Age Estimation in Libyan Children Based on Dental Panoramic Radiography

By

Ayman Salem Najem

Supervised by:

Associate professor Dr. Fowziya M.Ali

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University of Benghazi  Faculty of Dentistry

Department of pediatric dentistry

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This thesis was successfully Defended and Approved on: / / 2021

Supervised by:

Associate professor Dr. Fowziya M.Ali

Signature: ……..…….

Dr ……. (Internal examiner)

Signature: …….

Dr ……. (External examiner)

Signature: …….

Dean of faculty **Director of graduate studies and training**

﴿ هُوَ الَّذِي جَعَلَ الشَّمْسَ ضِيَاءً وَالْقَمَرَ نُورًا وَقَدَّرَهُ مَنَازِلَ لِتَعْلَمُوا عَدَدَ السِّنِينَ وَالْحِسَابَ ﴾

سورة يونس
الآية (5)

إهداء

إلى روح والدي الحبيب.. من غرس فينا عزة النفس والتعلم...

إلى والدتي الحبيبة.. نبع المحبة ونهر العطاء...

إلى أساتذتي الكرام...

إلى... كافة زملاء الدراسة في مجال طب الاسنان

إلى... جميع طلاب العلم

إليكم أهدى هذا الجهد المتواضع سائلاً المولى أن ينفع به وتجعله خالصاً لوجهه الكريم.

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Above all, my sincere gratitude and praise goes to the Almighty Allah, the everlasting judge, the most merciful.

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ABBREVIATIONS

A	Open apex width.
A_1	Width of open apex of permanent lower left central incisor.
A_2	Width of open apex of permanent lower left lateral incisor.
A_3	Width of open apex of permanent lower left canine.
A_4	Width of open apex of lower left first premolar.
A_5	Width of open apex of lower left second premolar.
A_{6a}	Width of open apex of mesial root of permanent lower left first molar.
A_{6b}	Width of open apex of distal root of permanent lower left first molar.
A_{7a}	Width of open apex of mesial root of permanent lower left second molar.
A_{7b}	Width of open apex of distal root of permanent lower left second molar.
CA	Chronological age.
CCD	Charge coupled device.
DA	Dental age.
g	Gender.
L	Tooth length.
ME	Mean prediction error.
N_0	Number of teeth with closed apex.
OPG	Orthopantomograph.
S	Sum of normalized open apices.
SPP	Storage phosphorus Plate.
x_1	Ratio of apex width and tooth length of permanent lower left central incisor.
x_2	Ratio of apex width and tooth length of permanent lower left lateral incisor.
x_3	Ratio of apex width and tooth length of permanent lower left canine.
x_4	Ratio of apex width and tooth length of lower left first premolar.
x_5	Ratio of apex width and tooth length of lower left second premolar.
x_6	Ratio of apex width and tooth length of permanent lower left first molar.
x_7	Ratio of apex width and tooth length of permanent lower left second molar.
μSv	Micro Sievert.

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Abstract

Background: Age estimation plays a key role in human identification process, and guiding police investigations. Tooth development is widely used in determining age and state of maturity. Dental age 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 on estimating chronological age 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 were belonging to boys and 80 girls children. Dental age of the subjects was determined through 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: 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 total, girls and boys study population respectively. The mean dental age assessed by Cameriere's method was significantly lower than 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 indicated that Cameriere's method is a powerful tool in age estimation. These results highlight the great accuracy and significance of developing teeth for more accurate estimation of age. According to the results of this research, it may be concluded that Cameriere's method [4] is suitable for dental age estimation in Libyan children.

1. Introduction

Age estimation plays a key role in human identification process, and guiding 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 critical role in pediatric dentistry, orthodontic treatment planning, and 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].

Over the last century, social problems and the discovery of X-rays encouraged the study of a number of methods for age evaluation in both adults and non-adults. Although skeletal maturation can play an important part in determining the age as orderly process, teeth and hand-wrist areas are the most common indicators of age in growing children.

Several studies have highlighted that mineralization is the main tool to determine the correspondence between biological age and chronological age. Since 1950, many researchers were induced to concentrate on mineralization due to the routine use of X-ray [3].

Many authors have developed scoring methods in Order to asses dental age using dental calcification stages of permanent teeth, Including Demirjian, Nolla, Goldstein, and Van der Linden and Cameriere [4,9,10,11]. In 1973, the most widely used dental maturity scaling system was first developed by Demirjian et al and

since then numerous studies were provided by many odontologists in the same way [3].

Demirjian and his colleagues had 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 [3].

Most of the results revealed the fact that the standards of dental maturation described by Demirjian et al. are not always suitable for these countries [3].

More recently, in 2006, Cameriere et al. [4] 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 [5].

One year after, the technique was tested in a large sample of children from various European states, providing a common formula useful for all these countries [2]. Recently, it has been reported that Cameriere's method is more accurate than other methods for estimating the age of children in age groups 6–13 years [6]. Marques Fernandes et al. [6] showed the great accuracy of this method in a Brazilian sample of 160 children aged between 5 and 15 years.

At present, the need to estimate the age of living individuals is a problem of increasing interest in our community, due to the progressively increasing numbers of persons without legal documentation of birth, who are suspected of having committed crimes and for whom it is necessary to assess actual age to establish importability.

In Libya, there are scare information about the age estimation in regards to Cameriere method except two studies. Those studies have only examined the third molars based on Cameriere role in determining if a subject is adult or not in Libyan population. There is no study had examined the chronological age for children by using Cameriere method.

1.1 Research Problem

The study endeavors to answer the following research questions: What is the accuracy of Cameriere's regression formula on estimating chronological age in sample of Libyan children?

To answer the key question, this study seeks to answer following sub-questions:

1. Is there any significant difference in chronologic age girls and dental age girls in sample of Libyan children?
2. Is there any significant difference in chronologic age boys and dental age boys in sample of Libyan children?
3. What is the relationship between the chronologic age and dental variables in sample of Libyan children?

4. What is the accuracy Cameriere's regression formula to predict chronologic age in Libyan of 6-13 years children population?

1.2 Significance of the Study

Generally, there has been a limited study that specifically focuses on regression formulas to predict chronologic age in Libyan children. Therefore, in this study, we have been conducted on Libyan children to assess the applicability of Cameriere's formula and to find out whether this formula turns out to be suitable for the Libyan population too.

The main reasons of the study include:

1. A few studies on this subject especially in Benghazi and generally in Libya.
2. The need to study Cameriere's formula and to find out whether this formula turns out to be suitable for the Libyan children population.
3. In light of the above facts, this study is necessary and will hopefully contribute significantly to the existing gap in the literature.

In line with this, the current study considering all of these age groups from 6-13 years for both girls and boys.

A final point on the significance of this research is its contribution to the literature in the field of the primary oral health care for children. Therefore, it will be more meaningful and significant if oral health status of children is evaluated considering its age groups.

1.3 Theoretical Frameworks

For the purpose of achieving the objectives of the study and answering questions, it is clear from the above discussion that previous studies have discussed several different frameworks of age estimation. The current study aims to study Cameriere's formula and to predict out whether this formula turns out to be suitable for the Libyan children population.

2. Literature Review

This literature review is structured as follows. The background section will cover the age estimation of dental age, Chronological age estimation methods, Age estimation using open apices (Cameriere method). This is followed by the supporting evidence section that will describe the impact of panoramic radiograph on age estimation. Historical background, the Principles of determination of dental age, types of panoramic radiographs will be discussed subsequently. The subsequent findings section will be grouped by the following headings: 1) Previous studies on the accuracy of age estimation between different methods, 2) Previous studies on validation of Cameriere method and 3) Previous studies on application of different formula through different countries.

2.1 Chronological age estimation methods

Teeth undergo various development stages in the first 25 years of a human's life and demonstrate secondary changes in the later years [7]. On the other hand, they are not highly influenced by nutritional and endocrine factors. Hence, legal dentistry has turned into a dynamic and active field of medicine during the past two decades [3]. Numerous techniques have been suggested to determine age according to dental characteristics. Demirjian's method is an extensively applied technique which utilizes radiographs and estimates dental age based on development stages of seven left mandibular permanent teeth [3].

Willem's method uses the same seven teeth and the eight development stages defined by Demirjian separately for boys and girls and calculates age by considering the set of indices for each tooth [1]. On the other hand, Cameriere's method determines chronological age based on the relationship between age and measurement of open apices in tooth roots [4]. Smith modified the technique developed by Moorrees et al [8] and Butti et al [9] used development stages for eight left mandibular teeth to estimate children's age [10]. Since few studies have evaluated various age determination techniques among Iranian children, the present study compared the accuracy of Demirjian's, Cameriere's, Smith's, and Willem's methods in estimating the age of the mentioned population.

2.2 Age estimation using open apices (Cameriere method)

Various studies assessed the relationship between the age and measurement of open apices in teeth [11]. The seven left permanent mandibular teeth were valued. The number of teeth with root development completed with apical ends completely closed was calculated (N_0). For the teeth with incomplete root development, that is, with open apices, the distance between inner sides of the open apex was measured (A). For the teeth with two roots, the sum of the distances between inner sides of two open apices was evaluated [11]. To nullify the magnification, the measurement of open apex or apices (if multirooted) was divided by the tooth length (L) for each tooth and these normalized measurements of seven teeth were used for age estimation. The dental maturity was calculated as the sum of normalized open apices (s) and the

numbers of teeth with root development complete (N_0). The values are substituted in the following regression formula for age estimation.

$$Age = 8.971 + 0.375\ g + 1.631\ x_5 + 0.674\ N_0 - 1.034\ s - 0.176\ s \times N_0$$

Where g is a variable equal to 1 for boys and 0 for girl [11].

2.3 Impact of panoramic radiograph on age estimation

Despite the use of time of tooth eruption in age determination, this index is widely affected by environmental factors including dental arch space, early extraction of primary teeth, tooth impaction, and tipping [7]. Therefore, several methods for evaluating dental age have been proposed a number of approaches to age determination. The methods comprise different numbers of permanent teeth and include various numbers of way such as evaluation of radiographic images [12], dental structure [13], Gustafson's method [14], and use tooth development stages as a more logical factor [14]. Among the many advanced imaging technologies and radiographic images utilized to estimate age. panoramic, periapical, cephalometric, and lateral oblique radiographs, panoramic radiographs are an accessible and inexpensive method to provide an outline of a person's dental system maturity [9].

2.4 Historical background

Determining the individual calendar age at the time of death involves the use of a variety of biochemical, morphological and histological techniques. According to the "Recommendations for Age and Sex Diagnostics of Skeletons"

[15], the determination of the individual calendar age includes the stages of dental development, the epiphysic saturation status, the status of ossification centers, the obliteration of the cranial suture, the condition of the pubic symphysis surface and the anatomical features of the femur head [16]. Rösing et al., also explore and attach importance to mineralization and tooth growth in adolescents by producing some useful standards in determining the calendar age of skeletons [19]. Other authors attribute importance to some more advanced techniques such as, for example, racemization of aspartic acid, number of layers of dental cement, and evaluation of histological features of the bones [17]. The use of dental status in forensic practice dates back more than 180 years ago when the growth of teeth was used in relation to child labor.

Rösing et al., research concludes that dental development has no significant relationship to maturity indicators, menarche, height growth or skeletal maturity [18]. These results predict that the mechanisms that regulate dental growth and development are independent on common growth mechanisms and are closely related to the age of the patient. In addition, tooth formation is affected much less by malnutrition, endocrinopathies, and other pathological conditions than any other tissue in the human body. This circumstance was discussed in the study of adolescents with severe abnormalities affecting sexual maturation and bone age but demonstrating a weak to a missing effect on dental development [19].

