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Dental Age Estimation using Panoramic Radiographs: A Study on Children in North Central Nigeria

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Abstract

Background: Age estimation is very important in forensic medicine, not only for identification of victims, but also in crimes and accidents. This study aimed to evaluate the applicability and compare the accuracy of Demirjian, Willems I, and Willems II methods for dental age estimation in children in North central Nigeria using panoramic radiographs.

Methods: This study was a retrospective study of panoramic radiographs from 70 children aged 7 to 17 years from a tertiary health institution North central Nigeria. Chronological age was calculated as the difference between the date of birth and the date on which the radiograph was made. Dental age was calculated using the Demirjian, Willems I and Willems II methods. Data was analyzed with SPSS VERSION 20.

Results: The chronological mean age of the boys and girls was 10.63±2.58 and 11.60±3.20 respectively. A mean difference (CA-DA) of 0.58/0.85, 0.01/0.03, 0.15/-0.11, was observed for Demirjian's , Willems I and Willems II methods for males and females respectively. The three tested methods underestimated the mean chronological age of males and females except the Willems II method which overestimated the mean age of the females.

Conclusion: The level of accuracy of these three methods in the children of North central,Nigerian population is acceptable. Demirjian's seven teeth method is recommended for age prediction in both sexes as it reveals highest correlation value with the chronological age. In forensic cases, when the sex is doubted, the Willems II method is appropriate.

Keywords: Chronological age, Dental age, Demirjian, Willems, Panoramic radiograph, Nigeria

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ORIGINAL ARTICLE

Introduction

Age estimation is very important in forensic medicine, not only for identification of victims of fatal accidents, but also carried out for reasons such as criminal cases, where the actual age is unknown and age assessment of the victim is required by the courts to make decisions. It is also used for purposes other than forensic uses, such as when birth records are unreliable or lost, where specific aging is needed to prevent cheating in age-graded sports competitions, employment criteria, and eligibility for marriage [1] or where individuals seek favourable outcomes in civil or criminal cases and some social activities [2].

There are various methods for the age estimation. Sakhdari, et al [3] stated that age estimation from teeth by radiological analysis in both children and adolescents has wide applications in several scientific and forensic fields [3]. Forensic dentistry is defined as the use of dental science for legal purposes [3].

Different methods have been proposed to estimate dental age using permanent tooth formation. Among these is Demirjian's [4] method formulated on a sample of French-Canadian children, which

involves the assessment of eight specific stages of tooth formation of the seven left mandibular teeth. Self-weighted scores, which are numerical and derived, are assigned to each tooth stage. The scores are added together to give a dental maturity score. Separate tables of dental maturity for males and females are used to convert the maturity scores to dental age [4]. The methodology gained worldwide acceptability and became the most used method for estimation of dental age [1].

Nemsi *et al.* [5] reported that Demirjian method has consistently overestimate age across populations, and expecting more accuracy, Willems *et al*. [6] suggested a new method using Demirjian maturation stages, approved in a Belgian Caucasian population that consists of new tables for each sex [5]. The tables presented scores that are directly expressed in years, so there is no need for conversion which is known as the Willems I method. Willems's method revealed consistently more accuracy of estimating the chronological age compared to Demirjian techniques. To facilitate the identification when sex is unknown, by using the Demirjian dental maturity stages, Willems *et al.* [6] presented non-sex-specific scores known as the Willems II method. In a developing country like Nigeria, one subject of continuous discussion has been how best to estimate an individual's chronological age for clinical and forensic purposes where birth records are either unavailable or not reliable [7].

While related studies had been carried out on a (south west) Nigerian population [7-8], no systematic review has yet evaluated the applicability of these methods in this setting. Hence, this study evaluated the applicability of Demirjian, Willems I, and Willems II methods for dental age estimation using panoramic radiographs from a sample of North central Nigerian children. The objectives of the study were to evaluate the accuracy of Demirjian, Willems I and Willems II methods on the relationship of chronological age and dental age with its reliability on panoramic radiographs and to determine the differences in dental age between the sex group using these methods. Furthermore, the study sought to compare the differences of chronological age and dental age between the sex group and to predict the chronological age formula from the data generated from the study.

