Original Article

COMPARATIVE ANALYSES OF THREE RADIOGRAPHIC DENTAL AGE ESTIMATION METHODS AMONGST NIGERIANS

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ABSTRACT

Background: Age estimation is a critical step in constructing biological profiles from human skeletal remains. This study aimed to compare three radiographic methods of age estimation with tested validity in different populations for accuracy and applicability in forensic investigations amongst Nigerians.

Methods: This was a retrospective study of panoramic radiographs (Planmeca Romexis®) captured from 46 young Nigerian patients between ages 6 to 21 years in a Federal Tertiary Health Institution in Southwest Nigeria between July and December, 2017. Parameters on the panoramic radiographs were measured and scored based on Demirjian, Cameriere and Kvaal radiographic dental age estimation methods. Data were analysed using SPSS version 20 at $p<0.05$.

Result and Conclusion: There was no significant difference between chronological ages and estimated ages of subjects considering Demirjian and Cameriere methods, but there was a significant age difference when Kvaal method was used ($p>0.5$). Demirjian method was found to be strongly correlated with chronological age ($rs = 0.763$); Cameriere method moderately correlated ($rs = 0.684$) and Kvaal method weakly correlated ($rs = 0.476$). Demirjian method showed the strongest direct relationship ($R^2 = 0.56$) followed by Cameriere ($R^2 = 0.44$) and Kvaal method ($R^2 = 0.22$). Demirjian system was the only significant predictor of the chronological age of Nigerian subjects using multiple linear regression.

Keyword: Age estimation, Demirjian, Kvaal, Cameriere, Nigeria

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INTRODUCTION

Age is an important concept with different focuses by many researchers on its implications as related with to gender and other social dimensions. Anthropological works have attempted to explain gender attachment to age and that men and women may use different yardsticks to weigh life changes and advancement. Understanding this helps our perspective on role assignment and resource allocation. Bearing this in mind, measurement of age must factor in gender difference in a cognitive association.[1] There are other social dimensions with close application and understanding with age structuring. These have a direct effect on behavioral patterns and life experience, which goes together with social locations. 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.[2,3,4,5] Currently, experts in forensic anthropology, sociology, anatomy and clinical disciplines such as dentistry and pediatric endocrinology have published works on how best to circumvent age identity of individuals from available variables specific to such individual and specific populations, but these are not

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without notable shortcomings.

Age estimation is a critical step in constructing biological profile from human skeletal remains.[6] The forensic anthropologist is often saddled with the responsibility of assisting medico-legal officials with identification by presenting a probable age range of a deceased through the examination of various physical traits which have been shown to degenerate with age in a predictable manner.[6] This question arises every day even in other issues of medico-legal concerns such as marriage, inheritance, insurance and disputed sex, criminal cases, misplaced identity as well as in patient's treatment planning.[7] Amongst various traits, teeth have been documented as one of the most reliable tools in the process of age estimation especially in the first and second decade using the stages of development as one of the most utilized and consistent indicators in assessing age of victims.[5,8]

Most methods of age estimation in literature, whether dental or skeletal, are population population-based while some are sex-specific due to variations in growth and development in both sexes.[9] For instance, Demirjian have studied and compared French-Canadian standards with Finnish, Swedish, Norwegian and South German children while Al-Emran (2008) have assessed the French-Canadian standard to the Saudi population.[10] Other authors and researchers have applied the different methods of age estimation to their local population to test for validity and evaluate suitability of using various standards for the local population. The United Nations Children's Fund in 2007 reports that birth registration is not a priority in many households in Nigeria.[11] This creates a problem of identification of missing or deceased persons, international cases of adoption and child trafficking and even with orthodontic treatment in the mixed or adult dentition.[11] Since the accuracy of age estimation is important in the Nigerian forensic context against the background of many unregistered births, the dearth of studies to test and/or compare established methods of age estimation is even more worrisome. Therefore, the aim of this study wasis study aimed to compare three radiographic methods of age estimation with tested validity in different populations for accuracy and applicability in forensic investigations amongst Nigerians.

METHODS

Study Population

This retrospective study comprised unknown patients with known birth dates, gender presenting for various radiodiagnostic purposes at the OPG section of the Oral Pathology Department of a federal tertiary health institution in southwest Nigeria. All available orthopantomographs of patients below 21 years of age available between July and December 2017 were retrieved and selected based on inclusion and exclusion study criteria. This was done because radiographic records done earlier than July 2017 were lost from the hospital database and could not be accessed. A total of 50 orthopantomographs available were collected from the Oral Radiology database at the of the hospital. Four of the assessed radiographs did not meet criteria for inclusion in the study and were hence excluded.