2.4.1 Principles of determination of dental age

The scientific literature provides a wealth of sources of information on a variety of methods, their technical implementation, and the underlying mechanisms [20]. Dental age can be determined by growth features such as mineralization, gingival clinging, quantum cementation, or narrowing of the pulp space. Degenerative changes such as tooth attrition or periodontal involution are also related to calendar age. In addition, a variety of other parameters - fluorescence intensity, dentin density, racemization of aspartic acid or dentinal sclerosis - help assess the age-related changes in dental tissue and can be used to determine human calendar age [20].

2.4.2 Previous studies on the accuracy of age estimation between different methods

A comparative study in India examined the difference between Cameriere and Demirjian methods [21]. Both methods were compared based on the difference between the chronological ages and dental ages. The data were collected from panoramic radiographs of 36 children aged between 7 and 12 years olds through dental practices. Chronological age was calculated by subtracting the date of births from the date on which the OPGs were taken. While Wilcoxon signed-rank test was used a comparison of the accuracy of Demirjian's and Cameriere's methods were evaluated by calculating the mean prediction error based. The findings indicated that Cameriere method resulted in a mean prediction error of 0.579 for girls and 0.483 for boys, however,

Demirjian's method resulted in a mean prediction error of 2.228 for girls and 2.046 for boys. Based on current investigation, as far as accuracy is concerned, Cameriere's European formula proved to be more accurate. Although, Demirjian's method is commonly employed for dental age estimation in pediatric dentistry, orthodontics, and forensic dentistry, Cameriere's method may serve as a more accurate and reliable method for dental age estimation.

One comparative study was conducted back in 2019 considered the difference of accuracy between Cameriere's method and Willem method [22]. The data were collected from 636 Turkish healthy children (319 male; 317 female) aged between 6 and 15 years used different images of panoramic radiographs. One important factor was calculated in the study; the chronological ages were calculated from children based on the date of panoramic radiographs. After measuring the chronological ages by using Cameriere's and Willem methods, the results showed that the mean chronological age (CA) of the children was 11.53 2.25 (min:6, max:14.99) years (boys: 11.29 2.34 years, girls: 11.77 2.15 years). Willems method overestimated the CA (p 0.001), in contrast, Cameriere method underestimated the CA (p 0.001) for both sexes. In different age groups the mean difference between the CA and DA calculated by Cameriere method (DA) ranged from 0.86 to 0.41 years for boys and from 1.00 to 0.21 years for girls, while the mean difference between the CA and DA calculated by Willems method ranged from 0.26 to 0.71 years for boys and from 0.19 to 0.76 years for girls. There seems to

be a Cameriere method performed slightly better. This method provided a better percentage of accuracy (84.6% and 77.3% for males and females, respectively) in the absolute difference values within 1 year compared to Willems method.

However, as Ozverena et al in 2019 indicated that Cameriere's method was more accurate than Willem method [22]. El-Bakary et al in 2010 explored the relationship between chronological ages and dental ages among Egyptian children and indicated different results [23]. Two hundred eighty-six orthopantomograms of 134 boys and 152 girls between five and 16 years of age were evaluated. The applicability of using Willems and Cameriere methods was the main target. In relation to real age, the estimated age by Willems method showed an average overestimation of age by 0.15 0.62 years for the total sample, 0.14 0.74 years for girls and 0.29 0.48 years for boys. While that by Cameriere method showed an average underestimation by 0.29 1.04 years for the total sample, 0.26 1.21 years for girls and 0.49 1.03 years for boys. The result showed that Willem method was slightly more accurate (98.62%) compared to Cameriere method (98.02%). Therefore, both methods can be recommended for practical application in clinical dentistry and forensic procedures on the Libyan population.

2.4.3 Previous studies on validation of Cameriere method

Cameriere et al. (2006) considered children residing in Italy, as an over-sample to individuals from 5 to 15 years of age as random, stratified samples,

through a cross-sectional investigation to provide a new method for calculating chronological age [4]. The relationship between age and measurement of the open apices in teeth was significant and negative correlation, while, chronological age was one of the main outcome variables. After the analysis, the authors found that Pearson's correlation coefficients between age and these variables showed that the correlations between age and the open apices in teeth were significant and negative. Furthermore, gender and the number of teeth with the apical end of the root canals completely closed (N_0) showed a significant correlation with chronological age. Statistical analysis indicated that these morphological variables explain 83.6% of the variations in estimated chronological age. The median of residual errors between the actual and estimated ages was −0.035 years [interquartile range (IQR) =1.18 years].

More recently, a total of 788 Orthopantamographs (495 boys and 293 girls) were analyzed in Saudi Arabia by using Cameriere's regression formula to predict chronologic age in Saudi Population, and if proven to be inaccurate, to develop a new algorithm specific for Saudi children [24]. The tooth measurement parameters were: number of teeth with closed apex (N_0), open apex width (a), crown length (l), A/L ratio for each tooth ($x_1$to x_7) and summation of all open apex width (s). The radiographic measurements were substituted in the formula:

$$Age = 8.971 + 0.375g + 1.631\, x_5 + 0.674\, N_0 - 1.034s - 0.176s \times N_0,$$

The mean dental age assessed by Cameriere's method was significantly lower than chronologic age in Saudi population and with both genders and total

study population ($p < 0.05$). While a stepwise linear regression analysis was used, the result showed that there was no statistically significant difference between predicted and actual chronologic age for 788 children using regression equation for Saudi population ($p=1$).

2.4.4 Previous studies on application of different formula through different countries

Back in 2007, an observational study was undertaken to provide a common formula to many European countries [(2)]. Orthopantomographs from 2,652 European Caucasian healthy children (1,382 boys, 1,270 girls) aged between 4 and 16 years were analyzed. All children were came from Croatia, Germany, Kosovo, Italy, Slovenia, Spain, and the UK. The orthopantomographs were taken as part of the routine treatment between 2000 and 2006. All morphological variables (predictors) ×5 (second premolar), s (sum of normalized open apices) N_0, and the first-order interaction between s and N_0 were the main outcome. While statistics analysis of morphological variables was provided, the results showed that all these variables contributed significantly to the fit, so that all were included in the regression model, yielding the following linear regression formula:

$$Age=8.387+ 0.282\ g-1.692\ x_5+0.835\ N_0-0.116\ s-0.139s \times N_0,$$

Where g is a variable, 1 for males and 0 for females. The equation explained 86.1% ($R^2=0.861$) of total deviance. The median of the residuals

(=observed age minus predicted age) was −0.114 years, with (2) interquartile range=1.22 years. In other word, the significant correlation between age and morphological variables imply that there is an importance to apply Cameriere method rather than previous methods.

Likewise, across sectional study was provided in Northern China to assess the accuracy of Cameriere's methods on dental age estimation in the northern Chinese population [25]. Data were collected from orthopantomographs of 785 healthy children (397 girls and 388 boys) aged between 5 and 15 years. All seven left permanent mandibular teeth were evaluated with Cameriere's method. Altogether a training set and a test set was extracted from the sample to provide a Chinese specific prediction formula in the first and to validate this novel provide formula in the second. After analysis, the difference between the estimated dental age and chronological age was the main indicator of the accuracy of the European formula and Chinese formula. The European formula verified on the collected Chinese children underestimated chronological age with a mean difference of around −0.23 year, while the Chinese formula underestimated the chronological age with a mean difference of −0.04 year. Significant differences in mean differences in years (DA−CA) and absolute difference (AD) between the Chinese-specific prediction formula and Cameriere's European formula were observed.

2.4.5 Digital panorama dental radiography

Digital panoramic imaging has become the latest technology of presenting radiographic details to the viewer for clinical diagnosis. Application of digital panoramic images is burgeoning due to its benefits such as fast communication of images, small storage space required and minimum contamination to the environment [26, 27]. Moreover, digital panoramic technique have also further advances in dental imaging technology due to its advantages of providing optimal diagnostic images with low radiation dose when compared to the conventional technique [28]. It has been reported that radiation dose in digital panoramic imaging was 5-14 µSv which is significantly lower than that of conventional panoramic imaging, which is 16-21 µSv [29]. However, further dose reduction could be achieved up to 76% if the lowest possible radiographic protocol setting was applied [30]. Nonetheless, there is always a tradeoff between the low-dose protocol setting and image quality. Therefore, the adjustment of image contrast and density in post-processing technique could improve the suboptimal quality image. This adjustment however, might not be sufficient to improve the sensitivity and specificity in the detection of dental pathologies and abnormalities [31].

2.4.6 Image quality assessment

In paediatric dentistry, panoramic radiography is considered an important diagnostic tool for monitoring the development of dentition and detecting caries, trauma, and oral anomalies [32]. Panoramic imaging does not require

placement of an intra-oral film; hence, better cooperation and tolerance is expected from children [33].

Modern advances in dental imaging have led to the development of various digital panoramic imaging techniques for minimizing the radiation dose and improving the quality of radiographs [34]. Compared to conventional radiographic techniques, digital panoramic images have a number of advantages, including reduced radiation exposure, faster acquisition and processing time, the need for less storage space, and minimal environmental contamination [35]. At the same time, the literature has suggested contradictory evidence related to image quality in conventional versus digitized radiographs [36].

In digital panoramic radiography, the reduced radiation dose compromises the quality of the image, thereby affecting its diagnostic accuracy [37]. For that reason, various techniques have been developed for enhancing the image quality without exposing the patient to additional radiation [38]. A digital radiograph consists of anatomical structures with varying textures and intensity; as a result, these processing methods tend to enhance a single specific anatomical feature, while obscuring the visibility of other structures [39].

Only a few recent studies have investigated whether image enhancement and processing techniques improved the overall image quality of complete panoramic radiographs, instead of specific anatomical structures [40-42].

In modern dentistry, regular conventional panoramic devices are being replaced by digital technology in order to obtain high-quality images, while minimizing patients' radiation exposure. At the same time, dose reduction directly affects image quality, which in turn can lead to the inaccurate identification of anatomical structures [31]. Other reasons for diminished quality are related to noise and patient positioning during image acquisition [43]. Image quality in paediatric patients with mixed dentition is of vital importance for diagnosis and treatment planning [31].

Post-processed digital panoramic radiographs allowed significantly better visualization of anatomical structures than standard non-processed digital images [38].

This finding is in accordance with other studies that used processing techniques to improve image quality [43-45]. In contrast, according to Sabarudin and Tiau [35], no significant mean quality and scoring difference was observed between pre- and post-processed images related to the visualization of anatomical structures.

2.4.7 Perception of anatomical structures

Digital radiography has been a common technique in medicine for many years, but digital systems for dental panoramic radiography have not been available until recently [46, 47]. Since the introduction of digital extra-oral imaging, scientific research on this topic has been rather limited [42, 48]. Studies using panoramic images have compared the quality of unfiltered digital images with

films, evaluated the effect of dose reduction on the detection of anatomical structures and/or dental pathologies or compared the performance of different panoramic receptors [27, 42, 48, 49].

It is well known that radiographic recognition of disease requires superior radiographic appearance of normal anatomy. For this purpose, the processing of digital images with the aid of various filters is recommended to produce a "conventional look" while overcoming the limitations of conventional film radiography [50]. However, so far, only a few studies have compared the effect of image filters that may enhance the quality of the panoramic image [27, 42, 44]. Although panoramic radiography is not the primary diagnostic yield for proximal caries diagnosis; a recent study focused on the evaluation of filters to maximize the diagnosis of proximal caries. The filters enhanced the overall quality of the image but visualization of important structures that may aid in the distinction of pathology from anatomy were not considered. For this purpose, Gijbels et al [42] tested the effect of different filters on the overall image quality using a charge-coupled device (CCD)-based panoramic system and reported a significant effect of contrast enhancement. An evaluation of various image filters on visibility of anatomical structures, as well as on overall image quality, using a storage phosphor plate (SPP)-based panoramic system was done in only one study. However, the authors used individually designed algorithms, rather than standard and commonly used filters, for image processing, which makes their results impractical [44].

