

## Age Estimation in Selected Kenyan Children Using Radiographic Analysis of Four Permanent Teeth

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### Abstract

**Background-** Age estimation is particularly important in situations where the documentations required for proof of a person's age are missing. It can also be significant in juvenile courts, identification of mass disaster victims, missing and found persons, also pediatric as well as orthodontic treatment planning. Several methods have been applied to estimate age of children. Most of these involve radiographic analysis developmental and morphological changes tissues. There's no approved method in Kenya that can be applied to the Kenyan population. There is a need to evaluate the performance of the existing documented age estimation methods so as to find one that is applicable.

**Objective-** To assess the applicability of the Demirjian four-tooth method in age estimation in selected Kenyan children.

**Study variables-** Socio-demographic data; gender and chronological age, independent variables; tooth type, stages and scoring, and dependent variables; dental age.

**Study design-** This was a descriptive cross-sectional study.

**Study population-** Orthopantomograms obtained from clinical records of children who had visited the University of Nairobi dental hospital.

**Study area-** The study was done at the university of Nairobi dental hospital.

**Data collection-** Data was obtained from existing clinical records and radiographs.

**Data analysis and presentation-** Data was coded, entered in Microsoft excel, cleaned and analyzed using statistical packages for social sciences. It was then presented in form of tables and figures.

**Results-** A sample of 160 radiographs of children aged 6.00-12.99 years were included in this study. 79(49.4%) of these belonged to females while 81(50.6%) belonged to males. The mean chronological age for all was 9.52 years. The mean chronological age for the males was 9.54 years and for the females it was 9.51 years. The overall mean dental age was 10.06 years. Mean dental age for the males was 9.96 years while for the females it was 10.15 years. The overall mean age difference was 0.53 years which indicated an overestimation by about 6 months of the overall age by the Demirjian four-tooth method. The method overestimated the age by about 5 months for male children and by about 8 months for female children.

**Conclusions-** The Demirjian four-tooth method of determining dental age can be used to reasonably estimate the chronological age of children in the Kenyan population.

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### I. Introduction And Literature Review

#### INTRODUCTION

Age estimation involves the determination of a person's age especially for individuals with no or non-valid age documentation. The estimation of age is very important in various fields such as forensic medicine in the identification of corpses, pediatric medicine and dentistry for treatment planning mainly children presenting with endocrinopathies or hereditary conditions, monitoring of growth, orthodontics treatment planning, as a legal requirement specially in civil cases such as juvenile criminal cases, people seeking asylum, immigration in

addition to citizenship especially if unaccompanied minors are involved and old age pension procedures, paleontology and archeology where studying of fossils and determining age is key(1)(2).

Several age estimation methods have been described. Majority of these methods are dependent on the biological and physiological maturation of different body tissue systems. Examples include; skeletal age which involves studying the ossification periods of different bones and joint formation, morphological age such as in biometric study of the face, secondary sex character age and dental age based on analysis of the developmental patterns of teeth. The latter is considered more definitive than the rest as developing dentition is less affected by variations in endocrine factors and nutritional factors(1). Dentition is particularly important in forensic age approximation of the unidentified as it is one of the body tissues that do not entirely get destroyed in disaster situations. Age estimation using dentition has been to be gender sensitive hence this should be put into consideration(2). Population variations should also be considered because most age estimations using dentition are produced from population specific data(2)(3).

The two most common criteria for the analysis of dental age are clinical tooth eruption and tooth mineralization(1). Several drawbacks have been associated with tooth eruption making it an inaccurate form of age estimation(1). Firstly, clinical tooth eruption is only but one part of the continuous process of tooth eruption, thus it is not indicative of dental maturation. Secondly, eruption is also influenced by local factors such as ankylosis, untimely shedding of deciduous teeth, crowding and impaction of permanent teeth. Thirdly, tooth eruption is only reliable up to the age of thirty months when deciduous dentition is complete and again after the age of six when the emergence of the first permanent tooth occurs(1). Tooth mineralization on the other hand is least affected by both intrinsic and extrinsic factors that affect eruption hence a more accurate indicator of dental maturity(1).

