

ESTIMATION OF THE CORRECTION FACTOR TO ASSESS THE CHRONOLOGICAL AGE OF GHANAIAN CHILDREN AND ADOLESCENTS USING THE DEMIRJIAN METHOD

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Abstract

Objective: To ascertain the correction factor for age estimation using the Demirjian method applicable to the study population in Accra, Ghana.

Methodology: It is a cross-sectional study of a secondary data involving 255 participants made up of 115 boys and 140 girls age between 5 and 18 years, attending the University of Ghana Dental School Clinic, Accra, Ghana. Their medical records were scrutinized for chronological age and their dental orthopantomograms analyzed for dental maturity scores and converted to dental age.

Results: Statistically, there was no significant difference between chronological age on one hand and both Demirjian age estimate and corrected factor predicted age. Factor predicted age however more closely matched chronological age. Above 15 years, the Demirjian method could not be applied to ascertain dental ages for boys.

Conclusion: Application of the factor predicted estimate to the Demirjian method can reliably predict the chronological age in the study population.

Key words: *Demirjian, Dental age, Ghana*

Introduction

Age is an individual's property, determined by date of birth. It confers assessment of biological growth progression and demographically as a means to personal and national identity. Skeletal and other hard tissue developments are used as bases for age assessment^{1,2,3} and identification as in forensics. Ghana has a social void for age determination in situations of undocumented birthing especially in the rural communities and in children released from bondage of modern-day child slavery, a practice that exists in areas of Ghana⁴. These children will grow up with no social and doubtful national identity. The scope extends through qualification for age-limiting events in sports, determination of age-associated legal culpability and in identification exercises in mass disasters.

Different protocols for age assessment exist. They could be based on skeletal examination especially of long bones, odontological, anthropological or psychological studies^{1,2,3}. These allow for an approximation of age assessment. In this study, one of the odontological methods, the Demirjian Method⁵ is used. It was conducted originally within a French-Canadian Caucasian ethnic grouping. It is generally accepted to yield a good approximation of dental

maturity from which age estimation can be derived. It involved the sub-adults' group (children and adolescents) between 5 to 18 years of age. This methodology is predisposed to population genetic variations, however. To increase its predictive value and accuracy, it's application in different ethnic groupings has had to go through ascertaining an appropriate correction factor, which is the primary aim of this study. This has not been conducted in Ghana before and it is hoped that future reviews will be undertaken to improve upon a consensus correction factor for age determination based on the Demirjian method for the Ghanaian population.

Materials and Methods

Study design

This is a retrospective study.

Study Site

Is the University of Ghana Dental School Clinics and it is a facility for undergraduate and clinical dental specialty training. Patients attending the clinics routinely have OPGs taken as part of baseline investigations especially if presenting for the first time and stored in a database at the records unit. Those who met the inclusion criteria had their films included as part of the study. Between 100- 150 patients are seen daily at the clinics.

Study Population

Ghanaian children and adolescents aged 5-18 years attending our clinics. Inclusion criteria are clear panoramic radiographs of adequate diagnostic quality without blurring or artefacts in the region of the lower left quadrant with permanent teeth present (with the

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exception of third molars) and free of pathology that might affect tooth maturation. Healthy growth with no reported incidence of amelogenesis imperfecta, regional odontodysplasia, nutritional deficiency, Down's syndrome *etc.* Presence of all permanent mandibular teeth, specifically on left side, whether erupted or un-erupted, on OPG taken for diagnostic and/or treatment purposes.

Exclusion criteria are OPG of patients with caries and periapical pathologies, developmental anomalies bilaterally, congenitally missing teeth or missing due to extractions, patients with image distortions due to over/under exposure. Children undergoing orthodontic treatment and identical twins.

Study sample

The study sample consisted of 255 digital orthopantomographs taken from children and adolescents aged 5-18 years and made up of 115 boys and 140 girls. The final selection excluded 6 boys and 1 girl whose determined dental maturity scores did not have an equivalent dental age on the Demirjian chart because they were far above the 18 years limit.

The sample population was stratified by gender into males and females and also by age into 13 subgroups of increments of one year. The dental ages of the children were obtained based on their dental maturity scores and read off the Demirjian chart. A regression model was deployed to obtain an estimated correction factor. The model provided the coefficient of the dental age and the intercept of the line. These two parameters were used to predict the chronological age(CA) with an improved accuracy as shown in the results (Table 4). Using the regression equation and the correction factor, each child's age was estimated to give the factor predicted ages.

Data collection Tool

A data extraction form was developed to collect demographic information from folders of dates of birth and sex and the outcomes of the OPG analysis for dental maturity scores.

Quality Control Measures

Three examiners self-trained and calibrated using 20 radiographs by following the schematic description of the Demirjian stages to improve inter- and intra-examiner reliability. Each examiner analyzed 20 sets of data by calculating the actual chronological age from the recorded date of birth compared with the OPG at the exposure date.