3. Aim of the study

The aim of this research was to assess the accuracy of the Cameriere method on estimating chronological age of a Libyan sample of 6 years old up to 13 years old children through analysis of panoramic radiographs on teeth, considering the relationship between age and measurements of open apices teeth. The objective of the study was:

- To verify Cameriere's regression formula to predict chronologic age in Libyan from 6 to13 years old children.
- If first objective is proven to be inaccurate, develop a new algorithm specific for Libyan children.

4. Materials and Methods

The present cross-sectional study used prospective evaluation of orthopantomographs of Libyan children to correlate chronologic age with dental age as estimated by Cameriere's method in Libyan population. In this study the details of the methodology used for this study covering the search methods, study design, data collection, and measurement, inclusion, exclusion criteria sampling, and identification of variable and lastly defines which type of model was used for statistical analysis.

4.1 Search Methods

Articles where searched using various combinations of the following key words: “age estimation”, “chronological age”, “dental age”, “panoramic radiograph”, “x-rays”, “private clinics”, “public clinics”, “age estimation methods”, “Cameriere's method”. Citation of these relevant articles published between 1989 and 2020 from Google Scholar, Research Gate, and Pub Med.

4.2 Study design

The present cross-sectional study used prospective evaluation of orthopantomographs of children who attended private dental clinics from different Libyan cities. All patients digital radiographs were obtained by a digital orthopantomograph unit (Planmeca® ProOne X-ray unit, Planmeca Oy, Asentajankatu 6, FIN-00880, Helsinki, Finland) (Fig. 1) . All the digital X-ray images were viewed and calibrated using computer with Planmeca romexis

imaging software revision 2.3.0. provided with the Planmeca digital X-ray unit (Fig. 2).

Figure (1) The digital orthopantomograph unit PLANMECA Pro0ne

Figure (2): Romexis viewer supplied with the device for editing images

The orthopantomographs of 156 healthy Libyan children (76 boys, 80 girls) aged between 6-13 year-old from different Libyan cities were analyzed. Only radiographs that satisfied the criteria and were included in the study.

All collected orthopantomographs were analyzed to correlate chronologic age with dental age as estimated by Cameriere's method in Libyan population. Here g is a variable equal to 1 for boys and 0 for girls, N_0 is the number of teeth with closed apex, x_1 is the ratio of apex width and tooth length of lower left central incisor and so on till x_7 for second permanent molar, s is summation of all teeth ratio (x_1, x_2 …. x_7).

4.3 Inclusion criteria

The inclusion criteria were all Libyan patients who are between 6 and 13 years old during time of obtaining panoramic radiograph. Children who were free from any medical conditions were included in the study.

4.4 Exclusion criteria

All patients from other nationality than Libyan, patients above 13years old or below 6 years of age. Incomplete medical or dental history, documented tooth extraction or agenesis especially in left lower quadrant, distorted radiographs. Moreover, Radiographs that were unclear, or with evidence of periapical lesions, fractured teeth and internal tooth resorption. Any evidence of systemic diseases, and congenital anomalies were excluded. Premature birth and hypodontia of permanent teeth except third molars or hyperdontia, or having history of orthodontic treatment were excluded as well. Permission to access patient's data was obtained while personal details were de-identified.

4.5 Data collection and radiograph measurement

The personal details that were obtained from case records were gender, date of birth and date of taken the radiograph. The date of birth mentioned in the case record was recorded from parents. The difference time period between dates as mentioned on the radiograph and date of birth was considered as chronologic age for each patient. The chronologic age at radiographic examination was recorded as completed years and months. Additional days, if

more than fifteen was rounded and considered as complete month. All patient radiographs were obtained by a digital orthopantomograph (Planmeca® ProOne X-ray unit, Planmeca Oy, Asentajankatu 6, FIN-00880, Helsinki, Finland). All the digital X-ray images were viewed and calibrated using computer with Planmeca romexis imaging software revision 2.3.0. provided with the Planmeca digital X-ray unit. The measurements on a panoramic radiograph were confined to mandibular teeth since measurements on maxillary teeth are difficult due to superimposed roots or other skeletal structures. The growth pattern is usually bilaterally symmetrical so only one quadrant (lower left) was used for all measurements. A sample radiograph shows all measurements for references Fig. (3,4,5). A) Number of teeth with closed apex (N_0): Teeth with complete root formation and closed apex. B) Open Apex width (a): distance between inner aspects of open apex measured in millimeters. C) Crown Length (l): distance from highest cuspal tip/incisal edge to root apex measured in millimeters. D) A/L ratio for each tooth ($x_1$to x_7): it is the ratio of open apex width and crown length. This ratio is taken to normalize possible errors in magnification and angulation. E) Summation of all apices (s): was obtained by adding the measurements of all teeth with open apices.

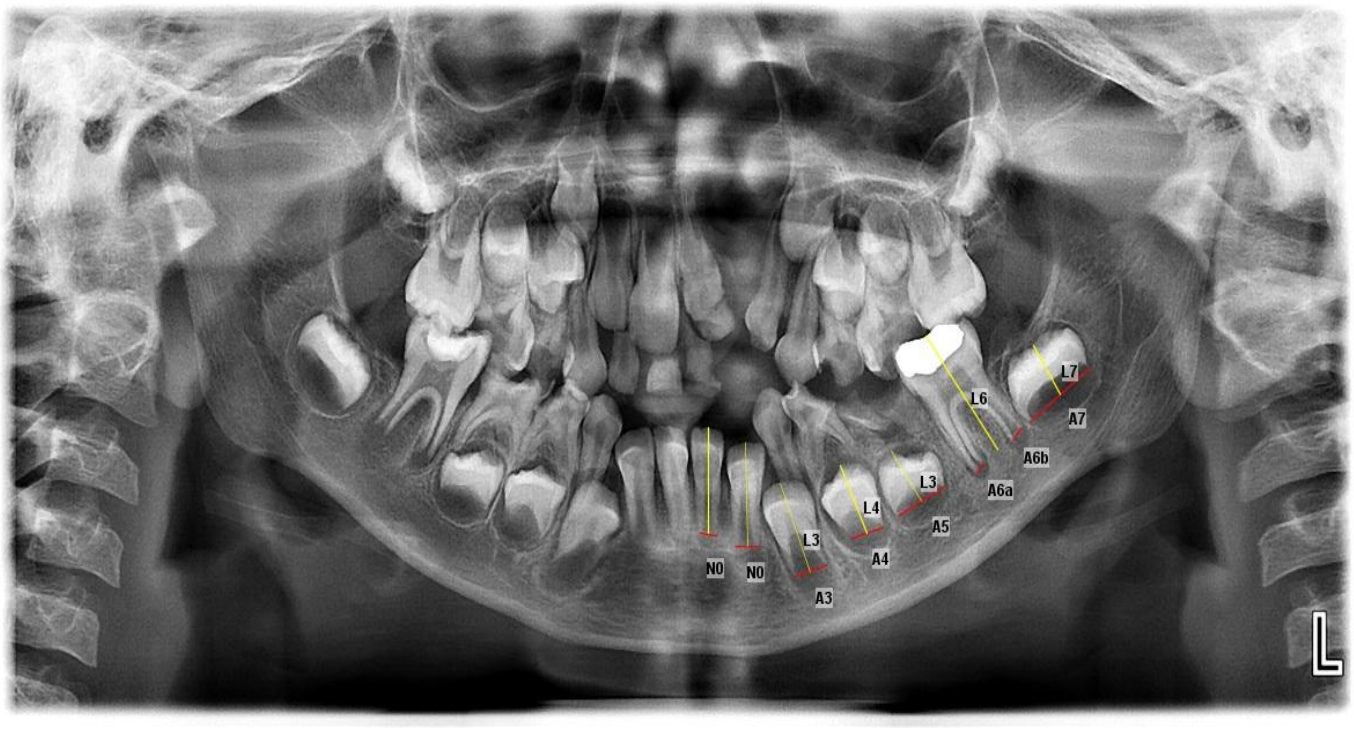

Figure (3): Image of demonstrate the measurements for Cameriere formula.

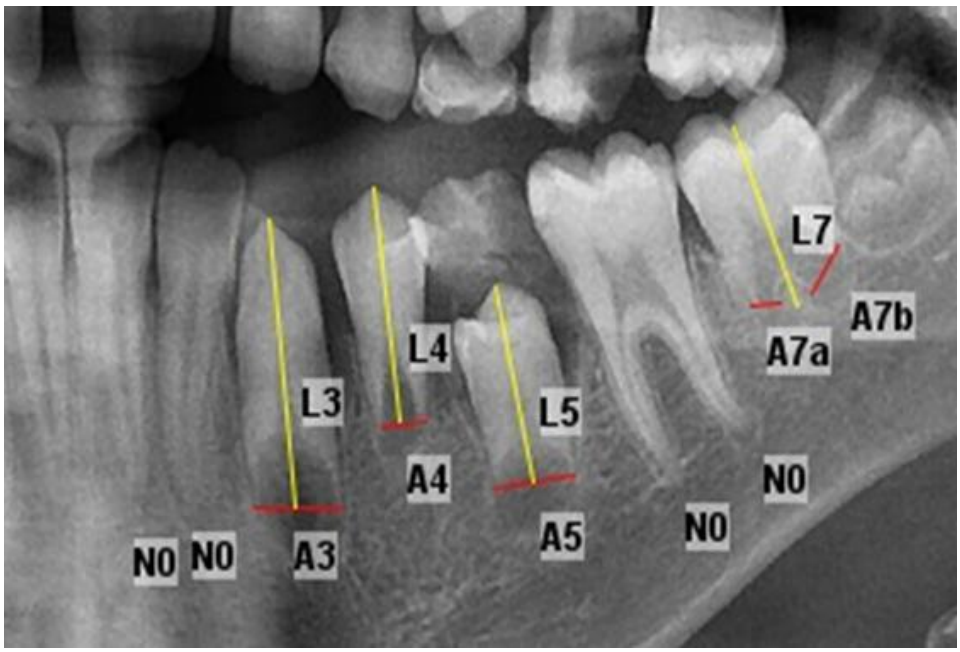

Figure (4). Measurement of apices of the tooth A_1 to A_5 represents the distance between the inner sides of apices of single rooted tooth. In teeth with two roots the sum of the distances (A_6a + A_6b) between the inner sides of the two open apices is measured. L_1 to L_7 represents the measurements of length of the tooth.