A number of methods to be used in the assessment of dental age have been proposed. Majority of these rely on the radiographic analysis of the level of calcification of developing teeth. One most commonly used method is the Demirjian standards of dental development(2). This method is based on eight stages of tooth mineralization. Demirjian et al in 1976 developed four systems of analysis in this method. These include; the original seven teeth technique(1), the revised seven teeth technique, the four-tooth technique and the alternative four-tooth technique(4). All these techniques involve the radiographic analysis of developing permanent teeth of the mandibular jaw on the left quadrant. A stage is then qualified for each tooth analyzed and a score is given. The sum of the scores per individual directly correlates with the dental maturity. Dental age is then estimated using conversion tables or percentile curves.

The aim of this research was to radiographically assess the dental age using the four-tooth technique/system and determine its applicability in a sample of Kenyan children by comparing the dental age with the known chronological age. The results from this study can be used to establish a basis for further research to define a definitive method for dental age analysis for the Kenyan population.

## **II. Literature Review**

### **The human dentition**

Dentition in human beings comprises of the deciduous dentition which is composed of 20 primary teeth; four incisors, two canines and four molars in each jaw(5). The deciduous dentition exfoliates and is replaced by the permanent dentition as a human being develops and matures into adulthood(3). Permanent dentition usually consists of 32 teeth; four incisors, two canines, four premolars and six molars on each jaw(5).

### **Anatomy of the human teeth**

To recognize the formation and mineralization of teeth, the basics of the anatomy must be well understood. The portion of the tooth that is exposed within the oral cavity constitutes the crown. The crown consists of specialized mineralized tissues including enamel which covers dentine which forms the bulk of the crown as well as the root and the pulp which constitutes the vascular and nervous supply to the tooth(5). The part of the tooth covered by the gingiva and embedded within the alveolar process is the root. The root is made up of the dentine covered by cementum, a thin layer of bone like tissue and the pulp canals which contain both the vascular and nervous supply of the tooth(5). The point where the crown and the root join is referred to as the neck of the tooth or the cervical line and it is demarcated by the cemento-enamel junction. The pulp constitutes the soft tissue of the tooth(6). The tooth is anchored in the alveolar bone in a socket by the periodontal ligament which makes up the periodontium together with the bone and the cementum(7).

Analysis of the level of mineralization of the hard tissues of the teeth is a key indicator of the degree of physiological maturity of a growing child(1).

### **Development of the human dentition**

Tooth development occurs in stages namely; bud, cap and bell stages. Each stage of development involves cellular changes(8). These changes include cellular migration and proliferation. Cellular differentiation

also occurs to form the specialized cell types involved in the formation of dental tissues. These include the ameloblast which form the enamel, odontoblast which form the dentine, cementoblast which form the cementum, fibroblasts and osteoblasts which are involved in the formation of the periodontium(9). Tooth mineralization occurs as development continues. This can be identified on a radiograph as mineralization progresses from the beginning of cusp calcification to root apex closure(9). Age estimation through radiographic analysis of the level of calcification of the developing teeth is hence possible(1).

#### **Demirjian method of age estimation**

Many methods of estimating age using dentition have been described. The Demirjian method is however the most widely used method because of its simplicity(10). The method is based on a study carried out by Demirjian et al in 1973 on a large French Canadian population in which a developmental chart, tooth maturity scores and age tables were developed(1). This method was based on analysis of radiographs of seven left side mandibular teeth of the lower jaw. Eight stages of calcification for each tooth were identified and each assigned a score and the sum of these scores would be the indicator dental maturity(4).



**Figure1.**An orthopantomogram (3)

The seven-tooth system had some limitations such as; it was hard to find sufficient numbers of children where all the seven teeth were present. Furthermore, it was hard to analyze all the seven teeth without errors, fewer teeth were more practical(4). For this reason, a new method was introduced in the study by Demirjian and Goldstein in 1976. In this, a revised seven teeth system and two new four-tooth systems were described.

