather contemporary data to generate virtual new human skeletal databases (Ramsthaler et al., 2010).

Furthermore, CT scan techniques provide more detailed images of soft tissues and bones without distortion due to the higher contrast resolution and producing more rapid image processing time compared to conventional X-ray methods. As they can provide high levels of reliability in recording bone measurements, the reconstruction of 3D bone images has become a gold standard (Stull et al., 2014). So, The aim of this study was to investigate role of three dimensional computed tomography in age estimation from mandible of a sample of Libyan Population in Tripoli.

II. SUBJECTS AND METHODS

II.1. Subjects

The study was a cross - sectional study that was carried out in National Cancer Institute, Tripoli Libya, for six months from 1st January to the end of June 2020. It included 200 subjects of both sexes, their ages ranged from 18 to 60 years. All subjects are patients that were represented to the radiology department to receive diagnosis or treatment. Written informed consent for participation was taken from each subject.

- **Exclusion criteria**

Subjects with any mandibular bone deformities for example damaged, mutilated, deformed, pathological diseased, fractured and developmental disturbances of the mandible

.II.2. Methods

All participants were exposed to 3D-CT scan on the mandible only after medical order (Inguinty Philips core 256, Netherlands). Seven mandibular parameters were assessed according to Krogman and Iscan (Gamba et al., 2014 & Kano et al., 2015) as follows:

a) Gonial angle (G-angle): It is formed by the line tangent to the lower border of the mandible and the line tangent to the distal border of the ascending ramus and condyle (Figure 1A).

b) Ramus length (Ramus-L): Distance between the condylion and gonion (Figure 1B).

c) Minimal ramus breadth (M-Ramus-Br): Smallest anterior–posterior diameter of ramus (Figure 1B).

d) Coronoid height (CO-Ht): Projective distance between coronion and lower wall of bone (Figure 1B).

e) Gonion-gnathion length (G–G-L): Mandibular base Length (Figure 1B).

f) Bicondylar breadth (BIC-Br): Distance between the condyles (Figure 2).

g) Bigonial length: Distance between the two gonions (Figure 2).

- Five of the above measurements were measured from the lateral reconstruction CT images, and they are G-angle, Ramus-L, M-Ramus-Br, CO-Ht, and G–G-L. All these measurements were taken from left side of mandible, as there is no statistical significant difference between right and left side (Dakhli and Abu El-Dahab, 2020).
- Other two parameters were measured from the axial reconstruction CT images, and they are BG-Br and BIC-Br.
- All the measurements were made by a single observer to avoid the inter-observer bias.

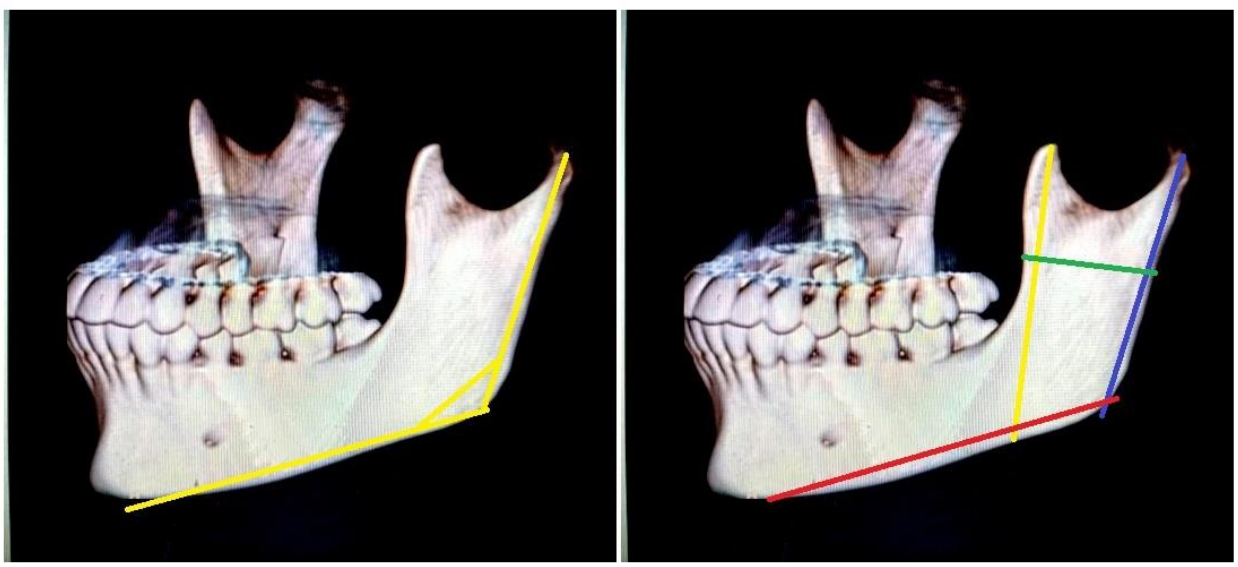

Figure1: Three dimensional computed tomography image of the mandible (lateral reconstruction) showing A) gonial angle. B) blue line= ramus length, green line= minimal ramus breadth, yellow line= coronoid height, red line= gonion- gnathion length

