Can a Regression Equation Developed from the Measurement of a Single Mandibular Canine be used for Dental Age Estimation?

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ABSTRACT

Background: Radiographic method of dental age estimation allows the clinician to monitor the full range of development of the tooth. The use of single tooth could reduce the complexity of dental age prediction

Objective: To develop and test the validity of a regression model for dental age estimation using a single mandibular canine tooth

Methods: This cross-sectional study involved 93 participants (56 males and 37 females) aged 5 to 18 years recruited from a tertiary health care facility in the North-Central region of Nigeria over 10 months. Linear measurements of the width of the open apex and the tooth length of a single mandibular canine were done on a digital peri-apical radiograph using the Carestream digital software. Linear regression was used to generate the regression model using the pulp width-tooth length ratio of a single mandibular canine and gender as predictive factors. Paired t-test was used to compare the chronological age and the predicted dental age. The level of significance was set at $p<0.05$.

Results: Gender and pulp-width/tooth length ratio significantly explained 62.2% ($R^2=0.622$) of the variation in the chronological age ($p<0.001$). The median of the residuals was -0.116 years with an interquartile range IQR of 1.36 years. On average, the regression model showed that predicted dental age was significantly overestimated among females ($p=0.007$) but not in males ($p=0.735$).

Conclusion: The regression model generated in this present study could serve as a guide for predicting chronological age among Nigerian children and adolescents.

Key words: Regression model, Mandibular canine, Dental age

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INTRODUCTION

Evaluation of maturation plays a vital role in orthodontics and paediatric dentistry. Similarly, it is a valuable tool for legal bodies and forensic science in identifying individuals. Maturation indicators such as height,[1] skeletal age using the cervical vertebrae and wrist bone,[2,3] secondary sexual characteristics,[4] biochemical methods such as insulin-like growth factor 1(IGF-1)[5] and dental development which involves dental emergence and mineralization[6,7] are used in the estimation of actual age. Some of these methods, such as the use of the cervical vertebrae, are complex, expensive and require radiation exposure, while IGF-1 is invasive and expensive.

Although the use of chronological age is a fast and easy way to estimate the developmental age, it often does not correlate with the maturation pattern and has been adjudged unreliable.[8]

Factors ranging from ethnicity, sex, climate, malnutrition, and endocrine in-balance could significantly impact maturation. However, dental calcification is less likely affected by environmental factors and local factors such as dental arch space, extraction of primary teeth, or tipping or impaction of teeth, which may interfere with the entire eruption process.[9]

Various researchers have used radiographs of the different morphological changes during dental development to estimate the developmental ages of the tooth.[10,11] However, the subjectivity of identifying the morphological changes prompted the development of objective linear measurement of these developmental stages for accurate dental age estimation.[12-14]

Cameriere et al,[14] assessed dental maturity using the open apices of the left seven permanent mandibular teeth. The dental age was estimated based on the relationship between the chronological age and the measurement of the open apices of the index teeth.[14] This method[14] is objective and reliable compared to Demirjian's method.[15] The initial regression model developed by Cameriere et al[14] from the panoramic radiograph of seven permanent mandibular teeth is more complex when compared to a subsequent model developed from the peri-apical radiographs of upper and lower canines.[16] When fewer teeth are used for dental age estimation, it reduces the complexity of age estimation and reduced radiation exposure, especially when peri-apical radiographs are utilized. Regression models developed from maxillary and mandibular canines for dental age estimation have been reported to be reliable in different population[17-19] with a strong correlation between single mandibular canine and chronological age.[20] The canine tooth is mainly used because it is the single-rooted tooth with the largest pulp area, which is very easy to analyse.[16]

There are few studies on dental age estimation among Nigeria Children. These studies used various methods that involved multiple teeth, such as the Demirjian and Cameriere methods[6,21], with various outcomes. Olusegun et al. [21] reported the Demirjian and Cameriere methods as valid tools for dental age estimation. At the same time, Ifesanya and Adeyemi[6] observed variation between chronological age and dental development using the Demirjian method. A meta-analysis by Esan et al.,[27] noted significant dental age overestimation in numerous populations with the Demirjian method, while the Willem method appeared more accurate.