The four-tooth system involves four left side teeth of mandible namely; the first premolar, the second premolar, the first molar and the second molar(4). The teeth with their level of calcification are radiographically analyzed. Orthopantomograms are used for this analysis. The eight stages are identified for each tooth and assigned a score. All scores are summed up for each child and the estimated age is determined by taking the total score and finding its location on a dental maturity percentile curve at the 50<sup>th</sup> percentile(4). Teeth on the maxillary jaw were not applicable because of the challenge in analyzing the maxilla on a radiograph due tooth overlap(4). Teeth on the lower jaw were easier to analyze. The mandibular jaw was shown to be symmetrical hence Demirjian et al 1973 chose to work with teeth on the left side(4). The four-tooth method has a wide range of application as it utilizes fewer teeth(3). Studies on various populations have shown the Demirjian method is only applicable to French-Canadian population on which it was originally done(11). To solve this problem, some populations have created their own percentile curves and scores based on the original maturity scores by Demirjian(12). Flood S.J et al in 2011 did a study to compare the four systems of the Demirjian method. This study showed the four-tooth method to have the lowest overall mean deviation hence the highest level of accuracy compared to the other systems. Compared to the other techniques by Demirjian, the four tooth method overestimated age by a mean difference of 0.04 years which was the least value compared to the seven tooth method which overestimated age by 0.51 years which was the highest value(13). Most studies in age estimation using the Demirjian methods mostly apply large sample sizes of up to 1000 and more(14). This is attributed to the fact that small samples are thought to have a limited variation in age ranges(14). However, the study done by Flood S. J et al in 2011 to evaluate the utility of small sample sizes when assessing dental maturity curves using

a sample of 144 multiethnic individuals showed small samples to be reliable in age estimation using the 4-tooth method by Demirjian(14). A mean age difference showing an overestimation or underestimation of 1 year is considered accurate in age estimation(15) The revised 7-toothtechnique, the 4-tooth technique and the alternative 4-toothtechnique by Demirjian et al 1976 are all considered accurate methods of age estimation as they meet the above criteria(13) There have been no publications showing the performance of the 4-tooth method by Demirjian on Kenyan population.

### **III. Statement Of The Research Problem, Justification, Study Objectives**

#### **STATEMENT OF THE PROBLEM**

Proof of a person's age is usually through legally accepted identification documents. When such documents are missing or invalid, this presents a challenge in the identification of the person and may lead to deprivation in terms of their legal rights and freedoms. A well-documented and published method of age estimation is required to ascertain their age. In Kenya, civil cases usually involving children such as child abuse, juvenile cases and child defilement require actual age documentation of the chronological age which in some instances may be missing. Age also needs to be determined for children especially at refugee camps. This is to ensure safety and protection of these minors. In mass disasters, unclaimed and unidentified bodies need to be accounted for in terms of the age and identity. Treatment planning in pediatric medicine and dentistry especially orthodontic treatment also require accurate age determination and assessment of the level of maturity and monitor growth. There's no approved method of age determination that can be applied to Kenyan population.

#### **JUSTIFICATION**

In Kenya there is no approved method of age assessment. There's a need to explore and analyze different age assessment methods. This can be done either from existing literature material or by developing new methods to ensure application of adequate techniques and accuracy in Kenyan people. In this study the applicability of the Demirjian four-tooth method was determined and the findings can be applied in future further studies. Publication of this study is also important for the reason that there's need for awareness particularly within the policy makers about age assessment and its vitality mainly for minors to ensure their rights and freedoms are protected. In the medical field, a clear definite method of age valuation needs to be defined to ensure agreement and appropriate communication among clinicians when it comes to treatment planning specially for pediatric medicine and orthodontic treatment.

#### **STUDY OBJECTIVES**

##### **Broad objective:**

1. To assess the applicability of the Demirjian 4-tooth method in estimating the age in a selected group of Kenyan children.

##### **Specific objectives:**

1. To determine the dental age of children in the study population.
2. To determine the chronological age of children in the study population.
3. To compare the dental age and chronological age of children in the study population.

#### **STUDY METHODOLOGY**

##### **Study Area**

The study was done at The University of Nairobi dental hospital situated along Argwing's Kodhek road off Valley road in Nairobi the capital city of Kenya. It's a teaching hospital which attends patients from all over Kenya. The patients are managed by dental students, dental interns and postgraduate dental practitioners under the supervision of consultant dental specialists.

##### **Study design**

This was a descriptive cross-sectional study.

##### **Study population**

It included orthopantomograms of children aged 6-12 years obtained from their clinical records at the University of Nairobi Dental Hospital.

##### **Variables**

VARIABLES	MEASUREMENT
Socio-demographic; Chronological age, Gender	Number of years Male or Female
Dependent variable; Dental Age	Number of years

### **Sample size and sampling method**

Calculation of the sample size was as follows;

Using the formula,

$$n = \frac{Z^2 P(1-P)}{C^2}$$

Where;

n= desired sample size when n is more than 10,000.