This study was carried out in Ibadan, the capital city of Oyo State with eleven Local Government areas. This panoramic X-ray machine is available in only two government hospitals in the South-Western part of Nigeria. This study is a retrospective study of panoramic radiographs (Planmeca Romexis®) from 50 young individuals

between the ages of 6 years and 21 years of age. These individuals are healthy Nigerian patients requesting panoramic radiograph for various purposes at the hospital, and whose radiographs were taken as part of routine treatment between July and December, 2017. Parameters on each orthopantomogram were recorded by means ofusing a digitizer attached to the X-ray viewer. Measurement of all parameters was made using Planmeca Romexis Viewer software. Developmental maturity stages from zero through A to H were assigned to each tooth and scored as defined in the diagrammatic scale of Demirjian for the Demirjian method (Figure 1, Figure 2 and Table 1). Measurements of various tooth dimensions according to the Kvaal and Cameriere methods were also recorded (Figure 3).

Research instruments

Planmeca Romexis rotational panoramic X-ray machine was used for the images which are stored via a computer. Parameters on each orthopantomogram were recorded by means ofusing a digitizer attached to the X-ray viewer and copied to compact discs. Measurements on the stored images were done using a software Planmeca Romexis Viewer 4.5.0.R (12/29/2016).

Demirjian Method

Developmental maturity stages from zero through A to H were assigned to each tooth and scored as defined in the diagrammatic scale of Demirjian (Figure 1). These were then converted to weighted maturity scores (Figure 2) which were summed up and used to calculate the dental age of the children according to the Demirjian criteria. As described by Demirjian, only teeth in the lower lower-left quadrants were assessed in this study. Chronological age was calculated from the birth date as recorded in the hospital record at first presentation to two (2) decimal points.

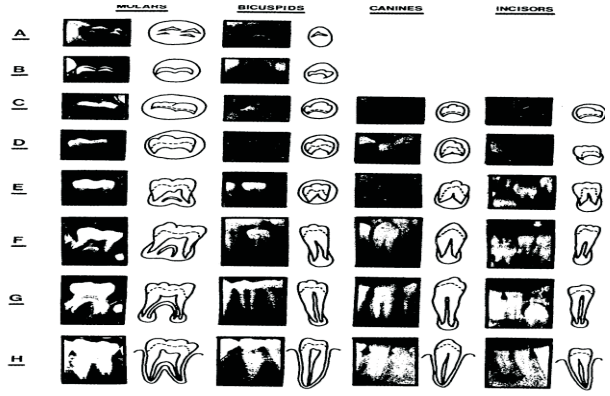

Figure 1: Demirjian staging for rating developmental stages of left lower mandibular teeth (excluding the third molar)[12]

Table 1: Self-weighted scores for Dental Stages according to the Demirjian Method[12]

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

Boys

Tooth	Stage 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

Tooth	Stage 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	1.8	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

Cameriere Method

A proforma was generated to record measurements of parameters on stored images using a software Planmeca Romexis Viewer 4.5.0.R (12/29/2016). Mandibular left teeth were examined, and Cameriere method was applied. Dental age estimation was done by using Cameriere's Regression formula:

Age = 9.402-0.879g+0.663No-0.711s-0.106sNo equation 1

where Where g is a variable equal to 1 for boys and 0 for girls; N0 represents the number of teeth with closed apex and s is the sum of A/L for every tooth at open apex. Ai: the radiographic distance between inner sides of the open apex or sum of the distance between inner sides of open apices in two-

rooted first and second molars. (Ai, i= mandibular left 1 2 3 4 5 (one root; for mandibular left 6, i= 6a+6b and for mandibular left 7, i= 7a+7b). 1= permanent central incisor, 2= permanent lateral incisor, 3= permanent canine, 4= first premolar, 5= second premolar, 6= first permanent molar, 7= second permanent molar with "a" and "b" representing the mesial and distal roots of mandibular left 6 and 7 respectively. Li: radiographic tooth length. (Li, i= mandibular left 1 2 3 4 5 6 7). Dental maturity is evaluated with the measurement of the seven left permanent mandibular teeth (Xi= Ai/Li, i= 1 2 3 4 5 6 7). Sum of normalized open apices, s= X1+X2+X3+X4+X5+X6+X7

