



Original article

Age Estimation in Libyan Children Based on Dental Panoramic Radiography

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ABSTRACT

Background: Age estimation plays a key role in the human identification process, and in guiding police investigations. Tooth development is widely used in determining age and state of maturity. Dental age (DA) is of high importance in forensic and pediatric dentistry and also orthodontic treatment planning.

Objective: The aim of this study was to assess the accuracy of the Cameriere method in estimating chronological age (CA) of a Libyan sample of 6-year-old up to 13-year-old children through analysis of panoramic radiographs on teeth, considering the relationship between age and measurements of open apices teeth.

Materials and methods: Orthopantomographic images of 156 radiographs were selected for the study of which 76 belonged to boys and 80 girls children. The dental age of the subjects was determined through the Cameriere method. Differences and correlations between chronological and dental ages were assessed by paired t-tests and Pearson's correlation analysis, respectively. Multiple regression analysis was used to predict chronologic age in Libyan from 6-13 years children population.

Results: A high positive correlation was found between chronologic age and dental age (as assessed by Cameriere's formula) with r values 0.882, 0.975, and 0.758 for the total, girls and boys study population, respectively. The mean dental age assessed by Cameriere's method was significantly lower than the chronologic age in the Libyan population with boys and the total study population ($p < 0.05$). Six out of nine parameters were significantly associated with chronologic age ($R^2=0.996$, $F(6,155)=2792.023$, $p<0.01$).

Conclusion: Our findings demonstrate that Cameriere's method is a robust tool for age estimation. These results underscore the high accuracy and importance of assessing dental development for precise age estimation. Based on this research, we can conclude that Cameriere's method is suitable for dental age estimation in Libyan children.

Keywords: Age estimation, Panoramic X-ray, Cameriere formula

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INTRODUCTION

The most prevalent measure of the aging process is typically determined by chronological age, which may not always be ascertainable or subject to manipulation. The identification of deceased individuals holds significant importance within the legal context, yet it can present a formidable challenge due to the multitude of potential circumstances.¹⁻⁴ Age estimation plays a key role in the human identification process and guides police

investigations. Due to the growing incidence of natural disasters, the accurate age estimation narrows the search within the possible victims.¹ Age also plays a crucial role in pediatric dentistry, as well as in the process of treatment plans for orthodontic patients and performing surgeries. Evaluation of skeletal age using radiological techniques is a suitable criterion for assessing individual biological maturation and is normally applied to answer forensic, pediatric, and orthodontic questions.^{2, 3} Although skeletal maturation can play an important part in determining age as an orderly process, teeth and hand-wrist areas are the most common indicators of age in growing children.⁴ Several studies have highlighted that mineralization serves as the main tool to determine the correspondence between biological age and

chronological age. Since 1950, many researchers have been induced to concentrate on mineralization due to the routine use of X-rays.⁵ Many authors have developed scoring methods in order to assess dental age using dental calcification stages of permanent teeth.⁶⁻⁹

Demirjian and his colleagues studied one method of age estimation. Their original sample comprised 1,446 boys and 1,482 girls of French-Canadian origin, and their data were later compared with other sample groups from several nationalities.⁵ Most of the results revealed the fact that the standards of dental maturation described by Demirjian et al. (1973) are not always suitable for these countries.⁵ More recently, in 2006, Cameriere et al.² presented a method for assessing chronological age in children based on the relationship between age and measurement of open apices in teeth, which gave reliable estimates of the ages of 455 Italian-Caucasian children. In the same year, the same authors also published a paper with additional samples from Kosovo and Slovenia, for a total number of 1,100 children.¹⁰

In recent times, accurately estimating the age of living individuals has become increasingly relevant. This is particularly crucial for those lacking legal documentation of birth, especially when they are suspected of committing crimes and their age needs to be assessed to determine importability. In Libya, there is scarce information about age estimation using Cameriere's method except for one study.¹¹ Those studies have only examined the third molars based on Cameriere's role in determining if a subject is an adult or not in the Libyan population. There is a lack of information on the validity of Cameriere's method in the Libyan population. Hence, this study aimed to assess the reliability of the Cameriere method in determining the chronological age of a sample of Libyan children. Additionally, if the method proves inaccurate, the study seeks to develop a new algorithm specifically tailored for estimating the chronological age of Libyan children.