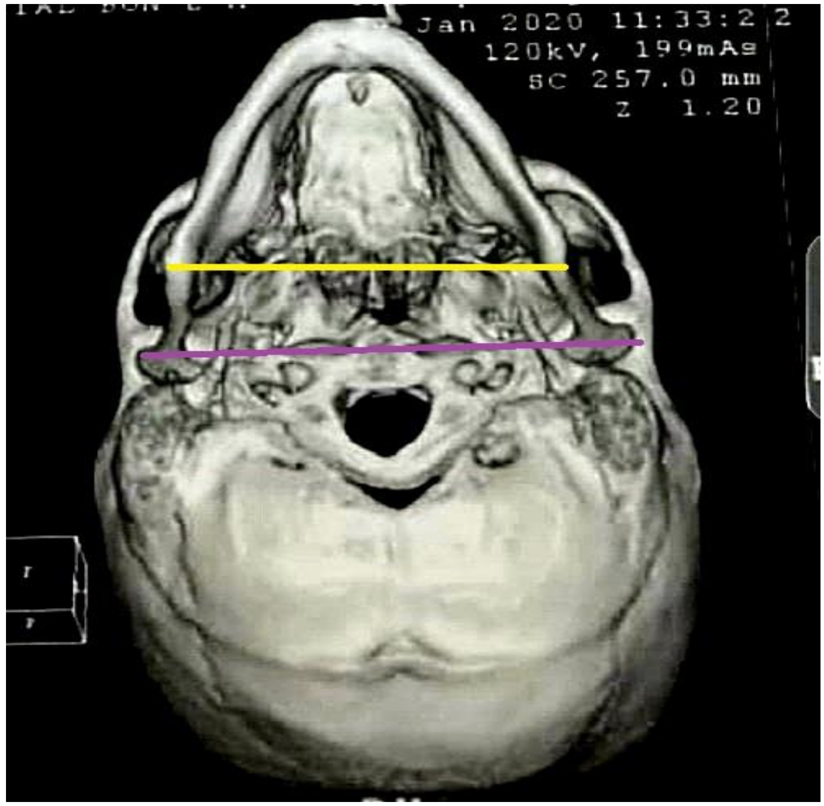

Figure 2: Three dimensional computed tomography image of the mandible (axial reconstruction) showing yellow line= bigonial length and violet line= bicondylar breadth.

II. 3 Statistical analysis

All data were collected, tabulated and statistically analyzed using SPSS 20.0 for windows (SPSS Inc., Chicago, IL, USA). Quantitative data were expressed as the mean ± SD & median (range), and qualitative data were expressed as absolute frequencies (number) & relative frequencies (percentage). Level of significance; p-value< 0.05 was considered statistically significant, p-value < 0.001 was considered highly statistically significant, and p-value ≥ 0.05 was considered statistically insignificant (NS). The following tests were used:

1) Independent samples student's t-test was used to compare between two groups of normally distributed variables.

2) Paired t test was used to compare between actual age and estimated age.

3) Pearson correlation coefficient was calculated to assess relationship between various study variables, positive sign indicate direct correlation & negative sign indicate inverse correlation, also values near to 1 indicate strong correlation & values near 0 indicate weak correlation.

4) Regression model: assesses the statistical significance of each independent variable included in the model. Formally, the model for simple linear regression is :

$Y = a + \beta X$

Y= the variable that we are trying to predict

X = the variable that are using to predict

a= the intercept (Constant)

β = coefficient of x ,represent the mean change in the dependent

III. RESULTS

III.1 Demographic data of the studied group

The mean age of the studied group was 43.36±11.75 years with minimum 18 and maximum 60 years. As regarding sex, 56.5% were male compared to 43.5% were female. There was no significant difference between male and female regarding mean value of age (Table 1&2 and figure 3).

Table1: Age distribution of the studied subjects (n=200).

	Age (years)
Mean± SD	43.36±11.75
Median (range)	45.0 (18-60)

SD: standard deviation; %: percent; n: number of subjects

Table 2: Statistical comparison between male and female as regard mean value of age using student t-test.