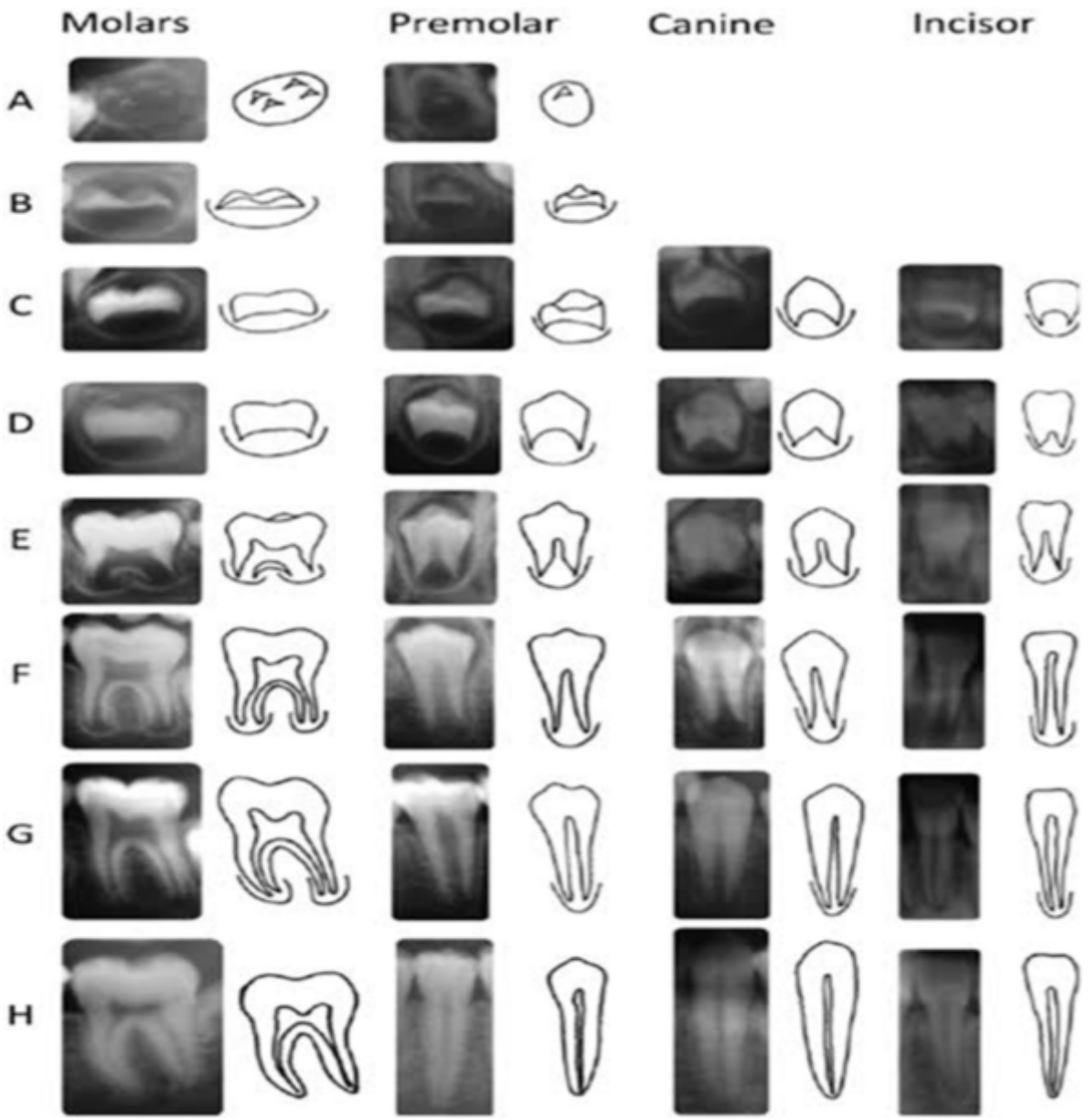
Materials and methods

This study was a retrospective study of panoramic radiographs from 70 young individuals between the ages of 7 and 17 years. These individuals are healthy Nigerian patients requesting panoramic radiograph for various purposes at the tertiary Heath institution, and whose radiographs were taken as part of routine treatment between July, 2014 and December, 2019. Ethical approval was sought from ethical board of the institution. All subjects whose Orthopantomographs were available with a documented date of birth and date of radiography were retrieved from the health records and examined for eligibility for the study. Radiographs of patient(s) with the following conditions; birth dates were not accessible (37 in number), with craniofacial malformative syndromes. with image distortion or lack of clarity. showing teeth with teeth root canal treatment showing shape and position anomalies of teeth, or with any history of systemic illness that has a direct influence on teeth development also Panoramic radiographs showing absence of a particular tooth type in both quadrants of the mandible were excluded from the study. A structured questionnaire containing demographic data; chronological age, dental age, and gender was administered by the researcher. Radiographic examinations were carried out by the researcher. Orthopantomograms were recorded by means of using a KODAK Dental Imaging Software V6, 12, 21, 0 attached to the X-ray viewer and saved as JPEG images. Windows Live Photo Gallery was used to view the radiographs and adjust the size, contrast and brightness for better quality and thereafter printed out

on plain sheets. Radiographs were excluded in cases of radiographic distortion affecting the staging of the left mandibular teeth or in the incidence of dental developmental abnormalities. The radiograph was reviewed by one investigator.

The study population was classified according to chronological age (CA) into five groups of two years each as 7-8, 9-10, 11-12, 13-14 and 15-16. The chronological age (represented in two decimal places) was determined using the difference between the date of birth (DOB) and the date on which the panoramic radiograph was taken (DODental age (DA) was assessed using three methods; Demirjian method, Willems I method and Willems II method. Each of the seven left permanent teeth of the mandible (excluding the third molar) was assessed and the stage of maturation classified as 'A' to 'H' using the Demirjian's dental staging method.

Table 1. Radiographic and schematic illustration of the developmental stages according to Demirjian et al. [4]



When a tooth is missing on the left quadrant, the corresponding tooth on the right quadrant was used for the assessment.

All orthopantomograms (OPGs) was examined by one observer. The observer was blinded with regards to the CA and other details such as the name, DOB and gender of the patient when evaluating the radiograph. To assess the intra-observer agreement, randomly selected 10 OPGs were re-evaluated by the same examiner, following one week of initial evaluation using Demirjian's method of dental staging and without any knowledge of the stages attributed in the first evaluation. Dental ages were reassessed using Demirjian's seven teeth staging method for all three methods.

Demirjian's Method

Demirjian's method stages the radiographic appearance of the seven mandibular teeth on the left quadrant. The seven left mandibular permanent teeth were staged (A-H), rated in the order of the second molar (M2), first molar (M1), second premolar (PM2), first premolar (PM1), canine (C), lateral incisor (I2) and central incisor (I1). Stages (A-H) represent the eight (8) stages of mineralization of the tooth from the beginning of calcification through to the final mature form together with stage zero for non-appearance. If there is no sign of calcification, the rating 0 is given; the crypt formation is not taken into consideration. Each stage of mineralization is given a maturity score (A-H) for each tooth (Table I) which provides an estimate of dental maturity. Each stage is then converted to a self-weighted score (Table II) separate for male and female, which is then summed up to give a total maturity score on a scale of 0-100 percentile charts, that will then be converted directly into a dental age using the standard conversion tables for male and female given by Demirjian (Tables 3A & 3B).

Table 2. Self-weighted scores for dental stages according to the Demirjian's method [4].