MATERIALS AND METHODS

Study sample

The present cross-sectional study used prospective evaluation of orthopantomographs of children who attended private dental clinics from different Libyan cities named Benghazi, Tripoli, Tobruk and Albyda. All patients' digital radiographs were

obtained by a digital orthopantomograph (Planmeca® ProOne X-ray unit, Planmeca Oy, Asentajankatu 6, FIN-00880, Helsinki, Finland). The same brand Planmeca® ProOne X-ray unit is consistently used in all the cities included in this research. All the digital X-ray images were viewed and calibrated using a computer with Planmeca Romexis 22 imaging software revision 2.3.0. Provided with the Planmeca digital X-ray (**Figure 1**).

The orthopantomographs of 156 healthy Libyan children (76 boys, 80 girls) aged between 6 and 13 years old were analyzed. Only radiographs that satisfied the inclusion criteria were included in the study. All collected orthopantomographs were analyzed to correlate chronologic age with dental age as estimated by Cameriere's method in the Libyan population. Here is a variable equal to 1 for boys and 0 for girls, N0 is the number of teeth with closed apices, x1 is the ratio of apex width and tooth length of lower left central incisor and so on till x7 for the second permanent molar, s is the summation of all teeth ratio (x1, x2 x7). The A/L ratio for each tooth (x1 to x7): the ratio of open apex width to crown length, which is used to correct potential errors in magnification and angulation.

Data collection

The personal information obtained from the case records included the patient's gender, date of birth and the date the radiograph was taken. The date of birth was recorded based on information provided by the parents. The difference in time between the radiograph date and the date of birth was used to determine the patient's chronological age. The chronological age at the time of the radiographic examination was recorded in completed years and months. If the difference in days was more than 15, it was rounded up to the nearest month. All patients' radiographs were taken using a digital orthopantomograph machine. The digital X-ray images were viewed and calibrated using computer software provided by the X-ray unit. The measurements on the panoramic radiograph were focused on the lower teeth, as measuring the upper teeth can be challenging due to overlapping roots or other structures. Since the growth pattern is usually symmetrical, measurements were taken from only one quadrant (lower left). An example radiograph displayed measurements for reference (**Figure 1**).

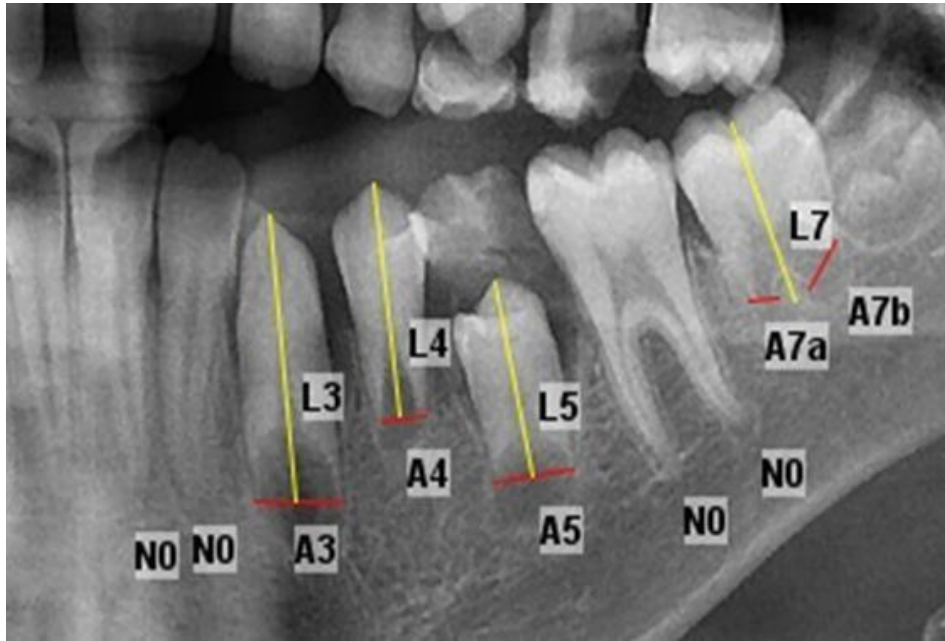


Figure (1): A panoramic image demonstrating the measurements for the Cameriere's formula. The measurement of tooth apices A1 to A5 is the distance between the inner sides of single-rooted teeth. For teeth with two roots, measure the sum of distances (A6a + A6b) between the inner sides of the two open apices. L1 to L7 represent the tooth length measurements.