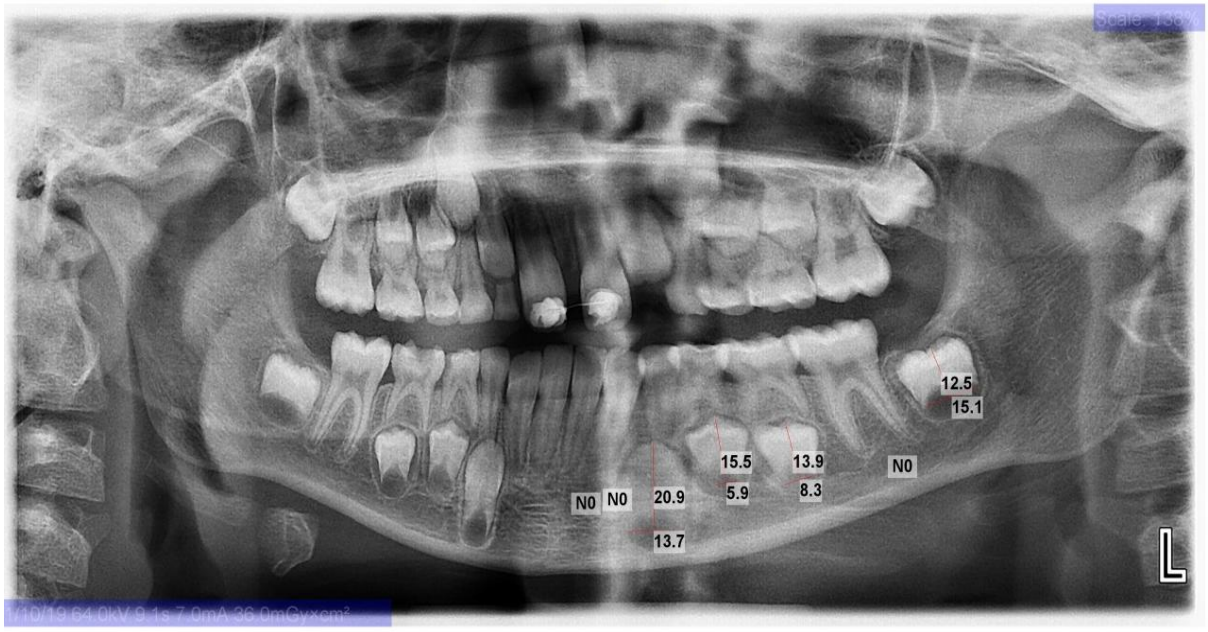

Figure (5): An example of measurements for Cameriere formula on a sample of panoramic radiographs.

4.6 Statistical analysis

Data obtained from any quantitative study needs to be analyzed and interpreted for it to be useful in meeting research objectives and answering the research questions. In the case of quantitative approach have pointed out three different motives for the use of statistical analysis, namely: firstly, to reduce large quantities of data to a manageable and understandable form, secondly, to aid in the study of population and samples, and thirdly, to assist researcher and to enable the deduction of reliable inferences.

All radiographic measurements were carried out by two independent observers. Twenty radiographs were randomly selected and were r-examined after an interval of two week to test intra and inter-observer reliability. Karl Pearson's correlation coefficient for open apices measurements between examiner 1 and 2 was 0.96 and within each examiner independently was 0.99

respectively ($p < 0.05$). The collected data was entered into an MS-Excel sheet and further analyzed using SPSS (25.0) software. The study variables were correlated with chronologic age by Pearson's correlation analysis. The comparison of chronologic age with dental age by Cameriere method was done using paired student's t-test. Multiple regression analysis was performed with all tooth variables to identify statistically significance in the mixed model. Later, step wise regression analysis was performed for a better model fit with more precise equation for predicting chronologic age. The level of significance was set at 5%. Lastly, in order to evaluate inter-observer error, a new random sample of 50 individuals was selected and re-examined after a period of 3 weeks by the second examiner. This sample was also measured by another observer who had not worked with this method before. The subsample was composed of 25 males and 25 females, and the same procedure for all measurements was followed [(4)]. After data collection, all measurements were entered into a computer database. The inter-observer reliability of the sum of normalized open apices (s) was studied by means of the concordance correlation coefficient, and k statistics (Cohen's Kappa coefficient) were used to measure the inter-observer reliability of the number of the seven left permanent mandibular teeth with root development complete (*N0*). Kappa values are scaled between 0 and 1, 0 indicating the amount of agreement expected if scores were assigned randomly to specimens, and 1 for perfect agreement.

4.6.1 Regression Analysis

Regression analysis is used to identify the relationship between a dependent variable and one or more independent variable(s). More specifically, regression analysis helps us to understand how the typical value of the dependent variable changes when any one of the independent variables is varied while the other independent variables are held fixed.

In the current study, multiple and stepwise regression models were built, and models were examined to evaluate the included independent variables on a single dependent variable. Before the beginning to conduct a multiple regression, it is worthwhile to review some key terms and present the following statistical criteria:

1. Evaluate the multiple correlation coefficient (R), the R-Square (R^2) and the adjusted R square (adj. R^2)**.** The multiple correlation coefficient (R) is considered to be one measure of the quality of the prediction of the dependent variable. While R^2 (also called the coefficient of determination) is the amount of variation in the dependent variable that can be explained by the independent variables. R^2 ranges from 0 to +1 and, the larger the R^2, the more the dependent variable is associated with the independent variable that is being used in the model. Adj. R^2 is a modified measure of R^2 that takes into account the number of independent variables included in the regression model and the sample size.

2. The F-ratio is the result of comparing the amount of explained variance to unexplained variance. This ratio is important to assess the statistical significance (p value) of the overall regression model and to decide whether the overall regression model is a good fit for the data. The larger the F-ratio, the more goodness fit of the overall regression model. A good model should have a high F-ratio value, more than one at least.
3. The unstandardized coefficient b and the standardized regression coefficient beta. The value of *b* represents the measure that indicates how much the dependent variable change with a unit change in an independent variable when all other independent variables are held constant. It refers to the strength of the relationship between an independent variable and the dependent variable. The coefficient beta represents the impact of the size and the direction of the independence on the dependent variable. It presents the degree of change in the outcome variable for every each unit change in the predictor variable. Beta coefficients range from -1 to +1. The greater the absolute value of the beta coefficient, the stronger impact of the independent variables on dependent variable.
4. The t-value and corresponding *p*-value refer can be thought of as a measure to identify which independent variables have statically significant coefficients and to determine the relative influence that independent variable is having on dependent variable. The t-test assesses whether the beta coefficient is significantly differences from zero. The *p* values for the

independent variable are considered significant when they are less than 0.05. Otherwise, they are not considered significant. In this research, the traditional level of significance ($\alpha = 0.05$) was chosen.

An extra step for moderate multiple analysis is to compare the adjusted R^2 of the original relationship with the adjusted R^2 change with the stepwise. If the F-change is significant ($p < 0.05$), then there is another step for choosing the regression.

5. Results

5.1 Data handling and analysis

The results and findings of the data survey, using a descriptive statistical technique, which refers to transformation from raw data to a form an organized and easy to interpret for descriptive information. The following subsections presented the analysis of the statistical results of the survey data and Cameriere's regression formula to predict chronologic age in Libyan from 6 to13 year's old children population.

5.2 The study subjects

General distribution regarding the gender, age groups for girls and boys of the survey respondents is presented in the following table (4.1): the majority of participating in the survey (58.8%) and (60.5%) from age 8-11 years for girls and boys respectively, the minority of participants from age 6-7 years (18.8%) for girls and (17.1%) for boys in this survey. Therefore, it was noted that the age groups for both girls and boys were symmetrical group sizes, so there is no gap between the two.

Table 4.1:
Description of the samples according to the gender and age groups.

Variables	Classification	Numbers of respondents	Percentage
Gender	Girls	80	51.3
	Boys	76	48.7
	Total	**156**	**100.0%**
Contained of Table 4.1			
Age groups for girls	6-7 years	15	18.8
	8-9 years	27	33.8
	10-11 years	20	25.0
	12-13 years	18	22.5
	Total	**80**	**100.0%**
Age groups for boys	6-7 years	13	17.1
	8-9 years	27	35.5
	10-11 years	19	25.0
	12-13 years	17	22.4
	Total	**76**	**100.0%**

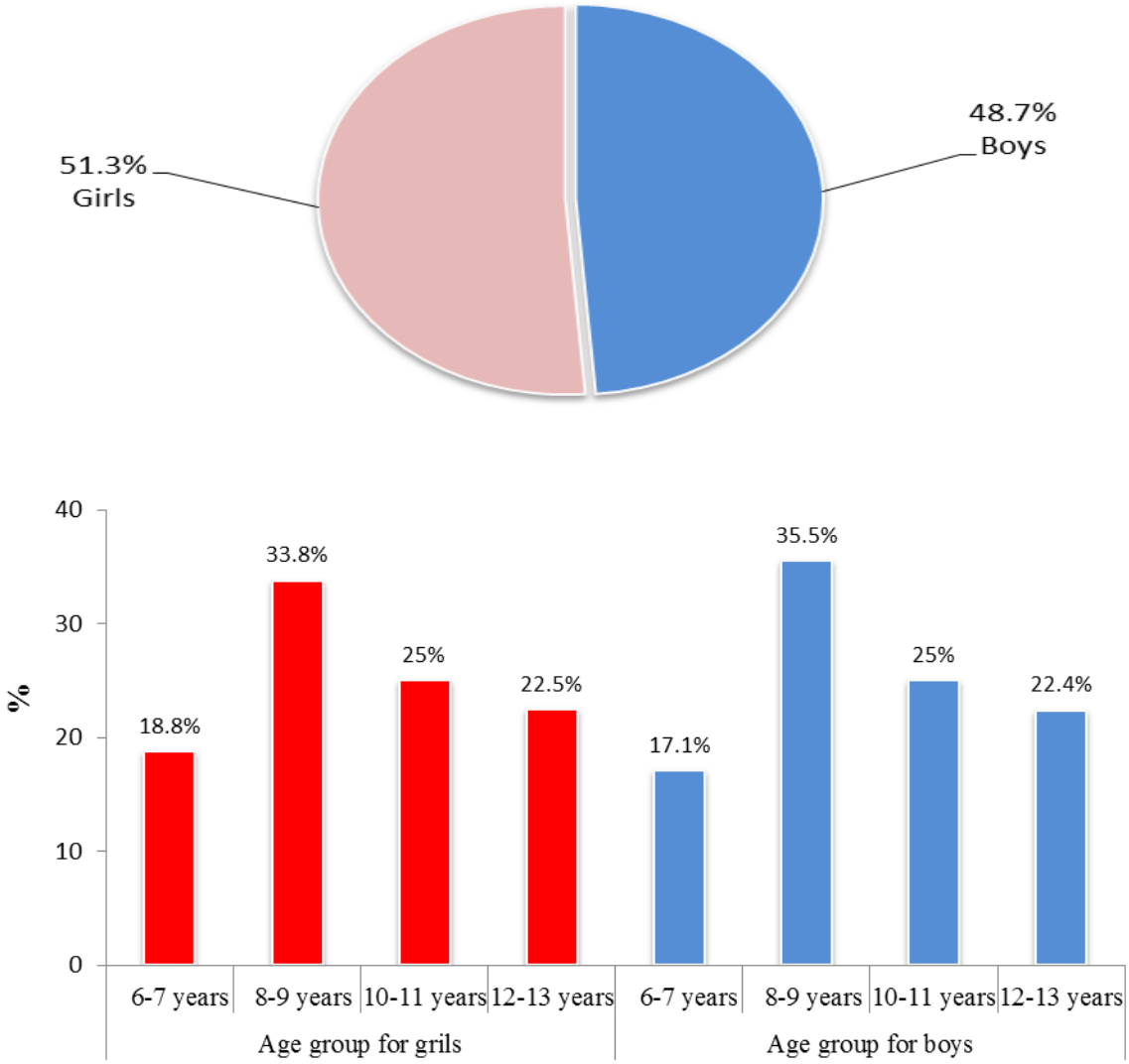

Figure (6): Represents gender & age groups for girls and boys.

Table 4.1 and Figure (6) state that 80 out of 156 (51.3%) of participants in the survey were girls and 76 out of 156 (48.7%) were boys, which were approximately equal to the sample size of participating in the survey.

5.3 Multiple Regression Using Cameriere method

Multiple regression model were built, and model were examined to find the predict of included independent variables on a single dependent variable. According to Cameriere et al., the following linear regression formula was used:

$$Age = 8.971 + 0.375g + 1.631\, x_5 + 0.674\, N_0 - 1.034s - 0.176s \times N_0$$

Where g is a variable equal to 1 for boys and 0 for girls, N_0 is the number of teeth with closed apex, x_1 is the ratio of apex width and tooth length of lower left central incisor and so on till x_7 for second permanent molar, s is summation of all teeth ratio ($x_1, x_2, \ldots, x_7$).