Z= standard error corresponding to 95% confidence level.

P= 0.5

C=degree of accuracy which is {100-confidence level (95%)}

$$n = \frac{1.96^2 \times 0.5 (1-0.5)}{0.05^2}$$

$$n = 384$$

Based on a prior study done in Western Australia, the sample size involved was 144(14).

Using the formula for;

$$n < 10,000$$

$$nf = \frac{n}{1+n/N}$$

$$1+n/N$$

Where nf = desired sample size with n<10,000 and N = estimated sample size =144

$$nf = \frac{384}{1+384/144}$$

$$1+384/144$$

Hence the proposed study was to include a minimum of 105 children.

The selection of the sample was through convenience sampling method.

### **Inclusion criteria**

1. Clear orthopantomograms with adequate details.

### **Exclusion criteria**

1. Radiographs showing local dental pathologies, systemic conditions/deformities and neoplasms.
2. Radiographs of adults
3. Radiographs of children not carried out in the study area.
4. Radiographs which are diagnostically inapplicable.
5. Records with no clear documentation of the dates of birth and dates when the radiograph was done.

### **Data collection**

Data was obtained from the patients clinical file records and collection of the existing radiographs of the children who had previously visited the university of Nairobi dental hospital and had an orthopantomogram taken. A data collection form was used by the investigator as a guide in data collection. 160 radiographs of children aged 6-12 years were collected and assessed by the investigator. All the assessed radiographs met the inclusion criteria.

### **Data analysis and presentation**

Chronological age was calculated by getting the difference between the date of birth and the date when the radiograph was taken. Then this was converted to years and months where months were determined as a fraction of twelve months.

Estimation of dental age was done using Demirjian four-tooth method(4), based on four permanent mandibular left teeth (1<sup>st</sup> premolar, 2<sup>nd</sup> premolar, 1<sup>st</sup> molar and 2<sup>nd</sup> molar). Each of the teeth was assigned a stage A-H, based on eight stages of development. The stages of development were based on Demirjian et al(1) written and pictorial criteria. Each obtained stage contributed a numerical score, which was gender weighted and summed up to get the total maturity score out of 100. The total maturity score was then converted to estimated dental age by reading a graphic curve specific to gender of the individual, at the 50<sup>th</sup> percentile.

The age difference was obtained by subtracting the chronological age from the estimated dental age (Dental Age-Chronological Age). A positive value indicated that the Demirjian four-tooth method was overestimating age in the study sample while a negative value indicated an underestimation.

Data on dental age was analyzed for statistical differences with the chronological age. Results were analyzed using Microsoft excel 2010 and statistical analysis was done using statistical packages for social sciences (SPSS). Data was presented in form of tables and figures.

### **Ethical considerations**

The data was coded and stored under password to enhance confidentiality. Before embarking on the study, the proposal was submitted to the Kenyatta national hospital and the university of Nairobi ethics, research

and standards committee for approval. Approval was obtained on 23<sup>rd</sup> of November 2016. Permission to use patient record from the university of Nairobi dental hospital was sort after from the relevant authorities.

**Benefits of the study**

The results obtained from the study can be used to establish a baseline for future further studies especially in determining a definite method that could be applied in age estimation of the Kenyan population.

**IV. Results**

**DEMOGRAPHICS**

A total of 160 children’s radiographs were included in this study. 79(49.4%) of these belonged to female children while 81(50.6%) belonged to male children. The age ranged from 6.00years to 12.99 years. The distribution of age, gender and the number of individuals are given in Table 1. The sample population was sorted into 7 age groups ranging from 6 to 12 years. Each age group included an age range, for example, age group 6 represented 6.00-6.99 years of age.

**Table 1: age and gender distribution**

AGE GROUP	MALES	FEMALES	TOTAL
6	4	12	16
7	18	9	27
8	9	14	23
9	17	10	27
10	10	11	21
11	15	13	28
12	8	10	18
<b>TOTAL</b>	<b>81</b>	<b>79</b>	<b>160</b>

**CHRONOLOGICAL AGE**

The overall mean chronological age was 9.52 years with a standard deviation of 1.92. The males were older than the females with a mean chronological age of 9.54 years with a standard deviation of 1.82. The mean chronological age for the females was 9.51 years with a standard deviation of 2.02. Table 2 shows mean chronological age group for each age group.