The present study was conducted among a Nigerian population to develop a specific regression formula from measuring the open apex of a single mandibular canine using a digital peri-apical radiograph. This study was conducted because there appears to be no record of specific regression formula developed for dental age estimation using the immature apex of a single tooth in a Nigerian population. Also, the regression model developed in this study was used to test the null hypothesis that it will significantly explain the variation in the chronological age of the study participants.

Furthermore, the model was applied among a cross-section of participants to determine if the predicted dental age differed significantly from the chronological age concerning gender and age groups. Finally, the predicted dental age was correlated with the chronological age to determine the level of association.

MATERIALS AND METHODS

This was a cross-sectional descriptive study conducted among patients resident in Keffi and visited the Child Health Dental Clinic of the Dental Surgery Department of the Federal Medical Centre, Keffi, Nasarawa State. Ethical approval was obtained from the Health Research Ethical Committee of the institution (FMC/KF/HREC/2571/21).

Informed consent was obtained from the parent/guardian of the participants, while verbal assent was also obtained from participants. Children aged 5 to 18 years who were healthy with no obvious clinical evidence of developmental abnormality and with clear, undistorted good quality digital peri-apical radiographs were recruited for the study. The

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participants were categorized into the following age groups; 5-6 (5-6.99 years), 7-8 (7-8.99 years), 9-10 (9-10.99 years), 11-12 (11-12.99 years), 13-14 (13-14.99 years), 15-16 (15-16.99 years) and 17-18 (17-18.99 years).

Participants with multiple missing teeth, special need health care needs, a history of endocrine disorders and those with severe childhood illness were excluded from the study. Digital peri-apical radiographs of 93 participants attending the hospital (Child Dental Clinic, Federal Medical Centre, Keffi) comprising 56 males and 37 females were used in the study.

The chronological age of each participant was calculated from the date of birth to the date the digital peri-apical radiograph was taken. Parents/guardians of younger participants less than 12 years provided the children's date of birth, while older participants 12 years and above provided their date of birth, verified with their patents. Participants were recruited from January 2021 to October 2021.

Data collection

Digital peri-apical radiographs of the right mandibular canines were obtained using the bisecting angle technique. The left mandibular canine was used when the right mandibular canine was not accessible. Carestream digital sensor, RVG 142 size 1 (24mm x 40mm), was used to obtain the digital peri-apical radiographs.

Linear measurements of a single mandibular canine (width of the open apices and the tooth lengths) were carried out on the Carestream digital software (Appendix 1), according to the method described by Cameriere et al. [14] The measurements were normalized by dividing the width of the open apex by the tooth length (pulp width-tooth length ratio) to take care of the angulation and magnification of the radiograph.

Ten digital peri-apical radiographs were randomly selected to determine the reproducibility of the measurements. A single investigator recorded the pulp width, tooth length and the pulp width-tooth length ratio. Two sessions of measurements were taken at two weeks intervals, and intra-investigator reliability analysis was conducted using the intra-class correlation coefficient. There was a substantial and statistically significant agreement between the measurements; pulp widths; r=0.989, p<0.001, tooth lengths; r=0.943, p<0.001 and pulp width-tooth length ratios, r=0.921, p<0.001.

Data analysis.

Data on chronological age, pulp width-tooth length ratio, crown length and gender were entered into Statistical Package for Social Sciences (SPSS) version 22 to be used as reference categories of the dental age. Multiple linear regression with stepwise selection method was initially used to determine which reference category contributed significantly and was associated with dental age. Gender and the pulp-width/tooth length ratio (PWTLR) were observed to have contributed considerably as reference categories and were included in the multiple linear regression for the development of the regression equation for dental age estimation. The level of statistical significance for the study was set at p<0.05.