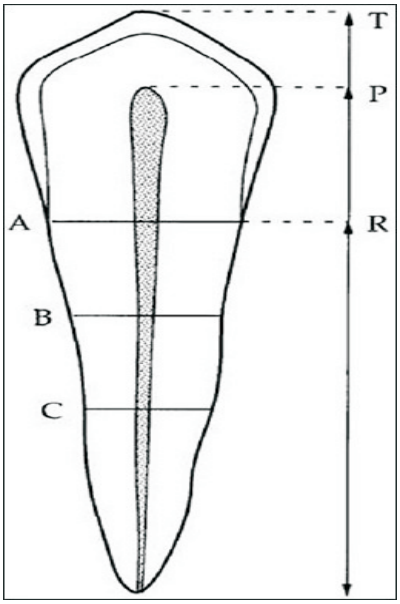

Figure 2: Diagram of a tooth showing parameters measured for the Cameriere and Kvaal methods.

Kvaal Method

Based on the description by Kvaal et al. 1995, six indexed teeth were selected. These include mandibular lateral incisors, mandibular canine, mandibular first premolar and maxillary central and lateral incisors and maxillary second premolar all on the left. Measurements on the stored images were done using a software Planmeca Romexis Viewer 4.5.0.R (12/29/2016). The following measurements were carried out on the radiographs of all six indexed teeth: the maximum tooth length, pulp length and root length on the mesial surface from the cemento-enamel junction to root apex. Other measurements are the root and pulp width at the cemento-enamel junction (level A), at mid-root level (level C), i.e. halfway between the cemento-enamel junction and the root apex and at the midpoint between the cemento-enamel junction and midroot level (level B).

RESULTS

A total of forty-six orthopantomographs were assessed in this study. The mean ± SD age of subjects whose panoramic radiographs were recruited in the study was 11.51 ± 3.58 years. A large proportion of the population were was within the age range of 10-14 years. Twenty-six (56.5%) were males and twenty (43.5%) were females. A large proportion 42 (91.3%) of the population of 42 (91.3%) belong to the Yoruba ethnic group (Table 2).

Table 2: Socio demographic Characteristics of subjects

Socio demographic Characteristics	n (%)
Age (years)	
< 10	16 (34.8)
10-14	20 (43.5)
15-20	8 (17.4)
>20	2 (4.3)
Mean	...
Gender	
Male	26 (56.5)
Female	20 (43.5)
Ethnicity	
Yoruba	42 (91.3)
Igbo	1 (2.2)
Hausa	1 (2.2)
Others	2 (3.6)

Difference in the mean between chronological age and age estimated by the three methods based on gender

Table 3 shows the comparison between the chronological age of subjects and the estimated age according to gender. The Kvaal method was the only method of estimating dental age that showed a significant difference when compared with the chronological age of subjects with a mean difference of 9.05 years in males and 15.19 years in females. See table 4.5 for details.

Correlation between Chronological age and the estimated age

Table 4 shows the relationship between chronological age of subjects whose panoramic radiographs were analysed in this study and the estimated ages by Kvaal, Cameriere and Demirjian methods. Demirjian method was found to be strongly correlated with chronological age (rs = 0.763). Cameriere method was moderately correlated with chronological age (rs = 0.684) while Kvaal method was weakly correlated with chronological age (rs = 0.476). Figure 3-5 shows the linear relationship between the three methods and chronological age. Demirjian method showed the strongest direct relationship (R^2 = 0.56) followed by Cameriere (R^2 = 0.44) and Kvaal method (R^2 = 0.22)

Table 3: Difference in the mean between chronological age and estimated ages by gender

Gender	Method	Mean	SD	Min	Max	Mean Diff	p-Value
	Chronological Age	11.81	3.80	6.11	20.01	-	-
	Kvaal	2.75	23.14	-61.28	43.85	9.05	0.008
Male	**Cameriere**	10.29	2.27	6.52	13.16	1.51	0.65
(N=26)							
	Demirjian	13.21	4.47	7.40	19.00	-1.40	0.67
	Chronological Age	11.13	3.33	7.40	20.60	-	
	Kvaal	-4.06	34.59	-103.72	55.24	15.19	0.007
Female							
(N=20)	**Cameriere**	11.09	2.05	7.44	14.04	0.03	0.99
	Demirjian	11.63	2.75	7.50	16.00	-0.49	0.93

Table 4: Correlation between Chronological age and the estimated age

Method	Chronological Age	Kvaal	Cameriere	Demirjian
Chronological Age	1.00			
Kvaal	0.476**	1.00		
	0.001			
Cameriere	0.684**	0.483**	1.00	
	0.000	0.001		
Demirjian	0.763**	0.485**	0.861**	1.00
	0.000	0.001	0.000	