All the morphological variables, $x_1, x_2, \ldots, x_7$, s, and N_0, and subjects gender were entered in an SPSS file, to be used as predictive variables for age estimation in subsequent statistical analysis.

Chronological age, calculated by subtracting the date of birth from the date of the radiograph، was also recorded. Intra-observer and inter-observer reproducibility of measurement was assessed by the concordance correlation coefficient.

Correlation coefficients between age and predictive variables were also calculated to obtain an estimate of age as a function of the morphological variables and subjects' gender and nationality, a multiple linear regression model with first-order interactions was developed by selecting those variables that contributed significantly to age estimations using the stepwise selection

method. Analysis of covariance was then applied to study possible interactions between significant morphological variables and gender.

Statistical analysis was performed with SPSS 25 statistical programs (SPSS 25 for Windows). The significance threshold was set at 5%.

5.3.1 Resulting of Comparison Analysis

The correlations (Pearson) of the variables of the regression models have also been presented to facilitate ascertaining the association between the variables.

A total of 156 radiographs were selected for the study of which 76 were belonging to boys and 80 girls children.

Towards answering the first and second questions of the study, 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 total, girls and boys study population respectively (see Table 4.2 for more details).

The mean dental age assessed by Cameriere's method was significantly lower than chronologic age in the Libyan population with boys and the total study population ($p < 0.05$).

Table 4.2 illustrates the paired t-test of chronologic age for total (CA-Total) and dental age for total (DA-Total), the test results show that there is significantly difference ($p < 0.01$) in total. From this we can observe that there is no significant difference in CA-Girls and DA-Girls ($p > 0.05$), whereas there

is significantly difference in CA-Boys and DA- Boys ($p < 0.05$). The test results also indicate that there may have been some differences in responses within the sample groups of girls.

Table 4.2:
Comparison of Chronologic and Dental Age by Cameriere formula.

Age	N	Mean	SD	Mean Diff.	SD Diff.	Paired *t*	P-value	*r*
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.

5.3.2 Resulting of Correlation Analysis

Data obtained from any research needs to be analyzed and interpreted for it to be useful in meeting research objectives and answering the research questions.

Although the data have been analyzed after conducting and answering the research third question of the study showed that a statistically significant correlation between all radiographic parameters (x_1, x_2,..., x_7) with chronologic age ($p<0.01$), whereas, no significant correlation was found between gender and chronologic age ($p>0.05$) (see Table 4.3). This reflects that the correlation results are significant for all radiographic parameters with chronologic age of both samples, It is interesting to note that there is very weak negative

correlation of gender with chronologic age. Therefore, they do not suffer from a lack of association chronologic age with gender, this might perhaps be happening because in Libyan of chronologic age 6-13 years children.

Table 4.3:
Correlation between chronological age with radiographic measurements.

Variables	Correlation between chronological age with		
	r-value	*t*-value	*p*-value
Gender	-0.084	-1.046	0.295
N_0	0.900	25.623	0.000**
x_1	-0.373	-4.989	0.000**
x_2	-0.525	-7.655	0.000**
x_3	-0.909	-27.066	0.000**
x_4	-0.836	-18.906	0.000**
x_5	-0.871	-22.001	0.000**
x_6	-0.660	-10.902	0.000**
x_7	-0.929	-31.152	0.000**

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

5.3.3 Resulting of Multiple Regression Analysis

Regression analysis is used to identify the relationship between a dependent variable and one or more independent variable(s). More specifically, regression analysis helps us to predict the value of the dependent variable from the independent. In this study multiple linear regression analysis with chronological age as dependent variable against nine other parameters as independent variables (*No, gender*, x_1, x_2,…, x_7), in the model revealed a statistically significant relationship ($R^2=0.996$, $F_{(9,155)}=1893$, $p < 0.01$), except x_1, x_5 and x_6 were not statistically significant ($p>0.05$), (see Table 4.4). Therefore, the regression model is:

$$Age = 9.370 + 0.328(gender) + 0.560N_0 + 0.402x_1 + 3.609x_2 - 2.004x_3 - 1.237x_4 - 0.309x_5 - 0.309x_6 - 1.560x_7$$

Table 4.4:
Multiple regression analysis of radiographic measurements on chronological age.

Independent variables	Unstandardized coefficients	SE of Reg. coefficient	Standardized Coefficients	*t*-value	*p*-value
Intercept	9.370	0.099	-	94.666	0.000**
Gender	0.328	0.035	0.076	9.326	0.000**
N_0	0.560	0.020	0.436	28.384	0.000**
x_1	0.402	0.524	0.011	0.767	0.444
x_2	3.609	0.409	0.121	8.816	0.000**
x_3	-2.004	0.192	-0.226	-10.455	0.000**
x_4	-1.237	0.118	-0.141	-10.516	0.000**
x_5	0.309	0.176	0.043	1.757	0.081
x_6	-0.309	0.244	-0.016	-1.265	0.208
x_7	-1.560	0.090	-0.405	-17.416	0.000**
R= .996, R^2= .992, $p(F_{(9,155)}=1893.491) < 0.01$, Std. Error of Estimate= .2051					

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

Therefore, in this study, all variables were played essential role in determining the dental age except x_1, x_5 and x_6 were not statistically significant (p>0.05). This an agreement with a European study [51]. In contrast, there are a number of studies which have found opposite results, for example, Saudi study found that there was no significant of most variables [52].

5.3.4 Resulting of Stepwise Regression Analysis

Using stepwise regression analysis, six out of nine parameters were significantly associated with chronologic age (R^2*=0.996, F(6,155)= 2792.023, p<0.01*), (see Table 4.4). The following linear regression equation was obtained:

$$Age=9.357+0.335(gender)+0.565N_0+3.880x_2-1.281x_3-1.848x_4-1.474x_7$$

Table 4.5: ***Stepwise multiple regression analysis of radiographic measurements on chronological age.***

Independent variables	Unstandardized coefficients	SE of Reg. coefficient	Standardized Coefficients	*t*-value	*p*-value
Intercept	9.357	0.093	-	100.803	0.000**
Gender	0.335	0.035	0.078	9.504	0.000**
N_0	0.565	0.018	0.440	31.735	0.000**
x_2	3.880	0.301	0.130	12.879	0.000**
x_3	-1.281	0.116	-0.147	-11.067	0.000**
x_4	-1.878	0.159	-0.212	-11.805	0.000**
x_7	-1.474	0.071	-0.383	-20.735	0.000**
R= .996, R^2= .991, $p(F_{(6,155)}=2792.023) < 0.01$, Std. Error of Estimate= .2068					

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

Chronological age estimation was modeled as a function of *gender*, radiographic measurements as independent variables, and to optimize the model, a stepwise regression analysis was applied. The results demonstrated in above table shows that the *gender* and the variables N_0, x_2, x_3, x_4 and x_7 of the first order interaction contributed significantly to the fit. Thus, only the variables that contributed significantly were included in the regression model, yielding the following linear regression formula for Libyan population age 6-13 years children.

The observed versus predicted plot shows symmetrical distribution and tendency to cluster towards the middle of the plot (Fig. 4.2). Plot of the residuals against the fitted values by using the regression model did not show any obvious pattern with few outliers (Fig. 4.3). Both plots support our regression model to estimate chronologic age. There was no statistically

significant difference between predicted and actual chronologic age for 166 children using regression equation for Libyan population.

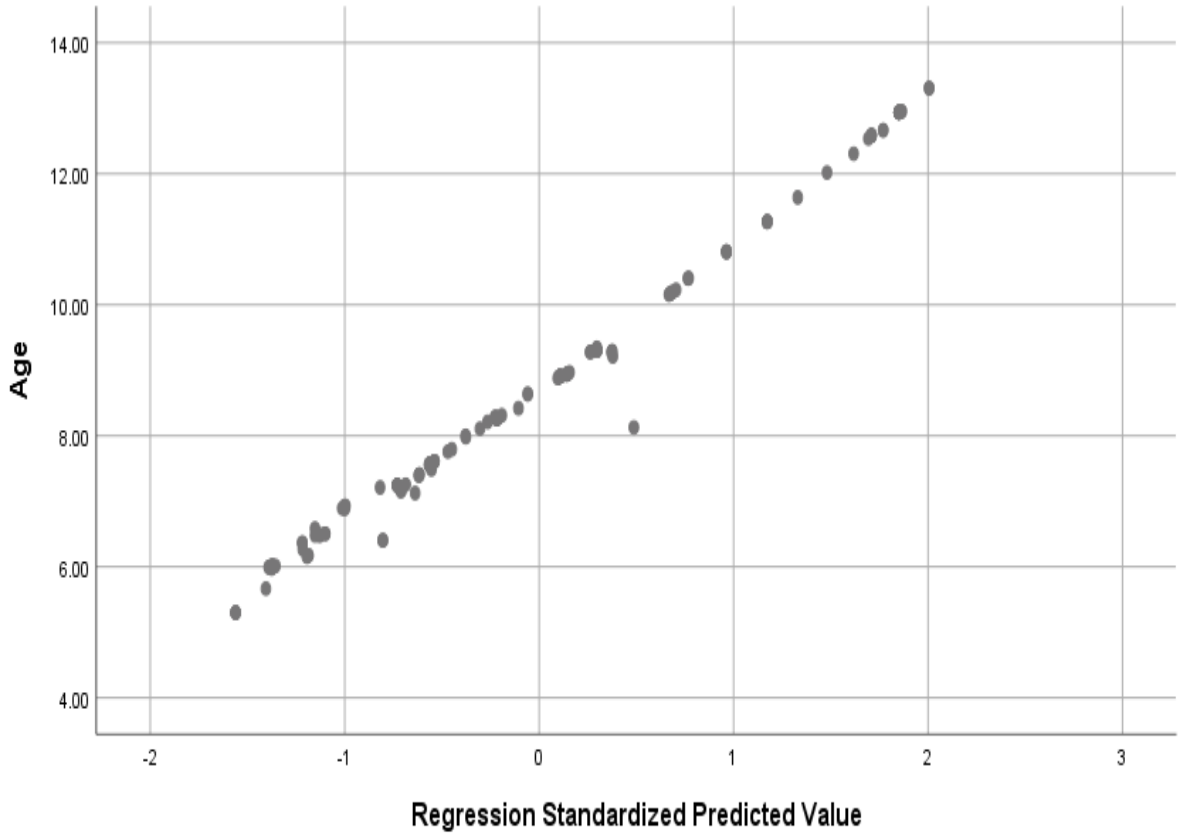

Figure (7): Scatterplot of dependent variable (age) against predicted value.