Inclusion Criteria

The study included Libyan patients aged between 6 and 13 years old who had undergone a panoramic radiograph investigation. Only children without any medical conditions were considered for inclusion.

Exclusion Criteria

Patients who did not hold Libyan nationality, those above the age of 13 or below the age of 6 were excluded from the study. Additionally, individuals with incomplete medical or dental histories, documented tooth extraction or agenesis (particularly in the left lower quadrant), distorted radiographs, unclear radiographs, or radiographs showing evidence of periapical lesions, carious teeth, fractured teeth, or internal tooth resorption were excluded. Patients with systemic diseases or congenital anomalies were also excluded. Premature birth and hypodontia of permanent teeth (excluding third molars) or hypertonia, as well as those with a history of orthodontic treatment, were excluded. Incorrect neck position

and anteroposterior error (chin tipped down) radiographs were excluded. Prior to accessing the patient data, permission was obtained, and all personal details were de-identified.

Statistical analysis

For this study, 20 radiographs were randomly selected and measured by two independent observers. After two weeks, the same radiographs were re-examined to assess measurement consistency. The correlation coefficient between the two observers for open apices measurements was 0.96, and within each observer independently was 0.99 ($p < 0.05$). The data was analyzed using SPSS version 23 software. Pearson's correlation analysis examined the relationship between study variables and chronologic age. A paired t-test compared chronologic age with dental age using the Cameriere method. Multiple regression analysis determined statistically significant variables in the mixed model. Step-wise regression analysis was conducted to create a more precise equation for predicting chronologic age ($p < 0.05$).

To assess inter-observer error, a new random sample of 50 individuals was re-examined after three weeks by a second examiner. This subsample was also measured by a third observer with no prior experience. The inter-observer reliability of the sum of normalized open apices ¹ was studied using the concordance correlation coefficient, and the inter-observer reliability of the number of the seven left permanent mandibular teeth with complete root development (N0) was measured using Cohen's Kappa coefficient (values range from 0 to 1, with 0 indicating chance agreement and 1 indicating perfect agreement).

RESULTS

The study analyzed a total of 156 radiographs, with 76 from male children and 80 from female children. The objectives of the study focused on the correlation between chronologic age and dental age determined by Cameriere's formula. The results revealed a significant positive correlation between the two. For girls, the correlation coefficient was 0.975, for boys, it was 0.758, and for the overall study population, it was 0.882. These findings are summarized in **Table 1**.

Table 1: Comparison of Chronologic and Dental Age by Cameriere formula.

Age	N	Mean	SD	Mean Diff.	SD Diff.	Paired <i>t</i>	<i>p</i> -value	<i>R</i>
CA-Total	156	9.025	2.160	0.256	1.050	3.039	0.003**	0.882
DA-Total	156	8.769	2.159					
CA-Girls	80	9.053	2.273	0.107	0.521	1.840	0.070	0.975
DA-Girls	80	8.946	2.343					
CA-Boys	76	8.995	2.050	0.412	1.395	2.573	0.012*	0.758
DA- Boys	76	8.583	1.947					

*Statistically significant at 5%, **statistically significant at 1% levels of significance.

There was a significant correlation between all radiographic parameters (x1 to x7) and chronological age, as determined through statistical analysis ($p < 0.05$). Surprisingly, no significant correlation between gender and chronological age was observed ($p > 0.05$). as indicated in **Table 2**.

Table 2: Correlation between chronological age with radiographic measurements.

Variables	Correlation between chronological age with		
	r-value	t-value	<i>p</i> -value
Gender	-0.084	-1.046	0.295
N₀	0.900	25.623	0.000**
x₁	-0.373	-4.989	0.000**
x₂	-0.525	-7.655	0.000**
x₃	-0.909	-27.066	0.000**
x₄	-0.836	-18.906	0.000**
x₅	-0.871	-22.001	0.000**
x₆	-0.660	-10.902	0.000**
x₇	-0.929	-31.152	0.000**

*Statistically significant at 5%, **statistically significant at 1% levels of significance.