**= p<0.01

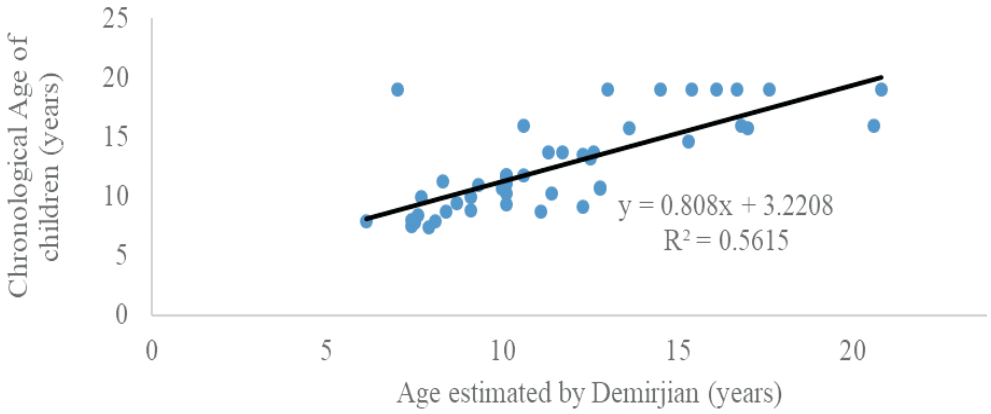

Fig 3: Linear relationship between chronological age and age estimated by Demirjian

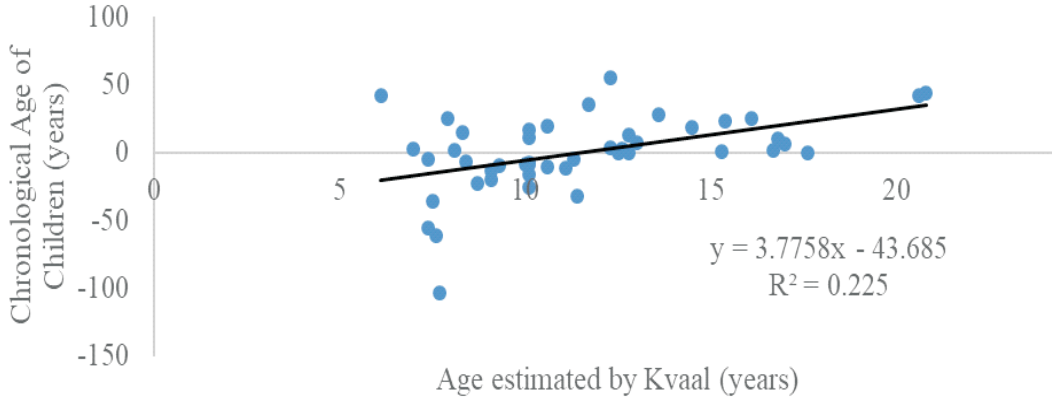

Fig 4: Linear relationship between chronological age and age estimated by Kvaal

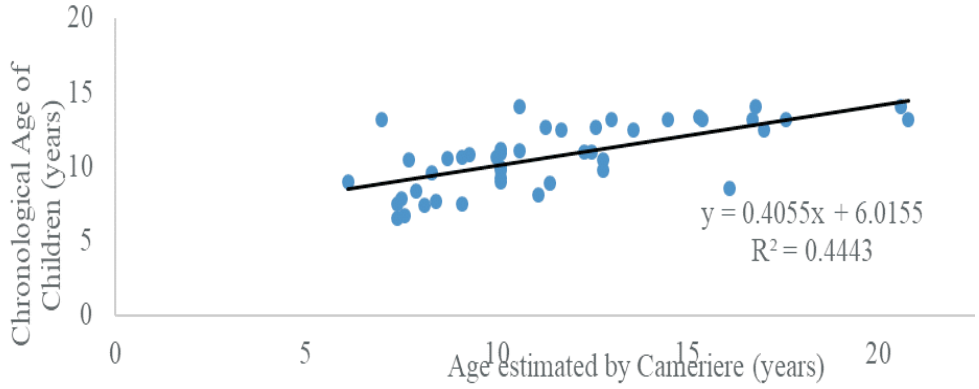

Fig 5: Linear relationship between chronological age and age estimated by Cameriere

Predictor of chronological age between Kvaal, Cameriere and Demirjian methods

A multiple linear regression was calculated to predict the chronological age based on the Kvaal, Cameriere and Demirjian methods. A significant regression equation was found ($F(3,41) = 20.64$, $P<0.00$, with an R^2 of 0.602.