	Male (n=113)	Female (n=87)	t	P-value
	Mean ± SD			
Age	43.25±12.9	44.5±9.87	1.12	0.169 NS

NS: Non significant (p>0.05) ; SD: Standard deviation; n: number of subjects

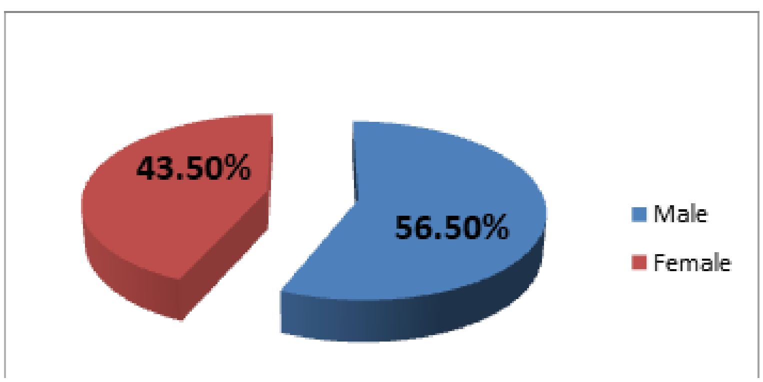

Figure 3: Pie chart showing sex distribution

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III.2 Age estimation from mandibular parameters

1) Correlation matrix between total participants' age and mandibular parameters.

There was significant ($P<0.001$) positive correlation between gonial angle, gonion-gnathion length and age. While, there was significant ($p<0.001$) negative correlation between ramus length, minimal ramus breadth, bicondylar breadth , bigonial length and age. But, there was no significant ($p>0.05$) correlation between age and coronoid hight (figure 4).

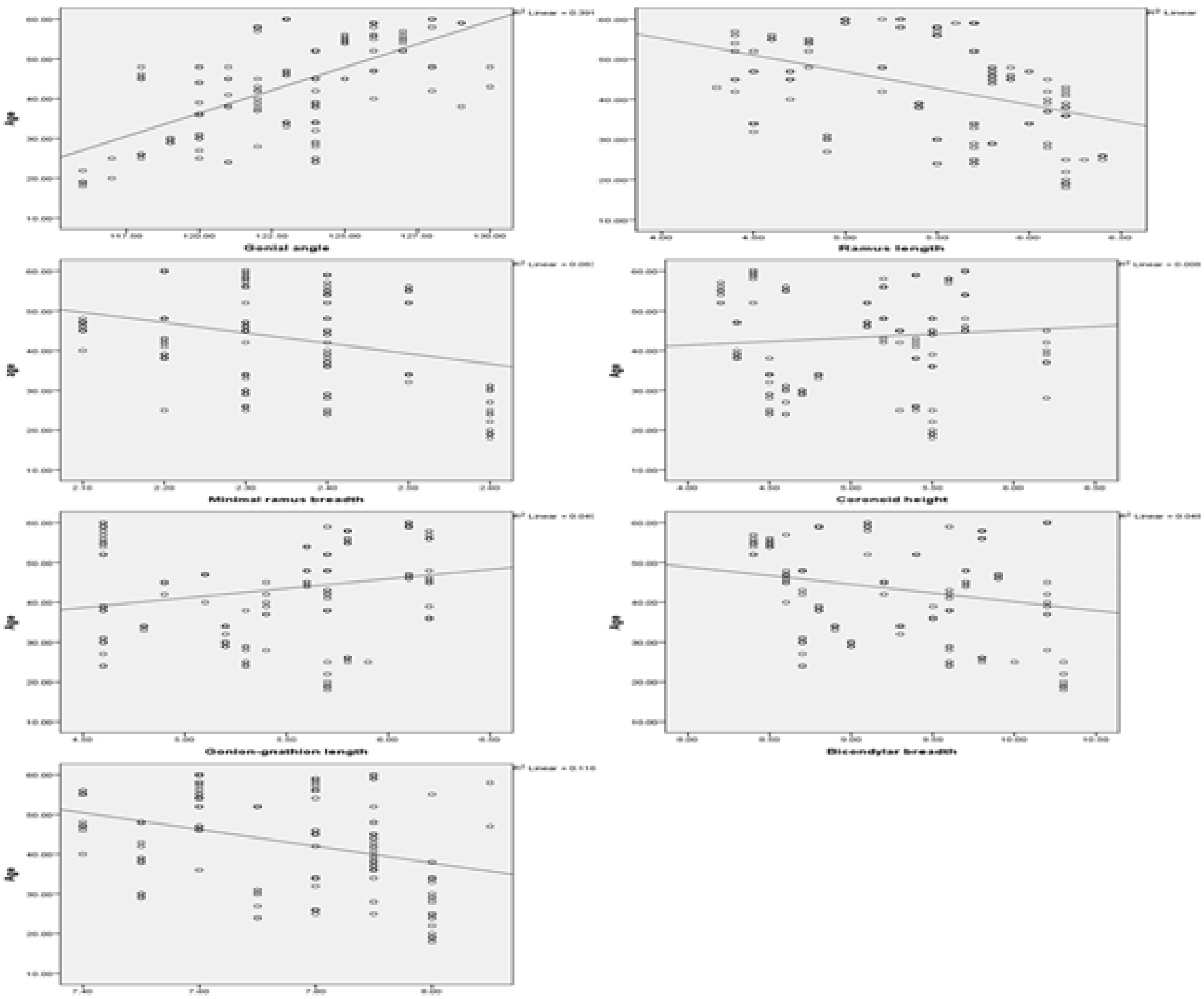


Figure 4: Scatter plot showing Pearson correlations between total participants' age and mandibular parameters.