Self-Weighed Scores for Dental Stages
7 Teeth (Mandibular Left Side)

					Boys				
	Stage								
Tooth	0	A	B	C	D	E	F	G	H
M_2	0.0	2.1	3.5	5.9	10.1	12.5	13.2	13.6	15.4
M_1				0.0	8.0	9.6	12.3	17.0	19.3
PM_2	0.0	1.7	3.1	5.4	9.7	12.0	12.8	13.2	14.4
PM_1			0.0	3.4	7.0	11.0	12.3	12.7	13.5
C				0.0	3.5	7.9	10.0	11.0	11.9
I_2				0.0	3.2	5.2	7.8	11.7	13.7
I_1					0.0	1.9	4.1	8.2	11.8
					Girls				
	Stage								
Tooth	0	A	B	C	D	E	F	G	H
M_2	0.0	2.7	3.9	6.9	11.1	13.5	14.2	14.5	15.6
M_1				0.0	4.5	6.2	9.0	14.0	16.2
PM_2	0.0	1.7	3.4	6.5	10.6	12.7	13.5	13.8	14.6
PM_1			0.0	3.7	7.5	11.8	13.1	13.4	14.1
C				0.0	3.8	7.3	10.3	11.6	12.4
I_2				0.0	3.2	5.6	8.0	12.2	14.2
I_1					0.0	2.4	5.1	9.3	12.9
NB: Stage 0 is no calcification									

Table 3A. Conversion Table of Maturity Score to Dental Age for Boys [4]

Age	Score	Age	Score	Age	Score	Age	Score
			Boys				
3.0	12.4	7.0	46.7	11.0	92.0	15.0	97.6
.1	12.9	.1	48.3	.1	92.2	.1	79.7
.2	13.5	.2	50.0	.2	92.5	.2	97.8
.3	14.0	.3	52.0	.3	92.7	.3	97.8
.4	14.5	.4	54.3	.4	92.9	.4	97.9
.5	15.0	.5	56.8	.5	93.1	.5	98.0
.6	15.6	.6	59.6	.6	93.3	.6	98.1
.7	16.2	.7	62.5	.7	93.5	.7	98.2
.8	17.0	.8	66.0	.8	93.7	.8	98.2
.9	17.6	.9	69.0	.9	93.9	.9	98.3
4.0	18.2	8.0	71.6	12.0	94.0	16.0	98.4
.1	18.9	.1	73.5	.1	94.2		
.2	19.7	.2	75.1	.2	94.4		
.3	20.4	.3	76.4	.3	94.5		
.4	21.0	.4	77.7	.4	94.8		
.5	21.7	.5	79.0	.5	94.8		
.6	22.4	.6	80.2	.8	95.0		
.7	23.1	.7	81.2	.7	95.1		
.8	23.8	.8	82.0	.8	95.2		
.9	24.6	.9	82.8	.9	95.4		
5.0	25.4	9.0	83.6	13.0	9511		
.1	26.2	.1	84.3	.1	95.7		
.2	27.0	.2	85.0	.2	95.8		
.3	27.8	.3	85.6	.3	95.9		
.4	28.6	.4	86.2	.4	96.0		
.5	29.5	.5	86.7	.5	96.1		
.6	30.3	.6	87.2	.6	96.2		
.7	31.1	.7	87.7	.7	96.3		
.8	31.8	.8	88.2	.8	96.4		
.9	32.6	.9	88.6	.9	96.5		
6.0	33.6	10.0	89.0	14.0	96.6		
.1	34.7	.1	89.3	.1	96.7		
.2	35.8	.2	89.7	.2	96.8		
.3	36.9	.3	90.0	.3	96.9		
.4	38.0	.4	90.3	.4	97.0		
.5	39.2	.5	90.6	.5	97.1		
.8	40.6	.6	91.0	.6	97.2		
.7	42.0	.7	91.3	.7	97.3		
.8	43.6	.8	91.6	.8	97.4		
.9	45.1	.9	91.6	.9	97.5		

Table 3B. Conversion Table of Maturity Scores to Dental Age for Girls [4].

Ago	Scare	Age	Score	Age	Score	Age	Serial
			Girl				
3.0	13.7	7.0	51.0	11.0	94.5	15.0	90.2
.1	14.4	.1	52.9	.1	94.7	.1	99.3
.2	15.1	.2	55.5	.2	94.9	.2	99.4
.3	15.8	.3	57.8	.3	95.1	.3	99.4
.4	16.6	.4	61.0	.4	95.3	.4	99.5
.5	17.3	.5	65.0	.5	951	.5	99.6
.6	18.0	.6	68.0	.6	95.6	.6	99.6
.7	18.8	.7	71.8	.7	95.8	.7	99.7
.8	19.5	.5	75.0	.8	96.0	.8	99.5
.9	20.3	.9	77.0	.9	98.2	.9	99.9
4.0	21.0	8.0	78.8	12.0	96.3	16.0	100.0
.1	21.8	.1	80.2	.1	96.4		
.2	22.5	.2	81.2	.2	96.5		
.3	23.2	.3	82.2	.3	96.6		
.4	24.0	.4	83.1	.4	96.7		
.5	24.8	.5	84.0	.5	96.8		
.0	25.6	.6	84.8	.6	96.9		
.7	26.4	.7	85.3	.7	97.0		
.8	27.2	.8	66.1	.8	97.1		
.9	28.0	.9	86.7	.9	97.2		
5.0	28.9	9.0	87.2	13.0	97.3		
.1	22.7	.1	87.8	.1	97.4		
.2	30.5	.2	88.3	.2	97.5		
.3	31.3	.3	88.8	.3	97.6		
.4	32.1	.4	89.3	.4	97.7		
.5	33.0	.5	98.8	.5	97.6		
.6	34.0	.6	90.2	.0	98.0		
.7	35.0	.7	90.7	.7	98.1		
.8	36.0	.8	91.1	.8	98.2		
.9	37.0	.9	91.4	.9	96.3		
6.0	38.0	10.0	91.8	14.0	98.3		
.1	30.1	.1	92.1	.1	98.4		
.2	40.2	.2	92.3	.2	98.5		
.3	41.3	.3	92.6	.3	96-6		
.4	42.5	.4	92.9	.4	98.7		
.5	43.9	.5	93.2	.5	98.8		
.6	45.2	.6	93.5	.0	98.9		
.7	46.7	.7	93.7	.7	90.0		
.8	46.0	.8	94.0	.8	99.1		
.9	49.5	.9	94.2	.9	99.1		

Willems Methods

Willems methods consider the developmental stages of the seven left permanent mandibular teeth also using the Demirjian's staging technique of 'A' to 'H' tooth mineralization stages. A score is obtained for each tooth from sex-specific tables for the Willems I method and from the non-sex-specific table for the Willems II method. The seven teeth, from A to H on the left quadrant of the mandible in the selected OPG, are coded as shown in Fig. 3.1 with the assistance of

the reference illustrations and radiographs given in table I. Finally, the Willems I and Willems II dental age estimation is obtained by adding up the score corresponding to each letter code for all seven teeth as shown in Table 4.