**Table 2: mean chronological age per age group, overall mean chronological age.**

**n, number of individual**

AGE GROUP	n	MEAN CHRONOLOGICAL AGE	STANDARD DEVIATION
6	16	6.43	0.30
7	27	7.52	0.31
8	23	8.47	0.28
9	27	9.50	0.30
10	21	10.48	0.31
11	28	11.51	0.26
12	18	12.45	0.32
<b>TOTAL</b>	<b>160</b>	<b>9.52</b>	<b>1.92</b>

**ESTIMATED DENTAL AGE.**

A demonstration on how dental age was obtained is shown below.



**Figure 2: Radiograph; one of the individuals included in the study to demonstrate the estimation of the dental age (MALE).**

**Table 3: A demonstration on estimation of dental age**

TOOTH (MANDIBULAR JAW LEFT SIDE)	1 <sup>ST</sup> PREMOLAR	2 <sup>ND</sup> PREMOLAR	1 <sup>ST</sup> MOLAR	2 <sup>ND</sup> MOLAR
STAGE	F	E	H	E
SCORE	23.8	17.4	27.4	18.4
TOTAL SCORE	87			
DENTAL AGE	10.5 YEARS			

The overall mean dental age was 10.06 years with a standard deviation of 2.23. The female children were shown to be older with a mean dental age of 10.15 years with a standard deviation of 2.48 while the mean dental age for male children was 9.96 years with a standard deviation of 1.97. Table 4 shows the mean dental age per age group.

**Table 4: Mean dental age per age group, mean overall dental age, mean dental age for both males and females. n, number of individuals**

AGE GROUP	n	MEAN DENTAL AGE	STANDARD DEVIATION
6	16	6.89	0.75
7	27	8.11	0.71
8	23	9.01	1.09
9	27	9.85	1.10
10	21	10.97	1.34
11	28	12.28	1.49
12	18	12.89	1.23
MALE	81	9.96	1.97
FEMALE	79	10.15	2.48
TOTAL	160	10.06	2.23

### **CORRELATION BETWEEN CHRONOLOGICAL AND DENTAL AGE**

The accuracy of dental age estimation was defined as how closely estimated dental age could be correlated to the chronological age. Figure 1 shows the overall distribution of both chronological age and estimated dental age per age group. It also shows the overall age difference.