2) Simple linear regression model for prediction of total participants' age from mandibular parameters.

By simple linear regression equations, age can be estimated from mandibular parameters that were proven to be statistically significant with highest R^2 (coefficient of determination) are gonial angle (0.391), ramus length (0.180) and bigonial length (0.116) shown in table (3). By paired t test, there were no significant (p>0.05) differences between actual age of total participants and estimated age by gonial angle, ramus length and bigonial length (Table 4).

Table 3: Simple linear regression model for total participants' age prediction from mandibular parameters:

n=200	R^2	Equation detect age	t	p
Gonial angle	0.391	-241.7+2.31* Gonial angle	11.285	<0.0001**
Ramus length	0.180	88.3+-8.27* Ramus length	12.864	<0.0001**
Minimal ramus breadth	0.083	104.2+-26* Minimal ramus breadth	-4.240	<0.0001**
Gonion-gnathion length	0.049	17.07+4.81* Gonion-gnathion length	3.204	<0.0001**
Bicondylar breadth	0.048	84+-4.386* Bicondylar breadth	-3.152	<0.0001**
Bigonial length	0.116	206.15+-21.04* Bigonial length	-5.105	<0.0001**

**: significant (P value<0.001); t : student -t-Test ; R^2: coefficient of determination; n: number of subjects

Table 4: Statistical comparisons between actual age of total participants and estimated age by gonial angle, ramus length and bigonial length using paired t test (n=200).

	Mean± SD	Paired t	P -value
Age	43.37±11.75	1.335	0.183 NS
Age estimated by gonial angle	42.50±7.33		
Age	43.37±11.75	0.011	0.991 NS
Age estimated by ramus length	43.37±4.98		
Age	43.37±11.75	0.039	0.969 NS
Age estimated by bigonial length	43.40±4.01		

NS: non significant (p>0.05); n: number of subject

3) Best fitting multiple linear regression model for prediction of total participants' age from mandibular parameters.

Using best fitting multiple linear regression model for predicting age from all mandibular parameters, the only statistically significant independent predictors were gonial angle, gonion-gnathion length and ramus length. The model explains 59% of age as described in table (5).

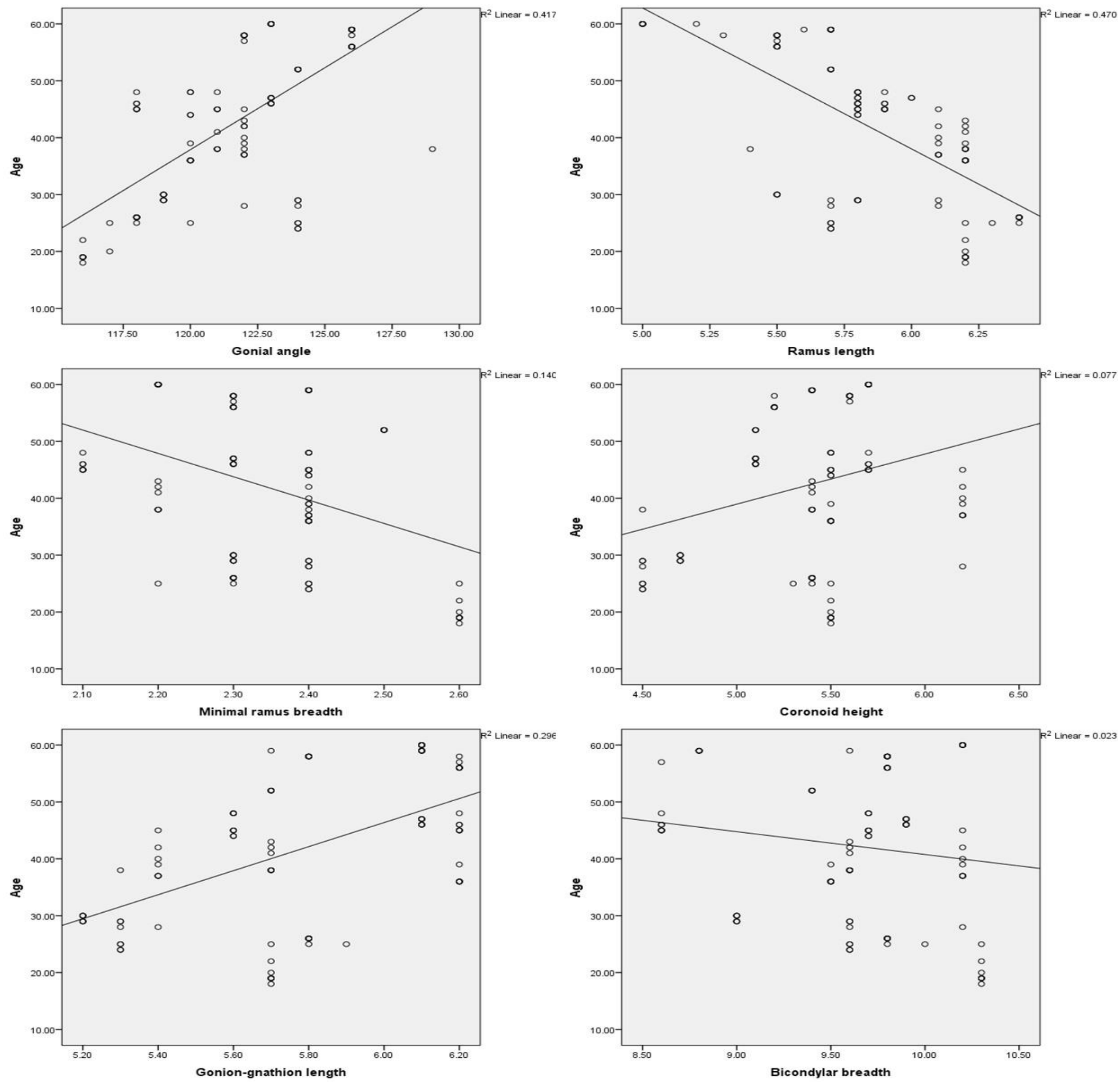
Table 5: Best fitting multiple linear regression model for prediction of total participants' age from mandibular parameters (n=200):