A multiple regression analysis was conducted to forecast age utilizing parameters (N_0 , x_1 to x_7) as independent variables and chronological age as the dependent variable. This analysis uncovered a highly significant relationship ($R = 0.996$, $R^2 =$

0.992 , $p(F_{(9,155)} = 1893.491) < 0.01$). Suggesting that these predictors accounted for the variability observed in age. However, it is worth noting that x_1 , x_5 , and x_6 did not exhibit statistical significance as indicated in **Table 3**.

Table 3: Multiple regression analysis of radiographic measurements on chronological age.

Independent variables	Unstandardized Coefficients	SE of Reg. coefficient	Standardized Coefficients	t-value	p-value
<i>Intercept</i>	9.370	0.099	-	94.666	0.000**
<i>N₀</i>	0.560	0.020	0.436	28.384	0.000**
<i>x₁</i>	0.402	0.524	0.011	0.767	0.444
<i>x₂</i>	3.609	0.409	0.121	8.816	0.000**
<i>x₃</i>	-2.004	0.192	-0.226	-10.455	0.000**
<i>x₄</i>	-1.237	0.118	-0.141	-10.516	0.000**
<i>x₅</i>	0.309	0.176	0.043	1.757	0.081
<i>x₆</i>	-0.309	0.244	-0.016	-1.265	0.208
<i>x₇</i>	-1.560	0.090	-0.405	-17.416	0.000**

$R = 0.996$, $R^2 = 0.992$, $p(F_{(9,155)} = 1893.491) < 0.01$, Std. Error of Estimate = 0.2051

*Statistically significant at 5%, **statistically significant at 1% levels of significance.

Hence, the Cameriere's equation for the regression model is $\text{Age} = 9.370 + 0.328(\text{gender}) + 0.560N_0 + 0.402x_1 + 3.609x_2 - 2.004x_3 - 1.237x_4 - 0.309x_5 - 0.309x_6 - 1.560x_7$. however, the utilization of stepwise multiple regression unveiled a significant correlation between chronological age and six

parameters out of the nine considered ($R^2 = 0.996$, $F(6,155) = 2792.023$, $p < 0.05$) as displayed in **Table 4**. Therefore, the obtained linear regression equation will be as follows: $\text{Age} = 9.357 + 0.335*(\text{gender}) + 0.565*N_0 + 3.880*x_2 - 1.281*x_3 - 1.848*x_4 - 1.474*x_7$.

Table 4: Stepwise multiple regression analysis of radiographic measurements on chronological age.

Independent variables	Unstandardized coefficients	SE of Reg. coefficient	Standardized Coefficients	t-value	p-value
<i>Intercept</i>	9.357	0.093	-	100.803	0.000**
<i>Gender</i>	0.335	0.035	0.078	9.504	0.000**
<i>N₀</i>	0.565	0.018	0.440	31.735	0.000**
<i>x₂</i>	3.880	0.301	0.130	12.879	0.000**
<i>x₃</i>	-1.281	0.116	-0.147	-11.067	0.000**
<i>x₄</i>	-1.878	0.159	-0.212	-11.805	0.000**
<i>x₇</i>	-1.474	0.071	-0.383	-20.735	0.000**

$R = 0.996$, $R^2 = 0.991$, $p(F_{(6,155)} = 2792.023) < 0.01$, Std. Error of Estimate = 0.2068

*Statistically significant at 5%, **statistically significant at 1% levels of significance.

The plot displaying the comparison between observed and predicted values exhibits a symmetrical distribution with a propensity to converge towards the center (**Figure 2**).

Similarly, the plot illustrating the residuals plotted against the fitted values, created using the regression model, does not reveal any discernible pattern, apart from a few outliers (**Figure 3**).

These findings from both plots provide support for the application of our regression model in estimating chronological age. Notably, when applying the regression equation to 166 children within the Libyan population, no statistically significant variation was observed between the predicted and actual chronological ages.