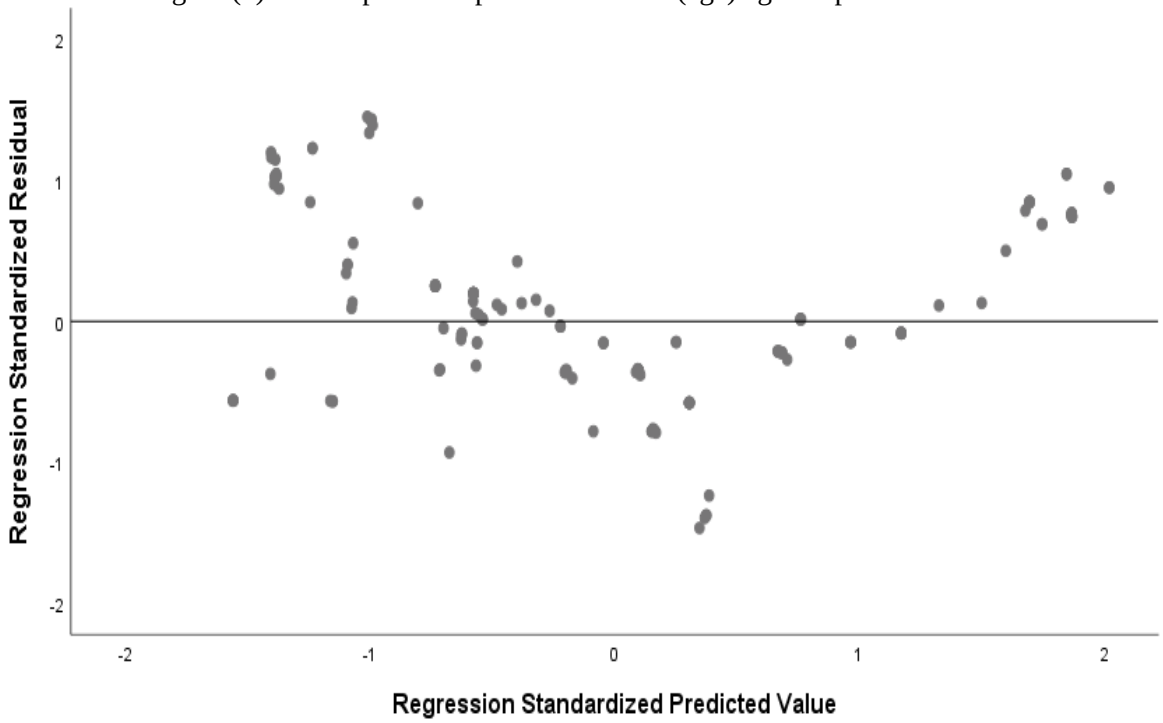

Figure (8): Regression residual against predicted value.

6. 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 [51].

In forensic contexts, with respect to the dead and the relative requirement for biological profiles, assigning an age to a living child of unknown identity may be necessary when the child is the victim of a crime, suspected of a crime when penal codes differentiate law and punishment for children of different ages, or when the child is a refugee of uncertain age [52-56].

Several morphological methods have been developed to estimate the same, but accuracy of these methods are defined by their ability to arrive at an age as close to the chronological age, within acceptable error limits [57, 58]. Among those, dental estimation is widely accepted as the most accurate and reliable scientific method, as it relates closely with chronological age than any other maturity indicators and is the least variable method compared to others [53].

Basically, there are two concepts in dental age assessment. 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, i.e. premature deciduous tooth loss, ankyloses, etc.; while the latter is a progressive phenomenon and easily definable by the staging of calcification and therefore is the most reliable dental indicator [57].

In the present study, a Libyan sample of 156 individuals were examined in order to ascertain whether Cameriere's formula can predict age accurately or whether population-specific equations can improve age assessment.

Malaysian population on being a multi-cultural country, with mixed ethnicity, consisting of Malays (50.7%), Chinese (23.1%), Indians (6.9%), and the remaining constituting minor ethnic groups and foreigners [59]. With every possible difference in environmental factors, dietary habits, growth rates and ethnicity, their influence on dental variables must be considered in formulating a linear regression model in the Malaysian population. However, analysis of covariance for ethnicity showed no significant influence on age estimation in our study population. Hence, ethnicity was not included as a factor in the model equation [60].

A moderate positive correlation was found between chronologic age and dental age as estimated by Cameriere's formula with *r* values 0.882, 0.975 and 0.758 for total, girls and boys study population respectively in the studied Libyan sample.

In our study, all variables were played essential role in determining the dental age except x_1, x_5 and x_6 were not statistically significant (p>0.05). This an agreement with a European study [51] but in contrast to Saudi study where all variable were at lower level of significantly.

Multiple linear regression analysis with chronological age as dependent variable against nine other parameters as independent variables (*N0, gender,* x_1 *to* x_7) in the model revealed a statistically significant relationship ($R^2=0.996$, $F_{(9,155)}=1893$, $p < 0.01$), except x_1, x_5 and x_6 was not statistically significant.

Furthermore, stepwise multiple linear regression showed six out of nine parameters significantly associated with chronologic age ($R^2=0.996$, $F(6,155)= 2792.023$, $p<0.01$).

This study and the results obtained are in agreement with other studies and insist on reframing the original Cameriere's formula to suit the population of the specific nation, and to focus on the influential variables that could possibly alter the development of tooth tissues to create a linear regression model according to the children of other nations.

Nonetheless, gender displayed significant influence on age estimation. All normalized open apices showed a significant correlation with age, hence, they entered the model equation (Equation 1) through the sum of normalized open apices (s) and number (N0) of teeth with complete root development. The

result allowed the use of a single equation to estimate the dental age of the Malaysian children population, independent of their ethnic origin [60].

In the Indian formula proposed for dental age estimation, the region of the country was considered to have significant correlation with age estimation [61]. In particular, no ethnicity or second molar variables were significant. Our results showed that not all the variables used for the European and Indian models were significant predictors of age estimation in the Malaysian sample [36, 61].

Results indicate that Cameriere's formula, yielding correct values for a European sample, can also be applied to a Mexican one. Mexico City, due to the great influence of people of European origin, including Spanish and non-Spanish immigrant groups (French, British, Irish, Italian, German and Dutch), is ethnically different. International organizations usually report that 11–25% of the city's population is represented by the descendants of the Spanish colonial population.

Other immigrants also arrived during the Second Mexican Empire (mainly French) and mostly from Italy, the United Kingdom, Ireland and Germany during the late 19th and early 20th centuries. White Americans, Croats, Greeks, Germans, Poles, Romanians, Russians and Ashkenazi Jews, together with many Spanish refugees fleeing the Spanish Civil War (1936–1939), also immigrated, seeking asylum or a better economic situation [62]. This probably

explains the high correlation between estimated age by Cameriere's method and chronological age in the studied Mexican sample [63].

Rai et al [64] tested Cameriere's European formula in a sample of 480 orthopantomographs (OPGs) of India children. It yielded a mean overestimation of 0.05 years for boys and 0.04 years for girls. This led the above authors to propose a specific formula for Indians. In a country as large as India, several tangible factors, such as climate, nutrition, socioeconomic levels and urbanization may all influence children's maturation rates.

The mean dental age assessed by Cameriere's method was significantly lower than chronologic age in Libyan population with boys and total study population ($p < 0.05$).

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. In fact, as Cunha et al. noted [53], the best method is sometimes the one which 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. 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. The mean prediction error (Mean differences) (ME) (standard deviation) (SD) was 0.63 years for girls and 0.52 years for boys [65].

Cameriere et al [65] also compared the ME for three methods, those of Willems et al [65], Cameriere et al [51] and Demirjian et al [66]. Cameriere's method provided 0.48 years for girls and 0.50 years for boys, which is close to the above results with the European formula in Mexican children. Using Cameriere's method, Galic´ et al [67] found ME 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. DA was overestimated with MEs of 0.58 and 0.65 for age groups in the range 5–6 and 6–7 years. 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 for 13–14 and 14–15 years [63].

Our results match those of many previous studies examining the applicability of Cameriere's method on various subjects from Europe and children from India and Egypt [64, 68].

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 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. In an Indian sample of 480 children between 3 and 15 years, Cameriere's method yielded a mean overestimation of 0.05 years for boys and 0.04 years for girls [64].

The origin of this trend may be found in variations both between and within studied populations, in observer variations and in the methods employed. Precision is mainly related to factors influenced by chance, i.e., random errors [69]. Frequently, as well as slight noticeable methodological errors, biological variation should also be considered [70].

It has been reported that growth of a child may be influenced by several factors including genetic, nutritional, racial, hormonal, climatic, social, etc., 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 [71]. These methods also differed

in their accuracy when different populations were considered. Hence this study focuses on improvement of the method developed by Cameriere et al. to suit the Libyan children.

This highlights the fact that Cameriere's technique is very accurate and represents a useful method 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 which shows the least variability with age [72].

7. Conclusion

This thesis had elaborately presented the whole journey of the study including: the background of the study, an environment analysis, the literature review, methodological issues, the findings and finally the implications of the study.

As regards the first aim of this study, these results highlighted the great accuracy and significance of developing teeth for more accurate estimation of age. According to the results of this research, it may be concluded that Cameriere's method is suitable for dental age estimation in Libyan children.

Regarding the meaningfulness and usefulness of these results in the legal sphere, this accuracy indicates that Cameriere's method is a powerful tool for forensic anthropologists and odontologists in age estimation in asylum and criminal proceedings. Nowadays, this formula can be used in all cases of crimes involving Libyan children, especially illegal immigration, juvenile prostitution or trafficking in children for sexual purposes. This set of problems has emerged as significant both within and outside the Libya, mainly from developing countries such as Libya.

8. Recommendation

In this thesis some general recommendations have been made, which may serve to advance the work of the pediatric dentistry in Libya and enhance their role to achieve the requisite effectiveness of age estimation.

It is important for both the researcher and the research users to be aware of the relevant limitations as they seek to develop and interpret the study results or clarify their meaning. For instance, the children might have missing teeth or any developmental anomalies, which they cannot measure the radiographic variables. Furthermore, it is possible that the x-ray may have lacked in clarity, which might have caused to measure the radiographic variables. Another limitation of the research The Cameriere method of evaluating dental age on open apices is accurate enough for clinical practice, at least in the 6–13 age-interval. Therefore, It is not be used outside this age range.

Further studies are to be conducted to evaluate the applicability of this formula on a larger sample size and to compare the reliability of this model with other methods of age estimation.