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-256.840	31.445		-8.168	.000
Gonial angle	2.194	.219	.593	10.033	<0.001**
Gonion-gnathion length	10.431	1.096	.482	9.520	<0.001**
Ramus length	-4.940	1.224	-.253	-4.037	<0.001**

**: highly significant ($p<0.001$); B: coefficient of regression; Std. Error: standard error; R^2 coefficient of determination =0. 59; Model ANOVA: F=92.094 $p<0.001$; n: number of subjects

4) Correlation matrix of male participants' age with mandibular parameters (n=113).

There was significant ($p<0.001$) positive correlation between gonial angle, coronoid hight, gonion-gnathion length and age. While, there was significant ($p<0.001$) negative correlation between ramus length, minimal ramus breadth, bigonial length and age. But, there was no significant ($p>0.05$) correlation between age and bicondylar breadth (Figure 5).



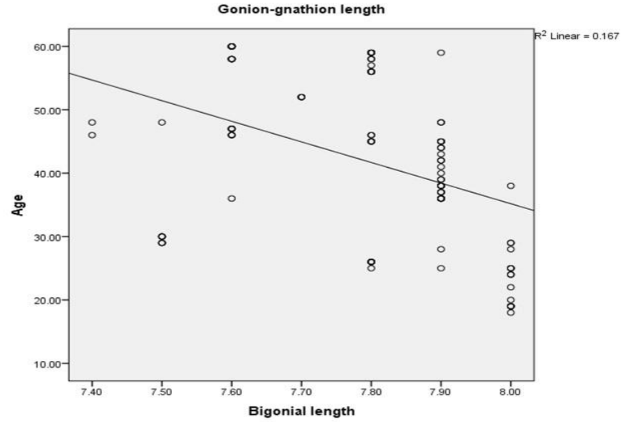


Figure 5: Scatter plot showing Pearson correlations between male participants' age and mandibular parameters.

5) Simple linear regression model for prediction of male participants' age from mandibular parameters.

By simple linear regression equations, age can be estimated from mandibular parameters that were proven to be statistically significant with highest R^2 (coefficient of determination) are ramus length (0.470), gonial angle (0.417) and gonion-gnathion length (0.296) as shown in table (6). By paired t test, there were no significant (p>0.05) differences between actual age of male participants and estimated age by gonial angle, ramus length and gonion-gnathion length (Table 7).

Table 6: Simple linear regression model for male participants' age prediction from mandibular parameters (n=113):

n=113	R^2	Equation detect age	t	p-value
Gonial angle	0.417	-307.67+2.88* Gonial angle	8.908	<0.0001**
Ramus length	0.470	186.69+-24.78* Ramus length	-9.931	<0.0001**
Minimal ramus breadth	0.140	138.17+-41.04* Minimal ramus breadth	-4.255	<0.0001**
Coronoid height	0.077	-5.09+8.81* Coronoid height	3.051	<0.0001**
Gonion-gnathion length	0.296	-80.44+21.14* Gonion-gnathion length	6.827	<0.0001**
Bigonial length	0.167	295.28+-32.51* Bigonial length	-4.715	<0.0001**

**: highly significant (P value<0.001); t : student -t-Test; R^2 : coefficient of determination; n: number of subjects

Table 7: Statistical comparisons between actual age of male participants and estimated age by gonial angle, ramus length and gonion-gnathion length using paired t test (n=113).