Subjects' predicted age is equal to **2.525 + 0.019 (Age by Kvaal method) + 0.182 (Age by Cameriere method) + 0.560 (Age by Demirjian method)** where the three methods were coded in years. The chronological age increased by 0.56 years for each age calculated by Demirjian method. The Demirjian method was the only significant predictor of the chronological age of participants

Regression analysis with the methods of age estimation (predictor) and Chronological Age as the dependent variable

Model	Unstandardized coefficient		Standardized Coefficient	Significance	
	B	Stand error	Beta	t-value	p-value
Constant	2.525	1.988		1.270	0.211
Kvaal	0.019	0.015	0.148	1.312	0.197
Camariere	0.182	0.283	0.11	0.642	0.524
Demirjian	0.560	0.165	0.599	3.399	0.002

Model equation; $Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3$

Where, β_0 = **Constant**

$\beta_1, \beta_2, \beta_3$ = Standard coefficients

X_1, X_2, X_3 = Three methods

DISCUSSIONS

This study aimed to compare the accuracy and validity of the Demirjian, Cameriere and Kvaal radiographic estimates of dental age in a Nigerian population for application in forensic practice. The study suggests that dental age estimated using Demirjian method put subjects ahead of their chronological age while Cameriere appears to underestimate the age of subjects which corroborates with the findings of Ifesanya and Adeyemi 2012[11]. The present study revealed that by the Cameriere dental age estimation method, Nigerian male children are 1.52 years behind their chronological age while their female counterparts are just about 0.04 years behind. The Demirjian criteria shows the reverse as both male and female Nigerian children were dentally ahead of their chronological age by 1.4 years and 0.5 years, respectively. The Kvaal method showed a significant difference in both male and female subjects when compared with chronological age with a mean difference of 9.05 years and 15.19 years, respectively. This showed that Cameriere method is more accurate than the Demirjian and Kvaal methods when adjusted for gender in children aged 6 to 20 years of age. The Demirjian and Cameriere methods that showed a significant relationship between chronological age and dental age of subjects seem to be more correlated in the female subjects than males irrespective of the side of the divide of chronological age. The results are consistent with other studies amongst Nigerian, Turkish, Chinese and Senegalese children using dental age assessment by the Demirjian criteria[11]. Other studies that assessed the validity of the Cameriere method established more varied results compared with the Demirjian method. For instance, Babu *et al*., in 2016 reported similar finding as this study by dentally overestimating age of subjects using Demirjian standards and underestimating age by the Cameriere method but established a statistically significant relationship between chronological age and dental age using the two methods[13]. Santana *et al*., 2017 did a study in a multi-population American study using Cameriere European formula and found similar result as in this study from the study population[14]. In a study comparing Cameriere, Haavikko and Willems radiographic methods of age estimation in Bosnian-Herzegovinian children, the authors reported that the Cameriere method gave an estimate that is ahead of the chronological age of girls by 0.09 year but underestimate the age of boys by 0.02 year in the study participants.

The present study also indicates that Demirjian method is strongly correlated with the chronological age of study subjects (rs = 0.763) while Cameriere (rs = 0.684) and Kvaal (rs = 0.476) are moderately and weakly correlated with the actual age of subjects respectively. The Demirjian system tends to estimate age closest to the chronological method than the Cameriere and Kvaal. While no study was found in the literature comparing age estimation using Demirjian and Kvaal, Dermijian correlated more positively with the chronological age of this population. This finding is supported by the findings of Alghali *et al.* 2016.[15] Babu *et al*., 2016 on the validity of Demirjian and Cameriere methods amongst Puducherry reported a more accurate and stronger correlation of estimate from the Cameriere method than Demirjian and Williem's.[14] Ifesanya and Adeyemi reported high correlation between the dental and chronological age of children studied, but the strength of this correlation was not stated by the coefficient of correlation.[11,15]

CONCLUSION

This study established a better accuracy of the Demirjian system over the Cameriere and Kvaal as well as its importance as the

only significant predictor of the chronological age of Nigerian subjects. This study therefore, therefore, recommends the Demirjian age estimation system as a valid tool for estimating the age of subjects with unknown birth records in forensic investigations. The Cameriere method is also recommended as a valid system for age estimation, especially where only periapical radiographs of a subject are available, especially in low resource settings where orthopantomographs are not available. It is clear from this study that the Kvaal method is not valid neither is it useful for age estimation during the first to early third decade.

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