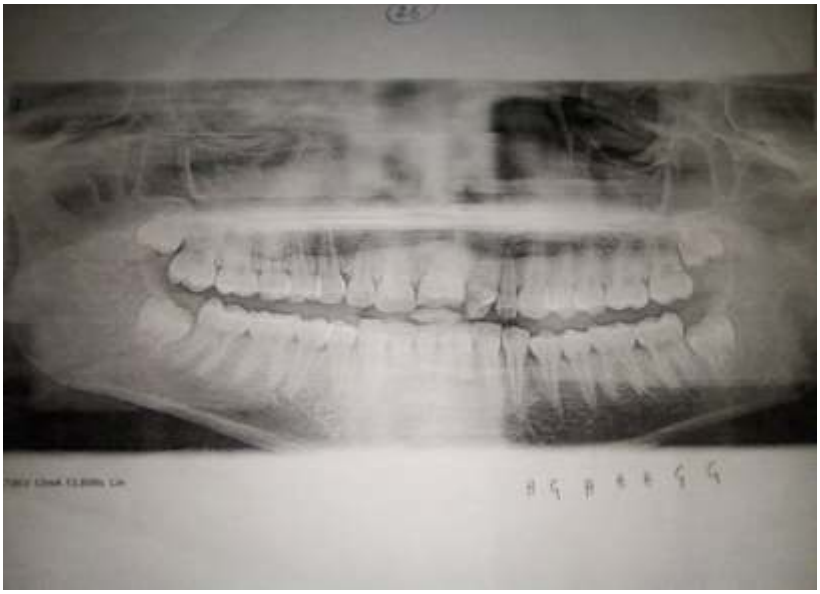


Figure 1: Panoramic radiograph marked with the staging codes corresponding to the different mineralization stages of each of the seven permanent teeth of the left lower quadrant using Demirjian method

TABLE 4. Age scores for each developmental tooth stage expressed directly in years for Willems' sex-specific and non-sex-specific methods [6].

Developmental tooth stages according to the Demirjian's technique (1) with corresponding age scores expressed directly in years for each of the seven left mandibular teeth

	Demirjian developmental tooth stages							
	A	B	C	D	E	F	G	H
Males and Females								
Central Incisor	-	-	1.87	1.88	1.97	2.40	2.71	2.74
Lateral Incisor	-	-	-0.82	-0.65	-0.57	-0.29	-0.01	0.07
Canine	-	-	1.13	1.11	1.27	1.51	1.85	2.20
First bicuspid	-0.07	0.31	0.54	0.84	1.05	1.67	2.07	2.64
Second bicuspid	-0.01	0.07	0.19	0.26	0.46	0.55	0.64	1.55
First Molar	-	-	-	0.75	1.14	1.70	1.95	2.28
Second Molar	0.17	0.32	0.50	0.61	1.04	1.79	2.25	4.42
Males								
Central Incisor	-	-	1.68	1.49	1.50	1.86	2.07	2.19
Lateral Incisor	-	-	0.55	0.63	0.74	1.08	1.32	1.64
Canine	-	-	-	0.04	0.31	0.47	1.09	1.90
First bicuspid	0.0015	0.56	0.75	1.11	1.48	2.03	2.43	2.83
Second bicuspid	0.08	0.05	0.12	0.27	0.33	0.45	0.40	1.15
First Molar	-	-	-	0.69	1.14			
Second Molar								
Females								
Central Incisor	-	-	1.83	2.19	2.34	2.82	3.19	3.14
Lateral Incisor	-	-	-	0.29	0.32	0.49	0.79	0.70
Canine	-	-	0.60	0.54	0.62	1.08	1.72	2.00
First bicuspid	-0.95	-0.15	0.16	0.41	0.60	1.27	1.58	2.19
Second bicuspid	-0.19	-0.01	0.27	0.17	0.35	0.35	0.55	1.51
First Molar	-	-	-	0.62	0.90	1.56	1.82	2.21
Second Molar	0.14	0.11	0.21	0.32	0.66	1.28	2.09	4.04

The sum of these age scores directly expresses the dental age of the patient. This way the conversion to dental age as was the case with Demirjian's method is not necessary, which is the basic modification from the Demirjian's method [6,9].

Data Collection

The study population was classified according to chronological age (CA) into five groups of two years each as 7-8, 9-10, 11-12, 13-14 and 15-16. The chronological age (represented in two decimal places) was determined using the difference between the date of birth (DOB) and the date on which the panoramic radiograph was taken (DOR).

Dental age (DA) was assessed using three methods; Demirjian method, Willems I method and Willems II method. Each of the seven left permanent teeth of the mandible (excluding the third molar) was assessed and the stage of maturation classified as 'A' to 'H' using the Demirjian's dental staging method (table I).

When a tooth is missing on the left quadrant, the corresponding tooth on the right quadrant was used for the assessment.

All orthopantomograms (OPGs) was examined by one observer. The observer was blinded with regards to the CA and other details such as the name, DOB and gender of the patient when evaluating the radiograph. To assess the intra-observer agreement, randomly selected 10 OPGs were re-evaluated by the same examiner, following one week of initial evaluation using Demirjian's method of dental staging and without any knowledge of the stages attributed in the first evaluation. Dental ages were reassessed using Demirjian's seven teeth staging method for all three methods.

To avoid observer bias and in order not to invade the privacy of the patients under study, patients' identities were not disclosed. Instead, each patient's OPG was coded numerically from 1 to 70.

The OPGs were examined for dental maturation score for the selected teeth. The examiner was blinded to sex, name and chronological age of the patients. The maturation scores assigned to each permanent tooth of the left mandible of selected OPGs was based on Demirjian's staging method 'A' to 'H' for all three methods.