	Mean± SD	Paired t	P -value
Age	42.26±12.95	0.034	0.973NS
Age estimated by gonial angle	42.29±8.36		
Age	42.26±12.95	0.016	0.987 NS
Age estimated by ramus length	42.24±8.88		
Age	42.26±12.95	0.027	0.979 NS
Age estimated by gonion-gnathion length	42.28±7.04		

NS: non significant (p>0.05); n: number of subject

6) Best fitting multiple linear regression model for prediction of male participants' age from mandibular parameters

Using best fitting multiple linear regression model for predicting age from all mandibular parameters, the only statistically significant independent predictors were ramus length, gonion-gnathion length and gonial angle. The model explains 76% of age as described in table (8).

Table 8: Best fitting multiple linear regression model for prediction of male participants' age from mandibular parameters (n=113):

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-142.580	39.365		-3.622	.000
Ramus length	-16.086	2.045	-.445	-7.866	<0.001**
Gonion-gnathion length	16.786	1.864	.432	9.003	<0.001**
Gonial angle	1.491	.253	.334	5.885	<0.001**

**: highly significant ($p<0.001$); B: coefficient of regression; Std. Error: standard error; R^2 coefficient of determination =0.76; Model ANOVA: F=112.654, $p<0.001$; n: number of subjects

7) Correlation matrix of female participants' age with mandibular parameters (n=87):

There was significant (p<0.001) positive correlation between gonial angle, gonion-gnathion length and age. While, there was significant (p<0.001) negative correlation between ramus length, bicondylar breadth, bigonial length and age. But, there was no significant correlation between minimal ramus breadth, coronoid hight and age (Figure 6).

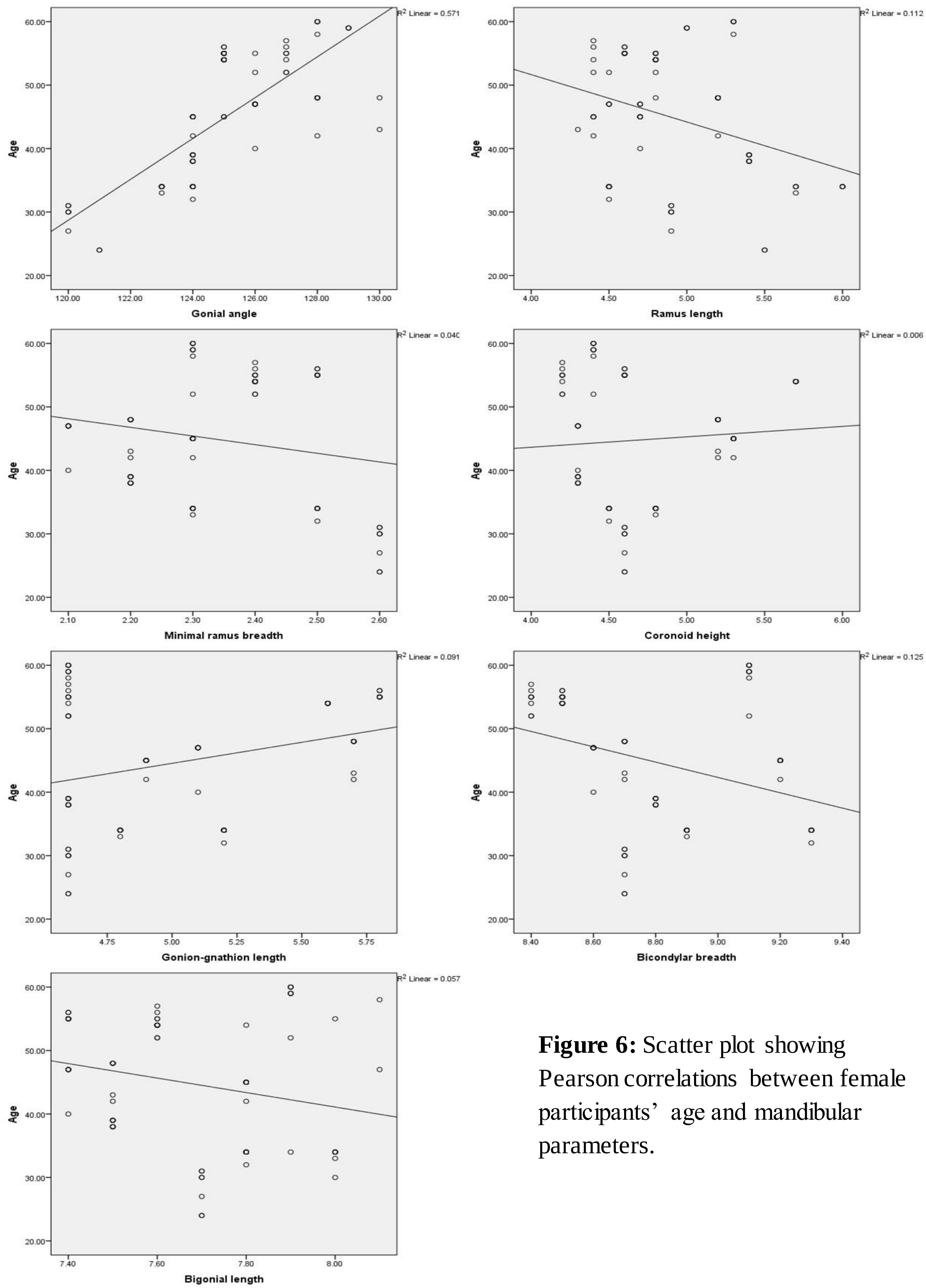


Figure 6: Scatter plot showing Pearson correlations between female participants' age and mandibular parameters.