The normality of the data distribution was determined using the Z-test Score.[23] The Z-test Score was obtained by dividing the skew value (0.438) of data distribution with the standard error of skewness (0.250). The value was compared with the absolute z-test score of ±3.29 for medium-size sample test (i.e., between 50 and 300). A score of 1.752 was obtained, less than the absolute z-test score for the samples considered. This shows that data obtained from this study were within normal distribution. A parametric test was used to analyse the data afterwards.

RESULTS:

Majority of the study participants (67) were between 7-12 years of age. Age group 9-10 had the highest number of participants among males (18) and females (10). See Table 1.

This model gave a good level of prediction (R) level of 0.789 and the coefficient of determination was 62.2%. Also, the table on ANOVA showed that the generated model is a good fit for the data (p<0.001). Tables 2 and 3

Gender and pulp-width/tooth length ratio were shown to explain 62.2% (R^2=0.622) of the variation of the chronological age (p<0.001). The median of the residuals (when the observed age was subtracted from the predicted dental age) was found to be -0.116 years with interquartile range IQR (i.e., median of the 75%quartile minus the median of the 25% quartile) was 1.36 years. The regression model was shown to have significantly predicted the outcome (mean square=244.15; F=72.20; p<0.001).

The linear regression formula generated was:

Age= 14.307-14.075(PWTLR)-0.844g (g=gender, 1 for males and 0 for females), as shown in Table 4.

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In both genders, the mean ages for the 5-6 years, 7-8 years, 9-10 years and 11-12 years age groups were over-estimated while the mean ages for the 13-14 years, 15-16 years and 17-18 years age groups were underestimated using the linear regression model. The mean difference in the over-estimation was highest among the 7-8 years age group, males (0.74 years) and females (1.90 years) but lowest in the 5-6 years age group in both genders (males: 0.16 years and females: 0.34 years). In comparison, the mean difference underestimation was lowest in the 13-14 age group (males: 0.77 years and females: 0.58 years) but highest in the 17-18 years (males: 3.55 years and females: 3.11 years).

Among the male participants, there was no statistically significant difference between the chronological age and predicted dental age across all the age groups. However, among the female participants, there was a statistically significant difference between the chronological age and predicted dental age among the 7-8 years, 9-10 years and 11-12 years age cohorts (p<0.001, p=0.011 and p=0.011 respectively). The lowest standard error of mean recorded between the chronological age and the predicted dental age by this model was 0.318 and 0.399 in male 11-12 years old age and female 7-8 age group participants, respectively. On the other hand, the highest standard error of mean were 1.470 and 0.710 among 15-16 years males and 17-18 years females. (Table 5)

There was variation in the estimation of the chronological age using the predicted dental age by gender. There was no statistically significant difference between the predicted dental age and the chronological age in males (0.08 years, p=0.735), while among the females, it was significantly over-estimated (0.85 years; p=0.007), Table 6.

There was some correlation between the actual age and predicted dental age, which differed in gender. A strong positive correlation was only noted among the male participants aged 5-6-years (r=0.956, p<0.001) and 15-16 years (r=1.000, p<0.001), while negative correlations were observed in the age groups 11-12 years (r=-0.578, p=0.103) and 17-18 years (r=-1.000, p<0.001). Among the female, a statistically significant strong positive correlation was noted between the chronological age and the predicted dental age among the 11-12 years age group (r=0.937, p=0.001) but a poor negative correlation in the 13-14 years age group (r=-0.277, p=0.821), Table 7.

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Table 1: **Distribution of the participants by age group and gender.**

Age group	Male	Females	Total
5-6	8	3	11
7-8	13	9	22
9-10	18	10	28
11-12	9	8	17
13-14	4	3	7
15-16	2	2	4
17-18	2	2	4
Total	56	37	93

.Table 2: **Model summary of the regression**

Model	R	R square	Adjusted R square	Std. error of the estimate	Dfi	df2	Sig F Change
1	0.789	0.622	0.614	1.81397	2	90	<0.0001

Table 3**: ANOVA**

Model	Sum of squares	Df	Mean squares	F	Sig
1 Regression	488.306	2	244.153	74.199	<0.0005
Residual	296.445	90	3.291		
Total	784.452	92			

Pearson correlation showed that chronological age had a negative moderate correlation coefficient with pulp-width/tooth length ratio (r = -0.776, p<0.001) and a negative poor correlation coefficient with gender (r = -0.074, p= 0.241).