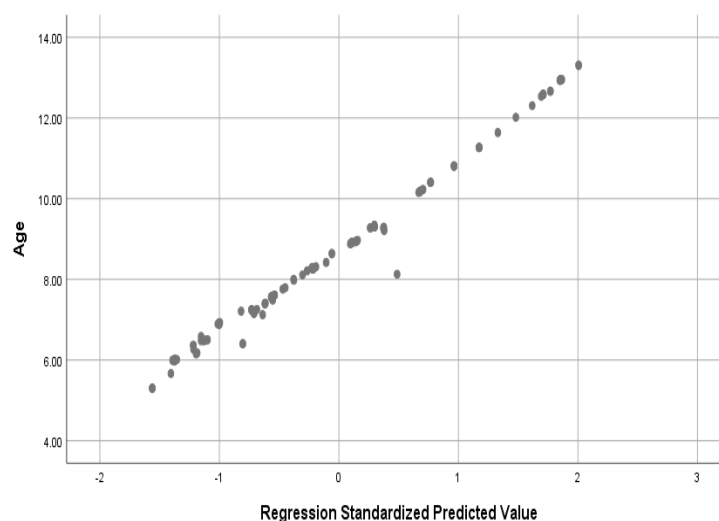


Figure (2): Scatterplot, showing the dependent variable (age) against predicted value.

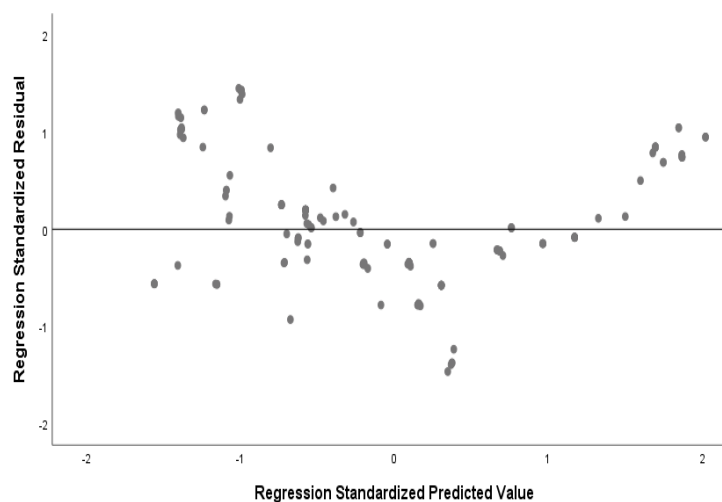


Figure (3): Scatterplot showing Regression residual against predicted value.

DISCUSSION

Though chronological age is essential in many situations, undocumented or missing birth data alerts the need to estimate the age of an individual. Age estimation plays an increasingly important role in forensic science, archaeology, pediatric dentistry and clinical aspects.¹⁰ In forensic contexts, particularly concerning unidentified deceased individuals, age estimation is crucial for creating biological profiles. However, the need to determine an age also arises for living children of unknown identity. According to scholarly literature, there are instances in which a child may encounter legal complications due to being either the target of a criminal act, considered a suspect in a criminal case, or classified as a refugee of indeterminate age.^{4, 12-15}

To determine the age of such individuals, various morphological techniques have been devised. However, the efficacy of these methods hinges on their capacity to yield an estimate that closely aligns with the individual's chronological age, within acceptable error limits.^{16, 17} In legal cases, it is also necessary to use non-invasive methods which are more precise and in compliance with legal requirements.² Among various methods, Cameriere's method of age estimation has been shown to be more reliable and accurate, as it relates closely with chronological age than any other maturity indicators and is the least variable method compared to others.⁴

In the field of dental age assessment, two main concepts can be identified. One is by assessing the age of tooth eruption in the oral cavity, and the other is by recording the stages of root and crown mineralization in primary and permanent dentition. The former possesses the disadvantage of being affected by local factors during the process of tooth eruption. Such as premature deciduous tooth loss, ankyloses, and others. While the latter is a progressive phenomenon and easily definable by the staging of calcification and therefore is the most reliable dental indicator.¹⁶