8) Simple linear regression for prediction of female participants' age from mandibular parameters

By simple linear regression equations, age can be estimated from mandibular parameters that were proven to be statistically significant with highest R^2 (coefficient of determination) are gonial angle (0.571), bicondylar breadth (0.125) and ramus length (0.112) as shown in table (9). By paired t test, there were no significant (p>0.05) differences between actual age of female participants and estimated age by gonial angle, ramus length and bicondylar breadth (Table 10).

Table 9: Simple linear regression model for female participants' age prediction from mandibular parameters (n=87):

n=87	R^2	Equation detect age	t	p-value
Gonial angle	0.571	-357.52+3.22* Gonial angle	10.64	<0.001**
Ramus length	0.112	81.52+-7.466* Ramus length	-3.282	<0.001**
Gonion-gnathion length	0.091	11.41+6.63* Gonion-gnathion length	2.916	<0.001**
Bicondylar breadth	0.125	151.01+-12.08*Bicondylar breadth	-3.486	<0.001**
Bigonial length	0.057	132.36+-11.408* Bigonial length	-2.271	<0.001**

**: highly significant (P value<0.001); t : student -t-Test; R^2 : coefficient of determination; n: number of subjects

Table 10: Statistical comparisons between actual age of female participants and estimated age by gonial angle, ramus length and bicondylar breadth using paired t test (n=87).

	Mean± SD	Paired t	P -value
Age	44.81± 9.87	0.253	0.801 NS
Age estimated by gonial angle	44.98±7.46		
Age	44.81± 9.87	0.003	0.997 NS
Age estimated by ramus length	44.81±3.31		
Age	44.81± 9.87	0.029	0.977 NS
Age estimated by bicondylar breadth	44.78±3.49		

NS: non significant (p>0.05); n: number of subject

9) Best fitting multiple linear regression model for prediction of female participants' age from mandibular parameters

Using best fitting multiple linear regression model for predicting age from all mandibular parameters, the only statistically significant independent predictors were gonial angle, ramus length and bicondylar breadth. The model explains 68% of age as described in table (11).

Table 11: Best fitting multiple linear regression model for prediction of female participants' age from mandibular parameters (n=87):

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-222.699	42.413		-5.251	.000
Gonial angle	2.936	.274	0.689	10.720	<0.001**
Bicondylar breadth	-9.112	2.152	-0.267	-4.234	<0.001**
Ramus length	-3.943	1.425	-0.177	-2.766	<0.001**

**: highly significant (P value<0.001); B: coefficient of regression; Std. Error: standard error; R^2 coefficient of determination =0.68; Model ANOVA: F=57.411, p<0.001; n: number of subjects

IV. DISCUSSION

Using mandible for age estimation in morphometric studies in the field of forensic anthropology is because that the mandible can be spared in many conditions (Damera et al., 2016). Furthermore, mandible shows a more rapid and profound growth in comparison to other facial bones during development, as well as, the dimensional and morphological changes accumulating over the years accurately reflect the skeletal developmental state (De Oliveira et al., 2015 & Rai et al., 2008). In the last few years, multiple researches have reported that, with aging in adults, statistically significant changes occur in the shape and size of certain craniofacial bones for both sexes, even after puberty (Neto et al., 2010).

Many studies have reported that adult growth does occur, but not as fast as in children. Some of these studies used anatomical measurements of the cadaveric bone (Junior et al., 2013 & Ludlow et al., 2007) or by using digital radiograph, such as panorama, cephalogram, or recently cone beam computed tomography (CBCT).Many investigators have demonstrated a significant correlation between chronological age of the individual and the mandible measurements, mainly the mandibular ramus length (Franklin et al., 2007 & Norris, 2002). This is in accordance with results of the current study, it was found that there was significant positive correlation between gonial angle, gonion-gnathion length and age. While, there was significant negative correlation between ramus length, bigonial length and age either in total, male and female samples.

By simple linear regression equations, age can be estimated from mandibular parameters proven to be statistically significant with highest R^2 (coefficient of determination) were gonial angle and ramus length either in total, male and female samples. Additionally, there were no significant differences between actual age and estimated age by gonial angle and ramus length either in total, male and female samples.

Using best fitting multiple linear regression model for predicting age from all mandibular parameters, the only statistically significant independent predictors were ramus length, gonion-gnathion length and gonial angle in both total and male samples, and ramus length, bicondylar breadth and gonial angle in female sample . The model explains 59% of age in total sample, 76% in male sample and 68% in female sample.