For the Demirjian's method, dental age (DA) was assessed for a selected radiograph by observing each of the seven left permanent teeth of the mandible (excluding the third molar). Each permanent tooth was assigned a code based on its developmental stage using the Demirjian's classification of tooth mineralization stage 'A' to 'H' chart (as shown in table I). The codes for each of the seven left permanent teeth of the mandible was then assigned a maturity score using the Demirjian's self-weighted scores table (as shown in table II) separate for boys and girls. The sum of this self-weighted maturation score which is usually on a scale of 0-100 percentile charts is then converted to a dental age using the Demirjian's conversion tables (as shown in tables IIIA & IIIB) which is separate for boys and girls for the selected radiograph.

For the Willems I method, dental age (DA) was assessed by simply adding up the age scores which corresponds to each mineralization stage of the Demirjian's 'A' to 'H' chart (table 1) of each of the seven left permanent teeth of the mandible (excluding the third molar) of the selected radiograph using the Willems' sex-specific table (as shown in table IV) separate for boys and girls. The sum of these age scores directly expresses the dental age of the patient. This way the conversion to dental age as was the case with Demirjian's method is not necessary, which is the basic modification from the Demirjian's method.

For the Willems II method, dental age (DA) was assessed also by adding up the age scores which corresponds to each mineralization stage of the Demirjian's 'A' to 'H' chart (table 1) of each of the seven left permanent teeth of the mandible (excluding the third molar) of the selected radiograph, this time using the Willems' non-sex-specific table (as shown in table IV) same for boys

and girls. The sum of these age scores directly expresses the dental age of the patient just like in the Willems I method.

A function of Microsoft Excel was thereafter used to calculate the difference between the date of birth and the date on which the panoramic radiograph was made to obtain the chronological age (CA) in two decimal places.

To assess the intra-observer reliability, randomly selected 10 OPGs were reevaluated by the same examiner, following one week of initial evaluation using Demirjian's method of dental staging and without any knowledge of the stages attributed in the first evaluation. The intraobserver reliability test using paired sample t-test was done as shown in Table 5. Dental ages were reassessed using Demirjian's seven teeth staging method for all three methods and recorded as shown in Table 7a and 7b

TABLE 5. Intraobserver reliability test using paired sample t-test

Pair	Mean±S.D	Pearson's Correlation		Paired Samples Test		
		r	P-value	M.D	t-value	p-value
DM-1 **DM-2**	10.56±2.20 10.48±1.96	0.952	<0.001	0.078	0.36	0.727
WM1-1 **WM1-2**	10.94±1.94 11.04±2.01	0.998	<0.001	-0.097	-2.055	0.070
WM2-1 **WM2-2**	10.95±1.96 11.02±1.98	0.998	<0.001	-0.072	-1.659	0.132

There were no significant different between the measurements taken at different periods by the same observer (P>0.05), and the correlations between the pairs DM (0.952), WM1 (0.998), and WM2 (0.998) were significantly high (P<0.001). Thus, suggesting high reliability in measurement technique (Table 5)

Statistical Analysis

The data collected was cleaned, edited, coded, and entered into Microsoft excel 2016. The entered data was then exported to Statistical Package for Social Sciences (SPSS) version 26 (IBM®, Amornk, USA) and STATGRAPHICS centurion CVI version 16.1.11 (Stat Point Tech., Inc.) for analysis.

Using SPSS, intraobserver reliability was estimated using paired sample t-test. The accuracy of each method of age estimation by the mean difference between chronological and dental ages (CA-DA), for each sex and age group, and the total sample. A positive result designates an underestimation, and a negative one indicates an overestimation of age. The extent of divergence between the chronological age and estimated dental age for all tested methods was statistically evaluated using the paired sample t-test. Independent samples t-test was employed to compare the differences (CA-DA) between sexes for the three methods.

The correlation between DA and CA was analysed using Spearman's rank correlation coefficient for each method, sex and for the total sample. Comparison of regression lines was used to determine the influence of sex on the relationship between CA and the estimated DAs. The analyses were performed at 95% confidence level and p-values less than 0.05 was considered significant.

Results

A total of 70 (39; 55.7% males and 31; 44.3% females) subjects with ages ranging from 7 to 17 years were grouped as presented in Table 4.

Table 6 contains the Chronological Ages (CA) and Dental Ages (DA) estimated from the orthopantomograms (OPGs) of the 70 patients under study using Demirjian's Method (DM), Willems I Method (WM1) and Willems II Method (WM2) respectively.

Table 6. Age distribution of study population

Age group	Male (%)	Female (%)	Total (%)
7 – 8	11 (28.2)	10 (32.3)	21 (30.0)
9 - 10	12 (30.8)	5 (16.1)	17 (24.3)
11 - 12	8 (20.5)	4 (12.9)	12 (17.1)
13 - 14	5 (12.8)	6 (19.4)	11 (15.7)
15 - 16	3 (7.7)	6 (19.4)	9 (12.9)
	39 (55.7)	**31 (44.3)**	**70 (100)**

The chronological mean age (CA) of the boys and girls was 10.63±2.58years and 11.60±3.20years respectively. A mean difference (CA-DA) of 0.58/0.85, 0.01/0.03, 0.15/-0.11 was observed for Demirjian's method (DM), Willems I (WM1) and Willems II (WM2) methods for males and females respectively as shown in Table 7 a and 7 b for males and females respectively. This result showed that the mean chronological age of both the males and the females were underestimated in all three tested methods except for the Willems II method which overestimated the mean age of the females. The mean difference was highly significant ($p<0.001$) in males and very highly significant in females ($p<0.0001$ for Demirjian's method, while the mean difference was not significant ($p>0.05$) in both males and females for the Willems I and II methods.