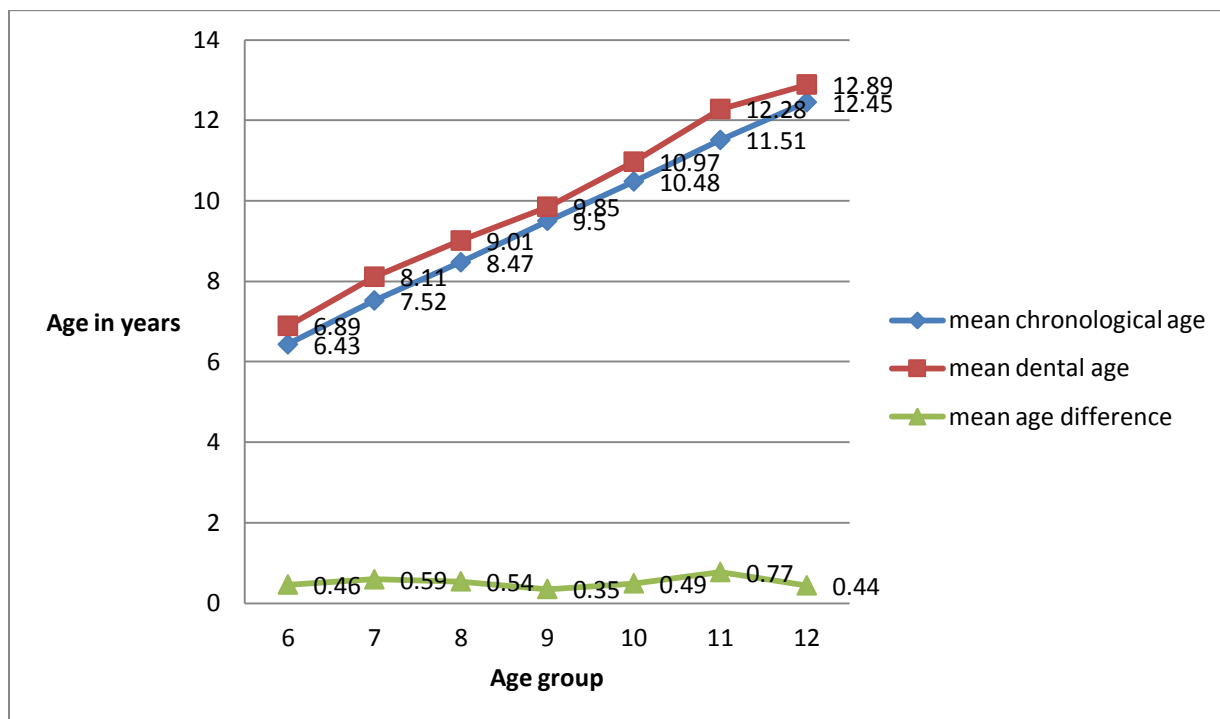


FIGURE 3: A comparison of the mean chronological age, the mean dental age at each age group in the sample used in this study.

**THE AGE DIFFERENCE BETWEEN THE DENTAL AGE AND THE CHRONOLOGICAL AGE**

The mean age difference (dental age-chronological age) for the study population was 0.53 years with a standard deviation of 1.07, thus a mean overestimation of age by about 6 months. The overestimation of age by Demirjian four-tooth method was higher in females with a mean age difference of 0.65 years (About 8 months). The mean age difference in males was 0.42 years (About 5 months). Table 6 shows that the mean age difference in each age group for both female and male children. An independent t-test revealed that the age difference was not statistically significant (t=1.349, p=0.179).

**Table 5: mean age difference in each age group, both male and female. n, number of individual. SD, standard deviation**

Age group	MALE				FEMALE			
	n	Mean age difference	Standard deviation	p	n	Mean age difference	Standard deviation	p
6	4	0.62	0.37	0.610	12	0.41	0.73	0.488
7	18	0.54	0.64	0.568	9	0.69	0.64	0.570
8	9	0.34	0.40	0.455	14	0.67	1.28	0.371
9	17	0.46	0.96	0.467	10	0.17	1.10	0.486
10	10	0.24	1.36	0.419	11	0.71	1.27	0.421
11	15	0.50	1.21	0.323	13	1.07	1.75	0.338
12	8	0.11	1.10	0.265	10	0.71	1.09	0.266