In the current study, all variables played an essential role in determining the dental age except x1, x5 and x6, which were not statistically significant ($p > 0.05$). This is in agreement with Cameriere et al (2006) study¹⁰ but in contrast to AlShahrani et al (2019) study¹² where all variables were at a lower level of significance. As regards repeatability, there were no statistically significant inter-observer differences between the paired sets of measurements carried out on the re-examined orthopantomographs. This emphasizes the fact that, although this technique involves more steps

during calculation, it is faster and easier than other quantitative methods. As noted by Cunha et al. (2009)⁴, the best method is sometimes the one that has been tested by many researchers on several different populations, and which is also suitable for a specific forensic context, practical, quick and inexpensive. Cameriere et al. (2006) showed that the relationship between chronological and estimated dental ages was evaluated for each gender and age group, as well as for the total sample by analysis of means and standard deviation.⁹

The mean prediction error (Mean differences)² (standard deviation) (SD) was 0.63 years for girls and 0.52 years for boys.¹⁸ Cameriere et al (2008)¹⁸ also compared the mean for three methods, those of Willems et al (2001)¹, Cameriere et al (2006)¹⁰ and Demirjian et al (1973)⁵ Cameriere's method provided 0.48 years for girls and 0.50 years for boys, which are close to the results in the current study and with the European formula in Mexican children. Using Cameriere's method, Galic' et al (2011)¹⁹ found mean of 0.53 years for girls and 0.55 years for boys. In the Mexican sample, Cameriere's method yielded a mean overestimation of 0.10 for girls and a correct mean estimation for boys. The estimation of DA was found to be overestimated, as evidenced by mean errors⁵ of 0.58 and 0.65 observed in the spanning 5-6 and 6-7 years respectively. It was also underestimated by MEs of 1.06 for girls in the age group 14-15 years. In addition, although a different trend was observed in boys, slight MEs of 0.02 and 0.27 were shown in older individuals in the age groups of 13-14 and 14-15 years.²⁰

The results in this study match those of many previous studies examining the applicability of Cameriere's method on various subjects from Europe and children from India and Egypt.^{21, 22} The other researchers studied a sample of 1089 Bosnian-Herzegovian children aged between 6 and 13 years. For girls, the mean DA was overestimated by 0.10 years according to Cameriere's method by the range of differences of - 0.80 to 0.60 years for all age groups. For boys, the mean DA was underestimated for -0.02 according to Cameriere's method by the mean of differences of -0.60 to 0.09 years for the 10-, 11-, 12- and 13-year-old groups, whereas it was 47 overestimated by the mean of differences of 0.09 to 0.45 years for the 6-, 7-, 8- and 9-year-old groups. In Egyptian children, Cameriere's method showed an average underestimation of -0.29 ± 1.04 years for the total sample, -0.26 ± 1.21 years for girls and -0.49 ± 1.03 years for boys. According to Cameriere,²¹ when

employing his method to the Indian sample of 480 children between 3 and 15 years, a mean overestimation of 0.05 years for boys and 0.04 years for girls was observed. This trend may be attributed to a combination of factors including inter and intra-population variations, discrepancies among observers and specific techniques used.

Precision is mainly related to factors influenced by chance, as in random errors.²³ Frequently, as well as slightly noticeable methodological errors, biological variation should also be considered.²⁴ It has been reported that the growth of a child may be influenced by several factors including genetic, nutritional, racial, hormonal, climatic, social, and others. Among the several maturity bio-indicators usually examined, teeth are least influenced by all these factors. It is to be counted that various dental age estimation methods recommended in the past did not provide a common formula for the population of the whole world.²⁵

These methods also differed in their accuracy when different populations were considered. Hence this study focuses on the improvement of the method developed by Cameriere et al. (2006) to suit the Libyan children. This highlights the fact that Cameriere's technique is very accurate and represents a useful technique for age assessment in children of this age group (5– 15 years). The accuracy of age estimation indicates how well chronological age can be predicted, and greater accuracy can be obtained by choosing the method that shows the least variability with age.²⁶

CONCLUSION

Cameriere's formula, as validated in a study conducted on children in Libya, has been proven to be a robust tool for estimating the chronological age of both male and female individuals. In order to enhance the accuracy of age assessment in Libyan children, it is recommended to develop a prediction formula based on Cameriere's method specifically tailored for this population. To further explore the reliability of dental age assessment using the new formula, future research should involve larger sample sizes and should aim to investigate the potential impact of regional background, nutritional factors, and the distribution of chronological age among Libyan children.

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