Table 7A. Mean (S.D) and mean difference (*md*) between C.A and the estimated DAs using DM, WM1 and WM2 in males

Age Group	N	CA	DM	CA vs DM *md* (p-value)	WM1	CA vs WM1 *md* (p-value)	WM2	CA vs WM2 *md* (p-value)
7 to 8	**11**	7.90±0.49	8.20±0.51	*-0.30(0.128)*	8.41±0.47	*-0.51(0.022)**	8.08±0.52	*-0.18(0.413)*
9 to 10	**12**	9.67±0.59	9.23±0.69	*0.44(0.107)*	9.86±1.00	*-0.19(0.577)*	9.63±0.99	*0.04(0.905)*
11 to 12	**8**	11.73±0.65	10.08±0.86	*1.65(0.001)***	11.43±1.11	*0.30(0.502)*	11.43±1.35	*0.30(0.580)*
13 to 14	**5**	14.01±0.59	12.71±0.88	*1.30(0.025)**	13.24±0.91	*0.77(0.151)*	13.46±1.13	*0.55(0.363)*
15 to 16	**3**	15.86±0.77	15.57±0.75	*0.29(0.670)*	15.20±1.44	*0.66(0.523)*	15.16±1.28	*0.70(0.463)*
Total	**39**	10.63±2.58	10.05±2.23	*0.58(0.001)***	10.62±2.25	*0.01(0.964)*	10.48±2.43	*0.15(0.340*

CA: Chronological Age, DA: Dental Age, DM: Demirjian Method, WM1: Willems I Method, WM2: Willems II Method
****p*-value <0.001, Very highly significant difference
***p*-value <0.01, Highly significant difference
**p*-value <0.05, Significant difference
p-value ≥0.05, Non-significant difference

Table 7B. Mean (S.D) and mean difference (*md*) between C.A and the estimated DAs using DM, WM1 and WM2 in males

Age Group	N	CA	DM	CA vs DM *md* (p-value)	WM1	CA vs WM1 *md* (p-value)	WM2	CA vs WM2 *md* (p-value)
7 to 8	**10**	8.09±0.63	8.13±0.75	*-0.04(0.894)*	8.01±0.87	*0.08(0.807)*	8.24±0.91	*-0.15(0.658)*
9 to 10	**5**	9.92±0.61	8.96±0.78	*0.69(0.132)*	11.83±4.29	*-1.91(0.353)*	11.99±4.36	*-2.07(0.232)*
11 to 12	**4**	12.11±0.79	10.23±0.34	*1.88(0.005)***	11.89±0.68	*0.22(0.688)*	11.81±0.57	*0.3(0.561)*
13 to 14	**6**	13.97±0.74	12.24±1.21	*1.73(0.014)**	13.37±1.12	*0.60(0.325)*	13.51±1.04	*0.46(0.398)*
15 to 16	**6**	16.12±0.84	15.45±0.95	*0.67(0.225)*	15.26±0.92	*0.86(0.122)*	15.38±0.91	*0.74(0.174)*
Total	**31**	11.60±3.20	10.75±2.89	*0.85(<0.001)****	11.57±3.27	*0.03(0.927)*	11.71±3.24	*-0.11(0.751)*

CA: Chronological Age, DA: Dental Age, DM: Demirjian Method, WM1: Willems I Method, WM2: Willems II Method
***p-value <0.001, Very highly significant difference
**p-value <0.01, Highly significant difference
*p-value <0.05, Significant difference
p-value ≥0.05, Non-significant difference

All tested methods revealed an underestimation of age (except the 7-8 and 9-10 age groups where an overestimation of age was sometimes observed) in both sexes. The application of Demirjian's method revealed statistically significant differences among the 11-12 and 13-14 age groups in both males and females, while only age group 7-8 in males showed a significant difference for the Willems I method.

The correlations between the chronological age (CA) and the estimated dental age (DAs) using DM, WM1, and WM2 for males and females were presented in Figs. 1, 2, and 3 respectively. The scatter plot graph showed a strong positive correlation between the two measures. The R^2 values were 0.900 (male) and 0.869 (female) for DM, 0.876 (male) and 0.705 (female) for WM1 and 0.866 (male) and 0.693 (female) for WM2.