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Table 4: **Linear regression predicting chronological age.**

	Value	SE	t value	P value	95% CI Lower	95% CI Upper
Constant	14.307	0.641	22.334	<0.001	13.034	15.580
PWTLR	-14.075	1.161	-12.128	<0.001	-16.381	-11.770
Gender	-0.844	0.386	-2.188	0.031	-1.610	-0.078

Key: PWTLR = pulp-width/tooth length ratio, SE- Standard error, CI-Confidence interval.

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Table 5: Paired t-test comparison of chronological age (CA) and predicted dental age (PDA) derived from the pulp width-tooth ratio of a single mandibular canine according to age groups.

Age (years)	Gender	CA(SD)	PDA(SD)	MD(SD)	SEM	95% CI Lower	95% CI Upper	T	Df	P value
5-6	Male	10.75(3.99)	10.91(2.85)	0.16(1.52)	0.536	-1.430	1.107	-0.301	7	0.772
	Female	5.67(0.58)	6.00(1.12)	0.34(0.86)	0.496	-2.470	1.797	-0.679	2	0.567
7-8	Male	7.77(0.44)	8.51(1.75)	0.74(1.72)	0.478	-1.776	0.305	-1.546	12	0.150
	Female	7.67(0.50)	9.57(1.40)	1.90(1.20)	0.399	-2.822	-0.982	-4.767	8	***0.000**
9-10	Male	9.44(0.51)	9.74(1.45)	0.30(1.53)	0.359	-1.058	0.458	-0.832	17	0.450
	Female	9.70(0.48)	11.17(1.56)	1.47(1.46)	0.461	-2.512	-0.424	-3.182	9	**0.011**
11-12	Male	11.11(0.33)	11.53(0.72)	0.42(0.95)	0.318	-1.153	-0.313	-1.322	8	0.223
	Female	9.63(2.88)	11.02(3.24)	1.39(1.15)	0.405	-2.349	-0.433	-3.435	7	**0.011**
13-14	Male	13.50(0.58)	12.72(0.84)	-0.77(0.72)	0.361	-0.372	1.923	2.152	3	0.121
	Female	13.67(0.58)	13.09(0.29)	-0.58(0.72)	0.412	-1.197	2.357	1.405	2	0.295
15-16	Male	15.50(0.71)	12.76(2.79)	-2.74(2.08)	1.470	-15.938	21.418	1.864	1	0.313
	Female	15.50(0.71)	13.20(0.10)	-2.25(0.61)	0.430	-3.214	7.714	5.233	1	0.120
17-18	Male	17.50(0.71)	13.96(1.20)	-3.55(1.80)	1.275	-12.655	19.745	2.786	1	0.220
	Female	16.50(0.71)	13.90(0.30)	-3.11(1.00)	0.710	-5.911	12.131	4.380	1	0.143

CA-chronological age; PDA- predicted dental age; MD- mean difference between PDA and CA, SD- standard deviation; SEM-standard error of mean; CI-confidence interval; *- p value <0.001.

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Table 6: Average Paired t-test comparison of chronological age (CA) and the predicted dental age (PDA) derived from the pulp width-tooth ratio of a single mandibular canine according to gender.