In accordance with results of present study, Ghaffari et al. (2013) in their study using CT scans obtained from 124 subjects (70 males, 54 females, aged 21-50 years), reported that for both sexes ramus length decreased with increasing age. While, the gonial angle increased with age

The results of present study were in line with those of Leversha et al. (2016) who studied age and gender correlation of gonial angle, ramus height and bigonial width in a dental school in Far North Queensland and found that gonial angle increases with age, whilst, bigonial length and ramus length are shown to decrease with age.Similarly, Assari et al. (2017) studied 400 hemi-mandibles, ranging in age from 18 to 75 years and found that, with aging, the mandibular linear measurements are statically significantly changed. There is positive correlation between age and gonial angle in the male sample. In the female sample, a positive significant correlation was observed in the mandibular angle and the mandibular base length.

Regarding results of regression analysis of present study, there are no sufficient studies to verify these results.

Against the results of present study, Chole et al. (2013) in their study on panoramic radiographs (854 dentulous subjects, 206 edentulous subjects; aged 15-66 years), observed that the gonial angle was not changed by the age or by dental status. Similarly, Dutra et al. (2004) in their study on panoramic radiographs (119 males, 199 females, age range 40–79 years), found that the gonial angle did not show any change with gender, age and dental status.

Additionally, Taleb and El Beshlawy (2015) found a statistically significant positive (direct) correlation between age and the mandibular ramus linear measurements and non significant negative correlation between age and gonial angle. As well as, regression analysis results showed that coronoid height was the only statistically significant predictor of age in males, females and in the whole studied sample. While, gonial angle has no role in age estimation. This difference may be attributed to the different age ranges and different dental status.

V. CONCLUSION and RECOMMENDATION

Gonial angle and ramus length are highly reliable for the estimation of age in forensic examinations. Regression equations derived from mandibular parameters measured by 3D-CT can be used for age estimation with high degree of accuracy and this may be applicable for disaster victim identification (DVI), criminal cases and accident investigations. Using new tools and large sample is recommended for proving the accuracy of these results and its applicability in forensic examination.

VI. CONFLICTS of INTEREST

There is no conflict of interest

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الملخص العربي

دور التصوير المقطعي ثلاثي الأبعاد في تقدير العمر من الفك السفلي لعينة من السكان الليبيين في طرابلس

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إن تقدير العمر أمر أساسي في فحوصات الطب الشرعي ، إما في الظروف القانونية التي تشمل الأشخاص الأحياء أو لتحديد بقايا الهياكل العظمية. يعطي الفك السفلي نموًا أفضل من عظام الوجه الأخرى ويقدم تغيرات مورفولوجية تتناسب مع الحجم وإعادة التشكيل أثناء النمو البشري. أقرت الدراسات السابقة استخدام إعادة بناء الوجه عن طريق التصوير المقطعي ثلاثي الأبعاد لتحديد هوية الفرد. ولذلك الهدف من هذه الدراسة هو دراسة دور التصوير المقطعي ثلاثي الأبعاد في تقدير العمر من الفك السفلي لعينة من السكان الليبيين في طرابلس. أجريت هذه الدراسة في المعهد القومي للسرطان بمدينة طرابلس بليبيا على مائتى شخص بالغ لمدة ستة أشهر (من بداية شهر يناير إلى نهاية شهر يونيو 2020). تم إخضاع الأشخاص لفحص التصوير المقطعي ثلاثي الأبعاد لتقييم سبع قياسات فكية وهى الزاوية الفكيه ، وطول الفرع ، والحد الأدنى لاتساع الفرع ، وارتفاع التاج ، وطول قاعدة الفك السفلى، وعرض اللقمتين ، وطول البيجون. أظهرت النتائج وجود علاقة ارتباط موجبة ذات دلالة إحصائية بين الزاوية الفكية ، طول قاعدة الفك السفلى ، والعمر. بينما كانت هناك علاقة ارتباط سالبة ذات دلالة إحصائية بين طول الفرع، طول البيجوني والعمرسواء في العينة الكلية اوعينة الذكور والإناث. ومن خلال معادلات الانحدار الخطي البسيطة ، يمكن تقدير العمر من قياسات الفك السفلي التي ثبت أن لها أعلى معامل انحدار ذات دلالة إحصائية وهى الزاوية الفكيه وطول الفروع سواء في العينة الكلية اوعينة الذكور والإناث. بالإضافة إلى ذلك ، لم تكن هناك فروق ذات دلالة إحصائية بين العمر الفعلي والعمر المقدر حسب الزاوية الفكيه وطول الفروع سواء في العينة الكلية أوعينة الذكور والإناث. يمكن استنتاج أنه يمكن تقدير العمر من قياسات الفك السفلي المقاسة بواسطة التصوير المقطعى ثلاثى الابعاد بدرجة عالية من الدقة.