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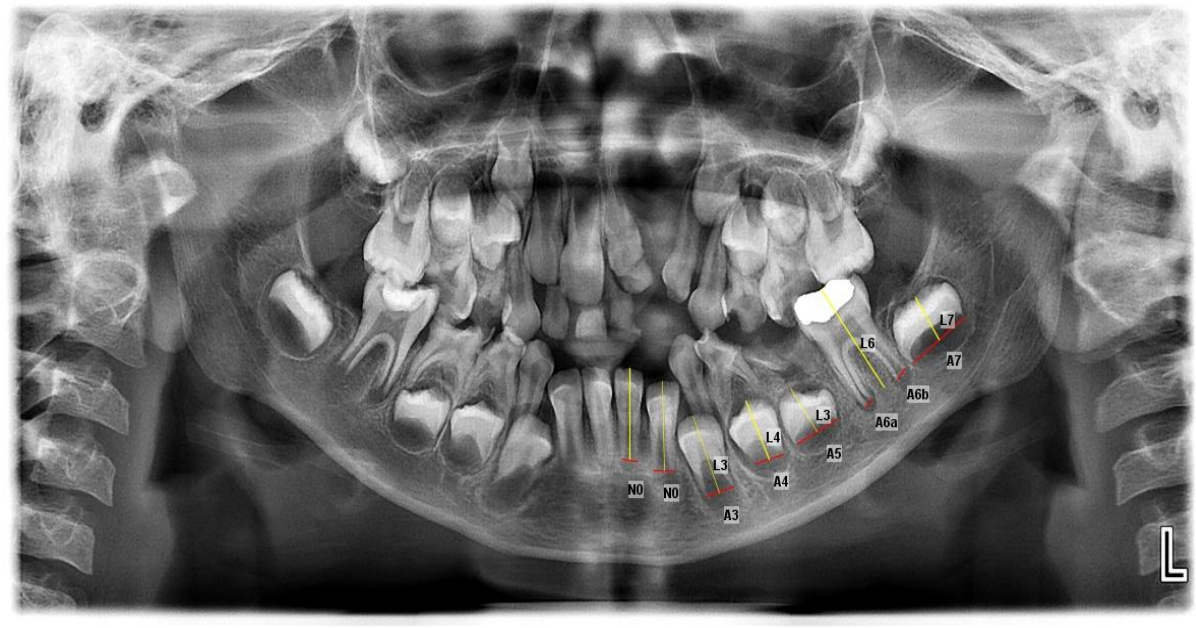
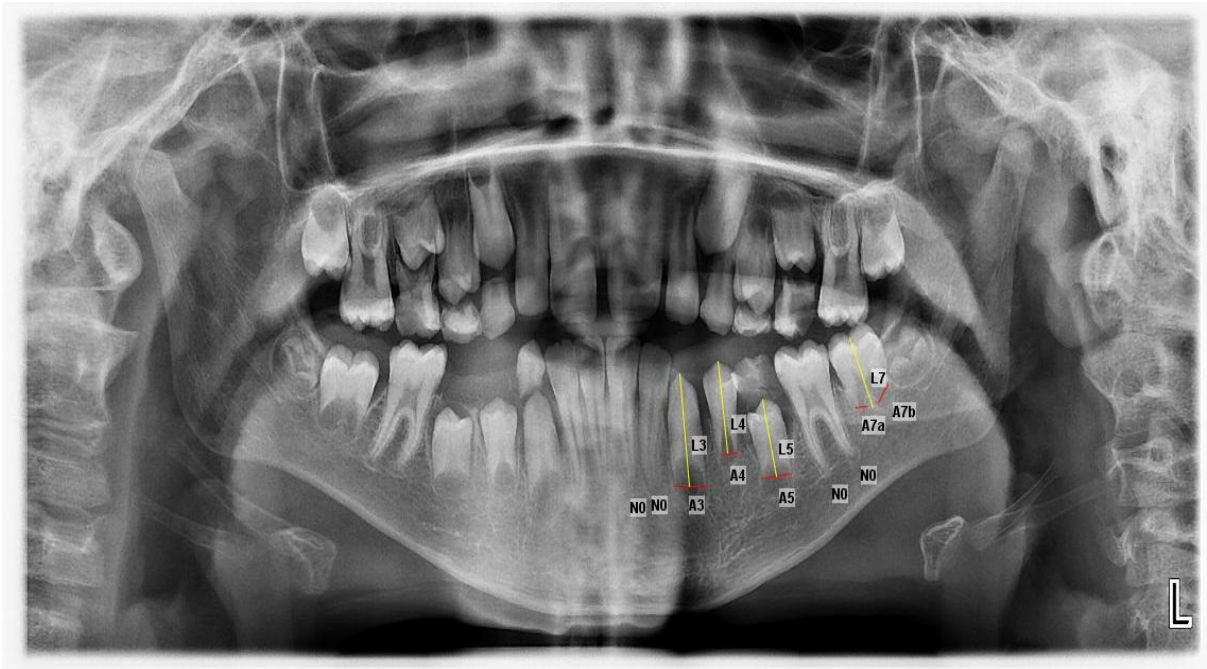
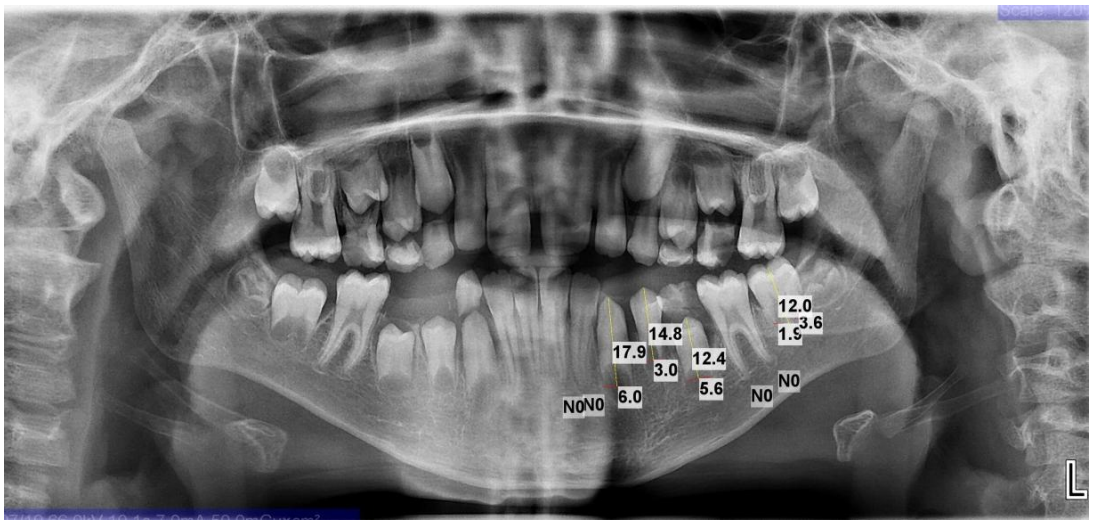
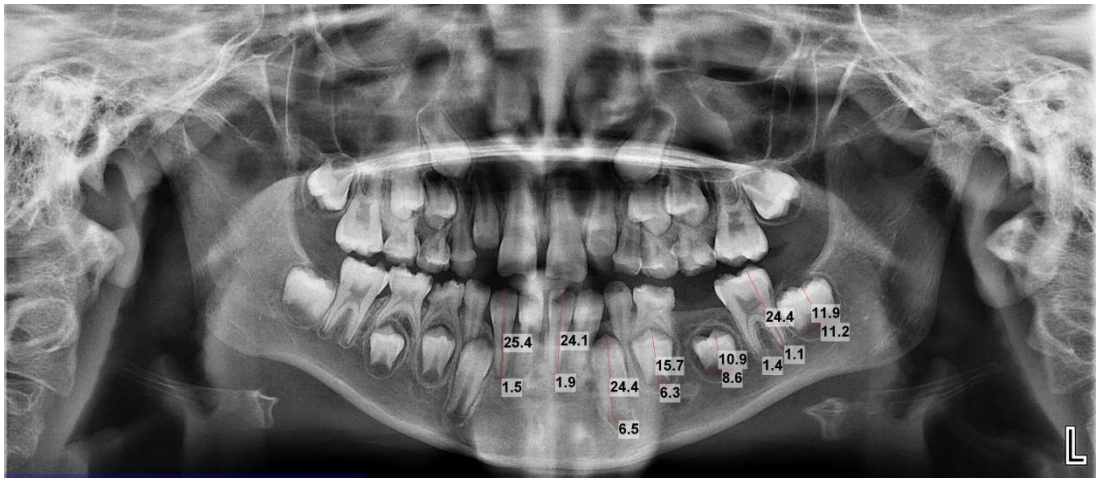
Appendix I: Standard of Radiographic Measurements