Gender	CA(SD)	PDA(SD)	MD(SD)	SEM	95% CI Lower	95% CI Upper	T	Df	P value	r (p-value)
Male	10.30(2.78)	10.38(2.22)	0.08(1.71)	0.228	-0.535	0.380	-0.341	55	0.735	0.789(*0.000)
Females	9.87(3.15)	10.72(2.58)	0.85(1.81)	0.297	-1.453	-0.212	-2.863	36	0.007	0.819(*0.000)
Average	10.13(2.92)	10.51(2.36)	0.39(1.78)	0.184	-0.752	-0.019	-2.089	92	0.039	0.789(*0.000)

CA- chronological age; PDA- predicted dental age; MD- mean difference between PDA and CA, SD- standard deviation; SEM-standard error of mean; CI-confidence interval; r-Pearson correlation coefficient. *- p value <0.001.

Table 7: Pearson's correlation coefficient between chronological age (CA) and predicted dental age (PDA) according to age groups.

Age groups (Years)	Gender	R	P Value
5-6	Male	0.956	*0.000
	Female	0.654	0.546
7-8	Male	0.188	0.538
	Female	0.533	0.122
9-10	Male	0.037	0.883
	Female	0.356	0.313
11-12	Male	-0.578	0.103
	Female	0.937	0.001
13-14	Male	0.533	0.467
	Female	-0.277	0.821
15-16	Male	1.000	*0.000
	Female	1.000	0.006
17-18	Male	-1.000	*0.000
	Female	-1.000	*0.000

*-p value <0.001

DISCUSSION

Estimation of dental age is important in children and adolescents for identification purposes, especially in forensic science and medico-legal reasons. In addition, orthodontic and paedodontic treatments rely more on the dental age of growing children to be able to implement adequate preventive and interceptive treatment measures.

Numerous studies have developed regression equations using a single tooth or a combination of several permanent teeth.[24,25] But in our study, we used a single permanent mandibular canine to develop a specific formula for Nigerian children. The mandibular canine was used because it is a single-rooted tooth with the largest pulp area and a single root canal, which makes it less complex to assess.[26] Also, it is less likely to suffer from tooth wear lesions.

Our present study presents a higher percentage of variation (62.2%) of chronological age explained when compared to a study conducted among an Indian population where a single maxillary incisor was used with a variation of 39.9%.[24]

The study[24] generated a regression using the area ratio of the pulp/teeth (AR P/T) and the width of the pulp/teeth at the mid-point of the root (W-P/T) as the morphological variables. The morphological variables (AR P/T and W-P/T) used in the Indian study[24] had a higher standard error of regression coefficient of 19.575 and 18.855, respectively, when compared to the standard error (1.161) in our present model. Incisors have smaller pulp sizes and variations in their canal system, thereby reducing the accuracy of their measurements. Also, the different morphological variables used in the study[24] and the different populations under consideration could have accounted for the differences observed. The coefficient of determination reported in our study is comparable to the findings (R^2 of 63.5%) by Ravipati and Guttikonda[25] in another Indian population, in

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which the mandibular first premolar was used to generate a regression equation.

In studies that analysed several teeth, the coefficients of determination were greater than the observation made in our study. At the same time, the median residual error and interquartile range reported by the authors were lower.[27,28] The increased number of morphological variables (numbers of teeth) and the larger sample size used in studies by Cameriere et al[27] and Rai et al[28] could have accounted for better accuracy.

Despite the limited sample population in our present study, the permanent mandibular canine still significantly (<0.001) predicted the chronological age among Nigerians.

In our study, the average correlation coefficient between the pulp-width ratio and chronological age was negative (r=-0.776), which showed that the mandibular canine development rate does not follow a linear pattern with an increase in age. This means there is a decrease in the pulp-width ratio as the age of the individual increases. This finding is comparable with the observations made by previous researchers in different populations.[16,17,29]

The moderate inverse correlation observed between our study's pulp width/tooth length ratio and chronological age is comparable to the findings (r=-0.685) reported among Iranians.[29] Varying observations have been made between the correlations of predicted dental age using maxillary or mandibular canines and chronological age.[16,29] Dehghani et al[29] reported a higher correlation of age prediction with maxillary canines when compared to mandibular canines. Babshet et al[17] noted that the positioning of the peri-apical digital sensor in the mandibular sulcus is more precise, making it more acceptable for prediction. Other studies reported a higher predictive power of the pulp volume of mandibular canine when compared to the maxilla.[30] These studies concluded that the canine tooth plays a vital role in estimating age.[20]