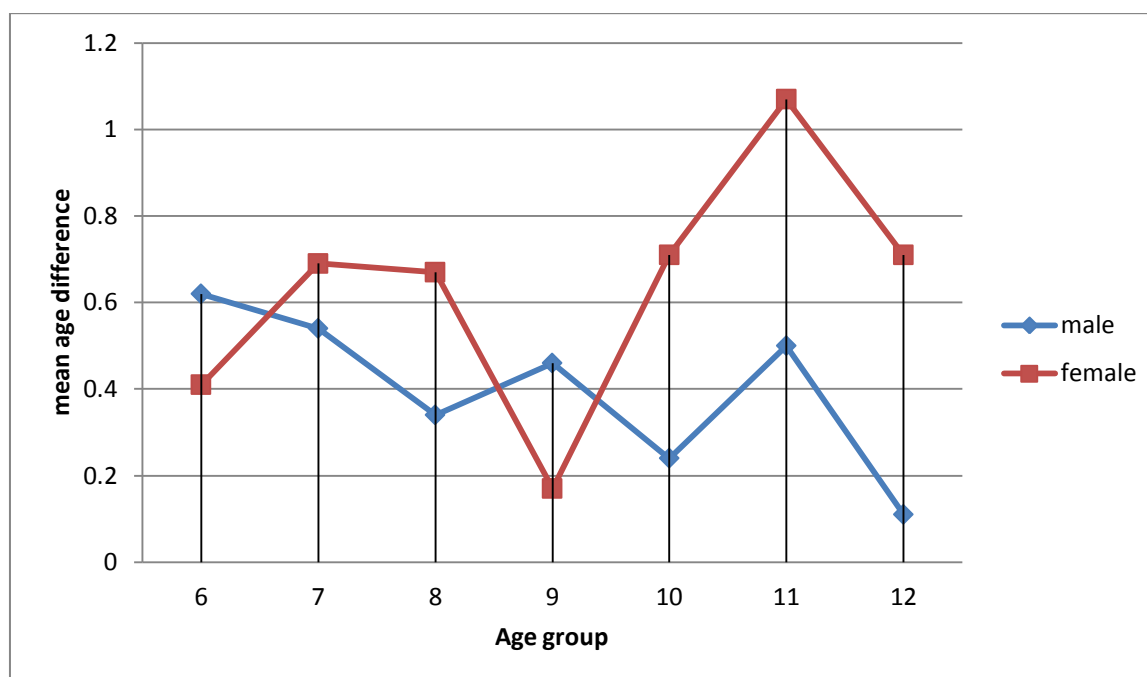


Figure 4: A comparison of the mean age difference between male and female children

#### LIMITATIONS

The study was done in partial fulfillment of the requirement for the degree of the bachelor of dental surgery. Time duration allocated to carry out the study was limited hence did not allow for adequate training in all aspects required to carry out the study.

The distribution of the number of individuals in each age group both male and female was varied. It was difficult to acquire same numbers of individuals at each age group

#### V. Discussion, Conclusion And Recommendation

##### DISCUSSION

The aim of this study was to assess the applicability of the Demirjian four-tooth method by analyzing its accuracy in estimating age in the selected group of Kenyan children.

The mean chronological age for both male and female children in this study closely compares with the mean chronological age from the study done by Flood et al which found a mean of 9.20 years in male children and a mean of 9.21 years in females children(13)(14). Most dental age estimation studies in children using various existing methods have shown to find the mean chronological age at about 9 years(3)(12)(13)(18)(20). This suggests that the expected age of children in most populations is 9 years of age.

Unlike in the study by Flood et al(13) where the mean chronological age showed the female children to be older than male children, in this study, the male children were shown to be older than the female based on the mean chronological age. This could be due to variation in the distribution of the number of individuals in each age group for both male and females.

##### ESTIMATED DENTAL AGE

The mean dental ages of males and females in this study were slightly higher when compared to the results obtained from the study by Flood et al where mean dental age of 9.24 years and 9.46 years for males and females respectively(13) in the Western Australian population which compared closely to the results in the study by Farah et al(18) in the same population. A study in the middle Southern United States showed that tooth maturity in black individuals is earlier than in Caucasians by about 5%(19), hence this could explain the difference in results obtained from this study in which majority of the population is of black race unlike in the western Australian population where majority of the population is Caucasian. The results also show the female children to be older than male children. Studies have shown female dental maturation is earlier than in male especially in the period of initiation and termination of dental development(15). However, the difference in mean dental age between male and female children was however not statistically significant.

## **COORELATION BETWEEN THE DENTAL AGE, CHRONOLOGICAL AGE AND THE AGE DIFFERENCE**

The Demirjian four-tooth method overestimated the chronological age by 0.53 years for the whole population included in the study, 0.42 years for males and 0.65 years for female children. An overestimation of 1 year and below is considered accurate(15) hence showing that the method was applicable in the selected study population. When compared to the findings of the study by Flood et al(13) in which there was an overestimation of 0.04 years and 0.25 years for males and females respectively, the overestimation in the selected population in this study was higher. A recent study done in a similar Kenyan population using Willems' method, a modification of Demirjian's seven-tooth method, overestimated age overall by about 3 months(20). This reveals that the performance of Willem's method was better when compared to the performance of Demirjian four-tooth method in the Kenyan population. The difference between the mean chronological and dental age at individual age groups for both females and males in this study was not statistically significant. This is useful as it shows that the Demirjian four-tooth method is applicable to both male and female children of similar age groups in the Kenyan population. The performance of the method was however better in males than in females overall and best at age group 9 for females and age group 12 for males.

## **VI. Conclusion**

The Demirjian four-tooth method overestimated the chronological age of the selected study population overall by about 6 months, about 5 months for males and about 8 months for females. This overestimation falls under the one year limit when determining the accuracy of a dental age estimation method hence showing that the Demirjian four-tooth method can be reasonably used to estimate the chronological age of the selected Kenyan population.

## **VII. Recommendation**

It is suggested that the Demirjian four-tooth method may be used to estimate the chronological age of children where applicable.

There is need to use bigger samples to further validate the accuracy of the method in the Kenyan population as well as research the performance of other existing age estimation methods in order to define one that is most applicable to the Kenyan population.

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