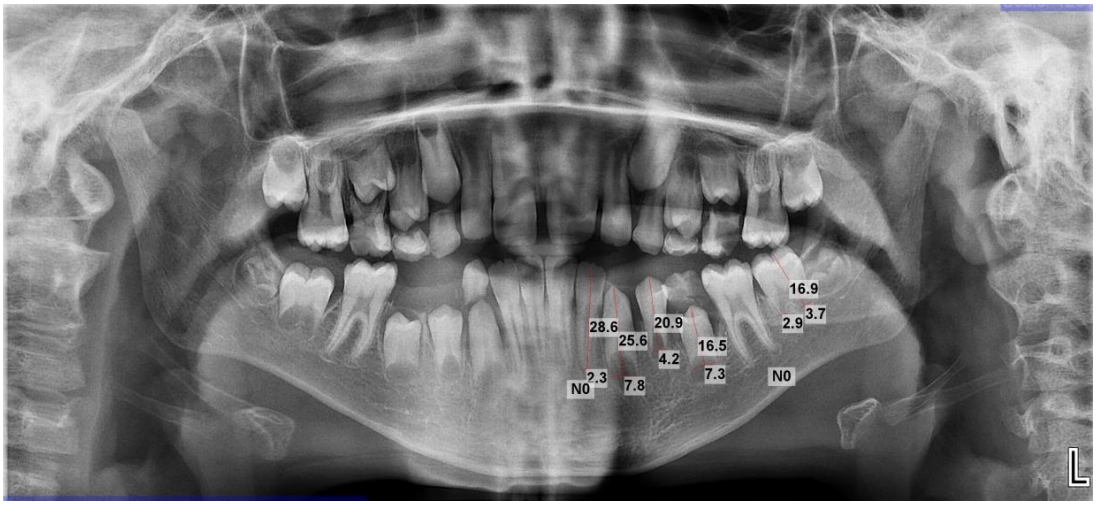


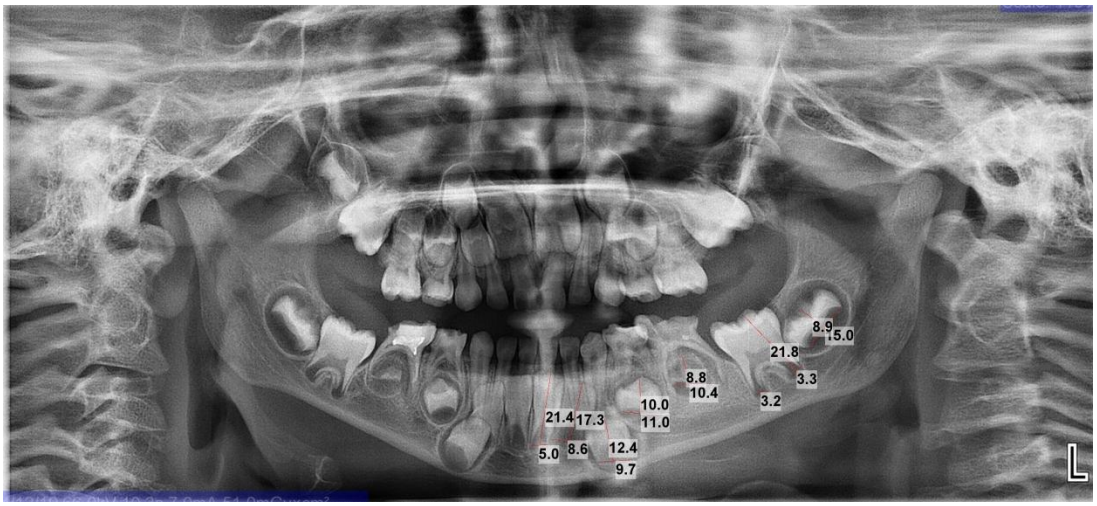


Appendix II: Samples of Radiographic Measurements





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15.0
21.8
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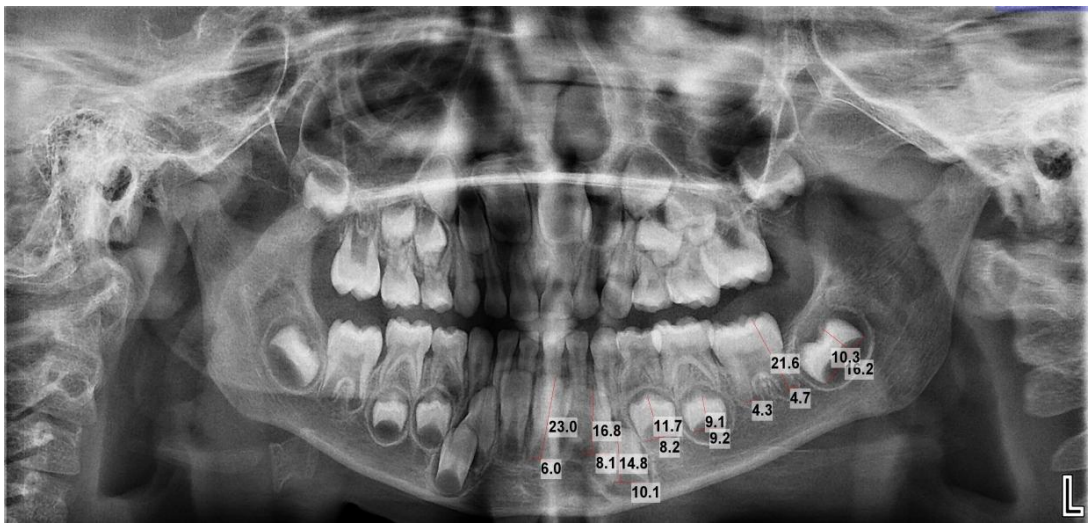
21.6
10.3
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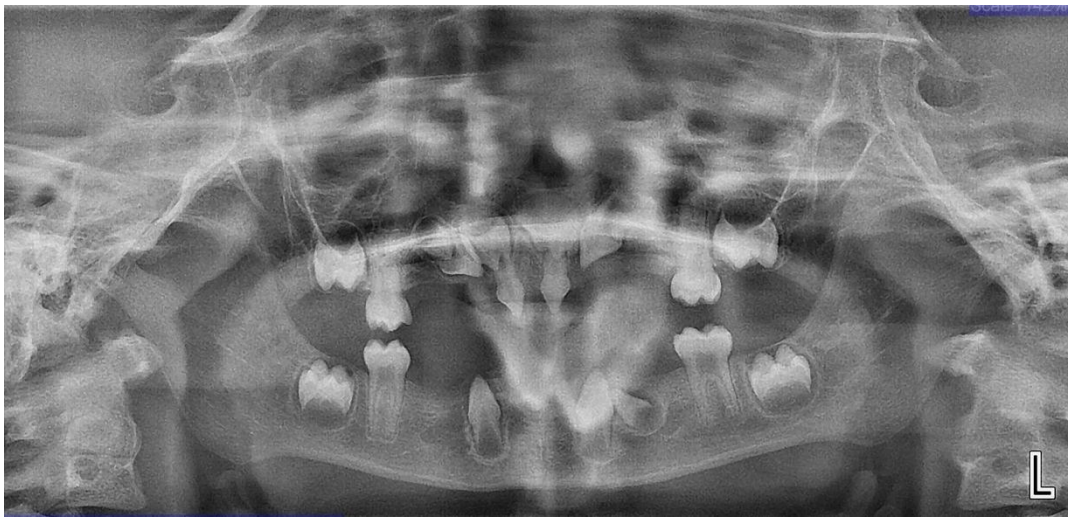
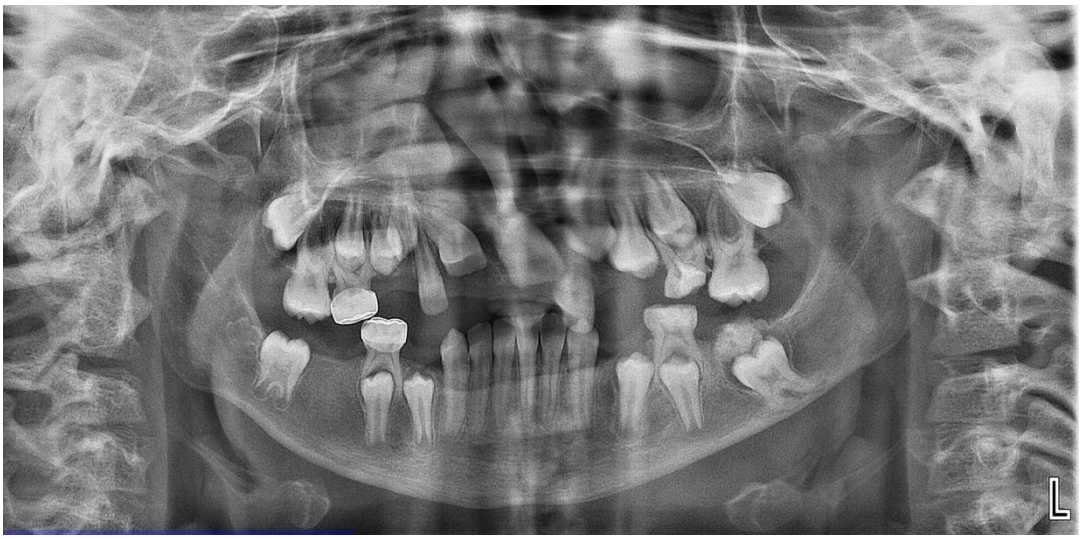
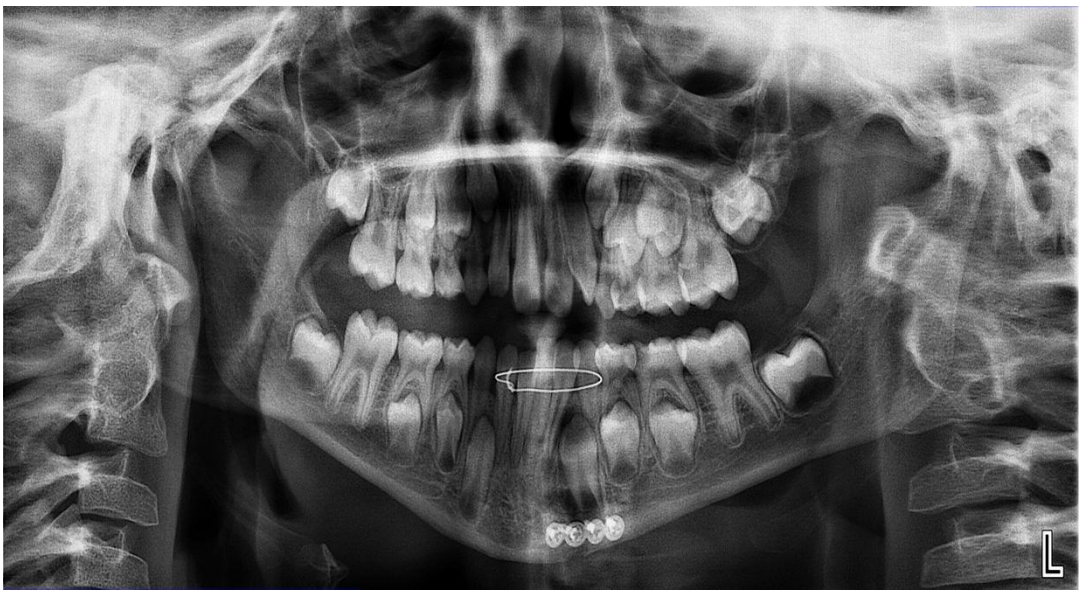
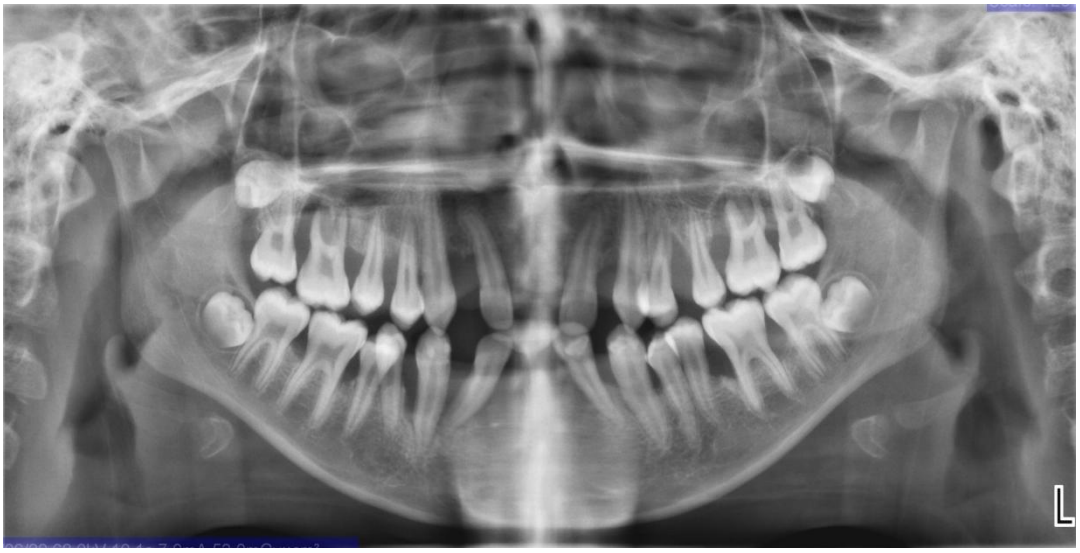
Appendix III: Samples of Excluded Radiographs









تقدير العمر عند الأطفال الليبيين على أساس التصوير الشعاعي البانورامي للأسنان

إعداد

ايمن سالم نجم

المشرف

د. فوزية مفتاح علي الزاوي

الملخص العربي

الخلفية: يلعب تقدير العمر دورًا رئيسيًا في عملية تحديد هوية الإنسان وتوجيه تحقيقات الشرطة. يستخدم نمو الأسنان على نطاق واسع في تحديد العمر وحالة النضج. يعتبر عمر الأسنان ذا أهمية كبيرة في الطب الشرعي وطب أسنان الأطفال وكذلك في تخطيط علاج تقويم الأسنان.

الهدف: تهدف هذه الدراسة هو تقييم دقة طريقة Cameriere في تقدير العمر الزمني لعينة ليبية من 6 سنوات حتى 13 سنة من الأطفال من خلال تحليل الصور الشعاعية البانورامية على الأسنان، مع الأخذ في الاعتبار العلاقة بين العمر وقياسات الأسنان المفتوحة القمة الجذرية.

المواد والطرق: تم اختيار 156 صورة بانوراما شعاعية للدراسة منها 76 صورة للأولاد و 80 صورة للبنات. تم تحديد فئة العمر السنية للعينات من خلال طريقة Cameriere. تم تقييم الفروق والارتباطات بين الأعمار الزمنية والأعمار الأسنانية من خلال اختبارات المقترنة وتحليل ارتباط بيرسون ، على التوالي. تم استخدام تحليل الانحدار المتعدد للتنبؤ بالعمر الزمني في الليبيين الذين تتراوح أعمارهم بين 6–13 سنة من الأطفال.

النتائج: الحصول على ارتباط إيجابي عالي بين العمر الزمني وعمر الأسنان (كما تم تقييمه بواسطة صيغة Cameriere) بقيم ارتباطية 0.882 و 0.975 و 0.758 لإجمالي مجتمع الدراسة، البنات والأولاد على التوالي. كان متوسط عمر الأسنان الذي تم تقييمه بواسطة طريقة Cameriere أقل من العمر الزمني في السكان الليبيين مع الذكور وإجمالي مجتمع الدراسة (p <0.05). ارتبطت ستة من أصل تسعة متغيرات بشكل كبير بالعمر الزمني (R = 0.996، 6) F، 2792.023 = (155، p <0.01).

الخلاصة: أشارت النتائج التي توصلنا إليها إلى أن طريقة Cameriere هي أداة قوية في تقدير العمر. وعليه فإن هذه النتائج تسلط الضوء على الدقة الكبيرة والأهمية لنمو الأسنان لتقدير أكثر دقة للعمر. وفقًا لنتائج هذا البحث ، يمكن الاستنتاج أن طريقة Cameriere مناسبة لتقدير عمر الأسنان لدى الأطفال الليبيين.

تقدير العمر عند الأطفال الليبيين على أساس التصوير الشعاعي البانورامي للأسنان

إعداد

ايمن سالم نجم

المشرف

د. فوزية مفتاح علي الزاوي

قدمت هذه الرسالة استكمالاً لمتطلبات الحصول على درجة الماجستير

في طب أسنان الأطفال

كلية طب وجراحة الفم والاسنان

جامعة بنغازي

سبتمبر 2021