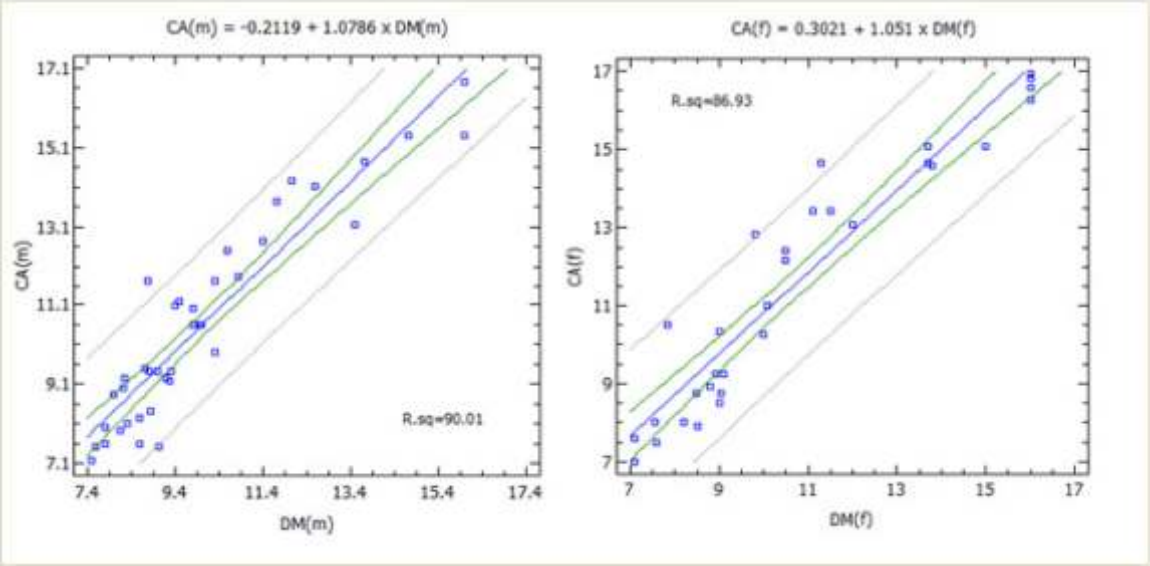


Figure 2: Correlation between C.A and the DM estimated age

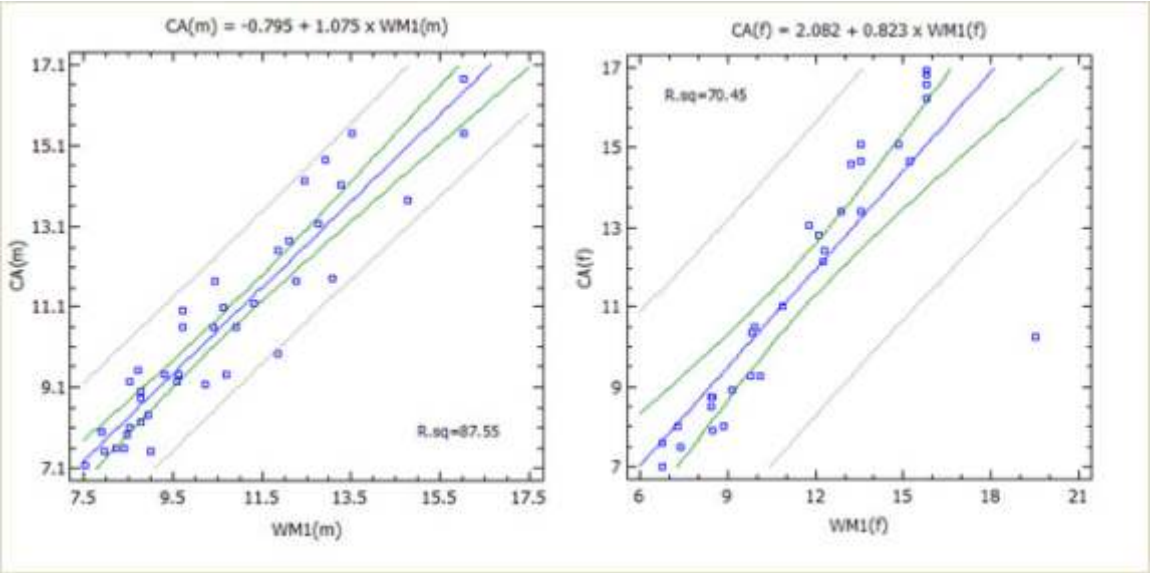


Figure 3 : Correlation between C.A and the WM1 estimated age

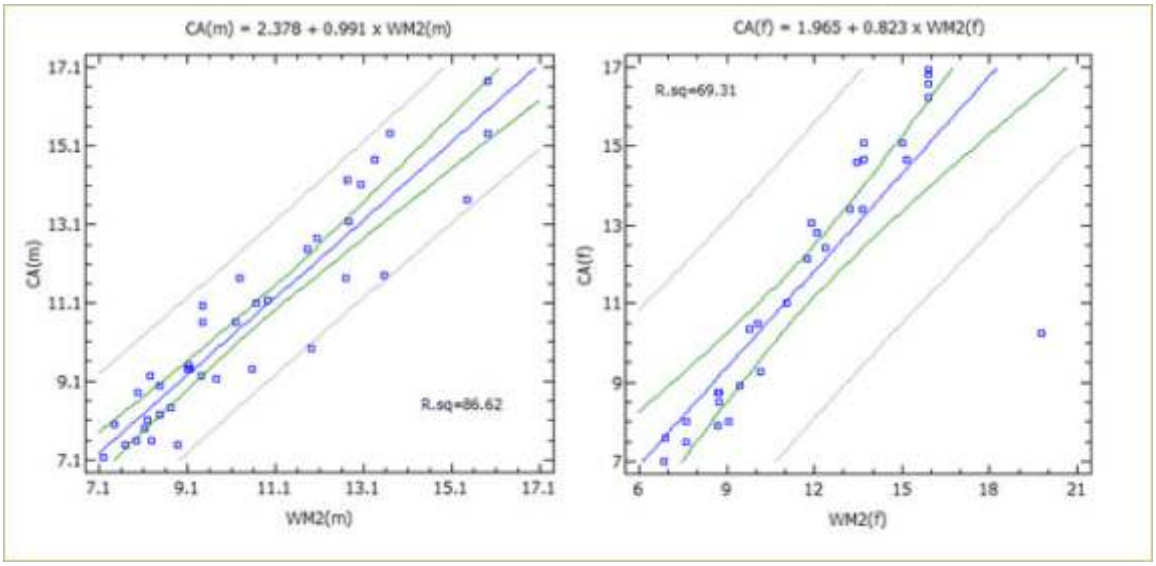


Figure 4 : Correlation between C.A and the WM2 estimated age

A prediction equation was also formulated and the suggested formulas for age prediction according to the interpreted data are as follows:

The equation for Demirjian's method:

Males: $CA = -0.2119 + 1.0786 \times DM$

Females: $CA = 0.3021 + 1.051 \times DM$

The equation for Willems I method:

Males: $CA = -0.795 + 1.075 \times WM1$

Females: $CA = 2.082 + 0.823 \times WM1$

The equation for Willems II method:

Males: $CA = 2.378 + 0.991 \times WM2$

Females: $CA = 1.965 + 0.823 \times Wm2$

From the result in Table 4.3, the slope and intercepts for DM and WM2 were not significantly different between male and female ($P>0.05$), though the predictions are significant ($P<0.01$). On the other hand, the slope for WM1 was significantly different for the sexes ($P=0.0461$) with significant predictions ($P<0.001$).

Table 8. The ANOVA for sex in the order fitted regression model

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
DM	513.217	1	513.217	529.83	<0.001
Intercepts	0.883	1	0.883374	0.91	0.3431
Slopes	0.082	1	0.082331	0.08	0.7716
Model	514.182	3			
WM1	447.667	1	447.667	241.01	<0.001
Intercepts	0.175	1	0.175285	0.09	0.7597
Slopes	7.677	1	7.67724	4.13	0.0461
Model	455.519	3			
WM2	445.681	1	445.681	228.95	<0.001
Intercepts	0.247	1	0.247244	0.13	0.7227
Slopes	3.709	1	3.70899	1.91	0.1721
Model	449.637	3			

DM: Demirjian Method, WM1: Willems I Method, WM2: Willems II Method
p-value <0.001, Significant difference
p-value ≥0.05, Non-significant difference

Discussion

Ideally, age estimation in a population should be done by using different methods presented by existing literatures and practices, as well as the development of new methods to ensure the application of the most adequate technique [10].