Our study showed that the regression model developed overestimated the dental age among ages 5 to 12 years, with the greatest standard error of mean noted among those aged 5-6 years old in both genders. Furthermore, it was observed that individuals between 13 to 18 years had their dental age underestimated, with the greatest standard error of mean among males aged 15 to 16 years and females between 17 to 18 years. Overestimation of predicted age among 8-8.9 years was similarly reported by Latić-Dautović et al[31] but their findings were among those aged 14-14.9 years, which is at variance with our observation. On average, our model revealed that dental age was underestimated among females, which is similar to the findings of Latić-Dautović et al[31] In our study, no significant difference was observed between the predicted dental age and chronological in males. The standard errors of mean in our study in the various age groups were higher than that documented by Latić-Dautović et al.[31] The study by Latić-Dautović et al. involved the analysis of multiple teeth may have increased the accuracy in the model generated.[31] Contrary to our study, Ifesanyan and Adeyemi[6] reported a significant difference between dental age and chronological age in males and not in females using the Demirjian method.

This study shows that clinicians may want to use the pulp-width tooth length ratio of a single mandibular canine as a guide in the estimation of dental age among Nigerian children. The number of morphological variables used in our regression model and the number of participants recruited for this study could have accounted for the variation in the standard error estimate of the regression coefficient and the standard error of mean when compared with other studies.

Further studies with large sample sizes on using a single mandibular canine tooth for dental age estimation are required.

CONCLUSION

The predictive variables used in this study which include gender and pulp-width/tooth length ratio were shown to have significantly (p<0.001) explained the 62.2% variation (R^2) in the chronological age. Chronological age had a negative moderate correlation coefficient with pulp-width/tooth length ratio (r = -0.776, p<0.001). Furthermore, the regression model overestimated the dental age in participants aged 5 to 12 with the greatest standard error of mean among the 5-6 years age group in both genders. Individuals between 13 to 18 years were underestimated with the greatest standard error of mean among males between 15 to 16 years and females between 17 to 18 years. On average, this model showed that predicted dental age was significantly overestimated among females (p=0.007); however, among the males, there was no statistically significant difference between the predicted dental age and chronological age (p=0.735).

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Conflict of interest.
The authors declare that they have no competing interests.

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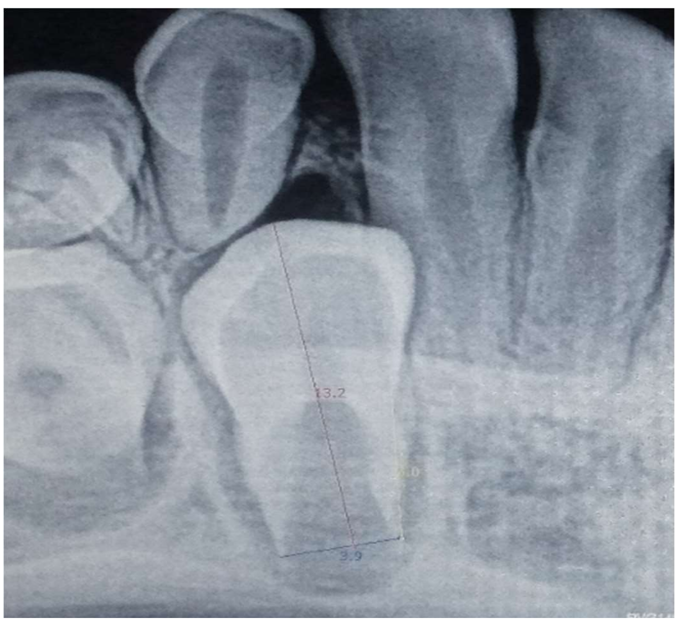
APPENDIX 1



Digital peri-apical radiographs of a study participant showing the permanent canine's pulp width and tooth length measurements.