This study aimed to evaluate the applicability and compare the accuracy of the Demirjian, Willems I and Willems II radiographic methods of estimating dental age of children in an Ilorin population for application in forensic medicine, pediatric dentistry and orthodontics.

In the majority of studies done using the Demirjian's seven teeth method, an overestimation of the chronological age was observed and was explained by a positive secular trend in growth and development during the last decades [5]. We cannot admit the same explanation for this study, which revealed an overall underestimation for the three tested methods (except in the younger age groups 7-8 and 9-10 where an overestimation of age was sometimes observed) for both sexes. This finding agreed with a previous study done on a Tunisian sample which revealed a noticeable overestimation for ages ranging from 3 to 8 years and a high underestimation for ages varying from 9 to 16 years using Demirjian's seven teeth method [11] and also on a Jordanian sample where dental maturity is advanced in young age groups and delayed in older ones [12]. The overall underestimation of chronological age could be due to a real delay of development of premolars and molars in the Ilorin population compared to the French-canadian one.

This study revealed that CA of the examined females were more underestimated compared to their male counterparts when using the Demirjian's technique (mean differences between EDAs and CAs of 0.58 and 0.85 years for males and females, respectively), hence suggesting sexual dimorphism. On the contrary, a previous study on a Nigerian population revealed that males were more dentally ahead of their CA than their female counterparts [8] which is similar to the findings in a population of Egyptian children where an overestimation of CA in both sexes by 0.466 years in the male group and 0.325 years in the female group was also observed [13]. This suggests the need for more population-specific age estimation studies of the Nigerian population.

Previous studies [14] have shown that tooth development varies in different populations and requires population specific studies. Studies of different ethnic populations gave different age estimates. Esan *et al.,* [10] stated that the reason for the variation among groups is not fully understood, although several explanations involving the interplay of genetic and environmental factors have been proposed.

The findings in this study also showed a very strong correlation between the chronological age and dental age, in both sexes for all three methods. No significant mean age difference was observed for both sexes using Willems I and Willems II methods.
The extent of the difference however observed in Demirjian's method (0.58(males) and 0.85 (females) which was statistically significant for both sexes was sufficient enough to cast doubts upon the utility of Demirjian's method for North central Nigerian population. This is similar to a study on northern Chinese children by Zhai *et al.* [15] but is in slight contrast to a previous study on a Nigerian population which revealed a significant difference in CA and DA among the males, but converse was the case among the female children [8].

The strong correlation however observed between the chronological age and dental age means that Demirjian's method can indeed still be used to validly estimate the dental age of Ilorin children.
Willems's methods revealed consistently more accuracy of estimating the chronological age (with a mean difference of 0.01/0.03 (Willems I) and 0.15/0.11 (Willems II) for males and females respectively) compared to Demirjian techniques (with a mean difference of 0.58/0.85 for males and females respectively). Willems I method yielded a higher accuracy in males, while the non-sex-specific scored Willems II method yielded higher accuracy in females which is similar to Hedge *et al*. [16] results on an Indian population of children aged 5-16 years and Altan *et al*. [17] study on the Turkish population [18]. However, the Willems II method overestimated age in the females in this study which is similar to findings revealed in a population of Serbian children [19], Indian children [16] and Egyptian children [20].
Of all the methods, the one that has been extensively used is Demirjian's method which is simple and practical as it clearly defines the stages of tooth development thereby leading to minimal inter and intra-observer variability.

Although the current results and other reports have suggested that Demirjian's method can be unsuitable as a forensic age estimation tool, Demirjian's method is still a recommended method to assess individual dental maturity. Notably, no method has the ability to accurately determine the exact CA, because differences between the estimated dental age (EDA) and CA appear, not only due to the accuracy of the applied method but also due to other factors, such as the examiners' skills and experience, the studied sample size and distribution, developmental and environmental variability between the studied subjects themselves, and the methods used to analyze and interpret the obtained results [13].
Although, our sample size appears small compared to those of similar studies, a small sample size is not considered a limitation in forensic scientific research.

Conclusion

In conclusion, Willems' methods are absolutely more accurate in the North central Nigerian population. Also, the level of accuracy of these three methods in the Ilorin population is acceptable. Although, significant differences between the estimated dental age and chronological age was observed with the Demirjian's method for both sexes, all methods could be relatively applicable to estimate age in an Ilorin population. However, for more accuracy, it will be judicious to use the most appropriate method, according to the results obtained, by sex. In forensic cases, when the sex is unknown or doubted, the Willems II method is appropriate.

Author's Contributions.

Conceived and designed by: OOO, all the other authors contributed substantially to data collection, analysis, and write up. All authors approved the final manuscripts.

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Funded by the authors.

Conflict of Interest

None declared

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The introduction must clearly state the question that the author(s) tried to answer in the study. It may be necessary to briefly review the relevant literature.

Only cite those references that are essential to justify the proposed study.

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This section should include only relevant, representative data and not all information collected during the study. Major findings should be presented clearly and concisely. Text, tables, and illustrations should be used sensibly while avoiding repeating in the text all the data depicted in the tables or illustrations and emphasizing or summarizing only important observations. Tables and figures should be restricted to those needed to explain the argument of the paper and to assess its support. It is necessary to cite the tables in the text and type them on separate sheets. It may also be useful to mention what the study did not find.

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Acknowledgements

In acknowledgements section, it is suitable to list all contributors who do not meet the criteria for authorship, such as a person who provided purely technical help, writing assistance, or a department head who provided only general support. Financial and material support should also be acknowledged.

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Each table should be typed in double-space on a separate sheet of paper. Tables not submitted as photographs must be numbered consecutively (Arabic numerals) in the order of their first citation in the text, with a brief but self explanatory title for each.
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