The dental developmental information analysis as per the Demirjian protocol was undertaken separately by each examiner. The data gathered by each examiner on each radiograph were compared and any differences if any were discussed and a consensus result arrived at. This was done to improve inter and intra-examiner reliability without estimating kappa coefficient of agreement.

Data Analysis Plan

Chronological and dental ages were summarized by means and Standard deviation. The two ages were compared using paired t-test. Pearson's correlation coefficient R was used to estimate the linear association between the chronological and the estimated dental age for both boys and girls. Regression model was used to test how well the dental age predicts the chronological age. The correction factor was derived from the coefficient of the independent dental age to the chronological age. Analysis was done using SPSS version 25.0 (IBM, Armonk, New York, USA).

Ethical Approval

The study was approved by the College of Health Sciences Ethical and Protocol review committee with approval number – *CHS-Et/M5-5.8/2020-2021*.

Results

A total of 255 participants involving 115 boys and 140 girls took part in the study (Table 1).

Demographic characteristics of participants

Table 1: Distribution of Age group by sex

Age	(Age range)	Sex		Total %
		Male %	Female %	
5	5.0 -5.99	8 (47.10)	9 (52.9)	17 (100)
6	6.0 - 6.99	12 (44.1)	15 (55.6)	27 (100)
7	7.0 - 7.99	18 (50.0)	18 (50.0)	36 (100)
8	8.0 - 8.99	20 (51.3)	19 (48.7)	39(100)
9	9.0 -9.99	11 (42.3)	15 (57.7)	26 (100)
10	10.0 - 10.99	14 (48.3)	15 (51.7)	29 (100)
11	11.0 - 11.99	12 (66.7)	6 (33.3)	18 (100)
12	12.0 - 12.99	6 (35.3)	11 (64.7)	17 (100)
13	13.0 - 13.99	5 (45.5)	6 (54.4)	11 (100)
14	14.0 - 14.99	7 (41.2)	10 (57.8)	17 (100)
15	15.0 - 15.99	2 (18.2)	9 (81.8)	11 (100)
16	16.0 - 16.99	0 (0.0)	5 (100)	5 (100)
17	17.0 - 17.99	0 (0.0)	2 (100)	2 (100)
	Total	115 (45.1)	140 (54.9)	255 (100)

Six boys with ages varying from 15.43 to 17.15 years and 1 girl aged 16.28 years were excluded from the analysis because their dental maturity values fell outside the upper limit of 18 years on the Demirjian chart. Therefore, no boy above 16 years (CA) qualified to be in the analysis. Generally, there was overestimation by both Demirjian and factor-corrected methods. For males, the mean over-estimation (MOE) by Demirjian was 0.93 years and factor predicted by 0.12 years. For females, there was overestimation by 0.83 for Demirjian only but not for the factor predicted. (Table 2).

Table 2: Descriptive summary of the chronological, dental and factor predicted ages by sex

Sex	Chronological Age (CA)	Predicted Age Using Demirjian Method (DAE)	Factor predicted Age (FPE)
Male (n=115)	9.48 ± 2.64	10.41 ± 2.74	9.60 ± 2.67
Female (n=140)	10.23 ± 3.25	11.06 ± 3.20	10.23 ± 3.12
Total (n=255)	9.89 ± 3.01	10.77 ± 3.01	9.94 ± 2.90

The correlation between the chronological age (CA), the Demirjian age estimate (DAE) and the factor predicted ages(FPE) are shown as follows, CA and DAE was 0.963, $p < 0.001$; CA and FPE was 1.000, $p < 0.001$. The comparison of mean ages for each age group of the three categories of CA, DAE and FPE ages are shown in Figures 1 and 2 for boys and girls. For both boys and girls, the graphs indicate that the FPE ages were closer to the CA than the DAE. There was therefore significant improvement on the estimates of the ages by FPE over DAE. For boys, just before 14 years of CA, there is a dip to underestimation by FPE but soon after at CA of 15.4 years, a gross increase in dental maturity scoring occurs making DAE impossible.

This may signify a spurt in dental maturity at this period for the boys. For girls, by 15 years, a general underestimation occurs for both DAE and FPE but more deeply for the later. However, the difference between overestimation and underestimation was not statistically significant (Table 3).

Comparisons of over and under estimation between males and females

Table 3: Over and under estimation categories

Row Labels	Over-estimation		Under-estimation	
	N	percent	N	Percent
Boys	60	52.17%	55	47.83%
Girls	80	57.14%	60	42.86%
Grand Total	140	54.90%	115	45.10%

Test for significant: $\chi^2 = 0.44491$, $df = 1$, $p = 0.5048$

Table 4. Regression model for males and females

Coefficients		Unstandardized Coefficients		Standardized Coefficients Beta	t	Sig.
		B	Std. Error			
Male Model	(Constant)	-.285	.237		-1.206	.230
	Predicted Age Using Demirjian Method	.938	.022	.970	42.676	<.001
Female Model	(Constant)	-.556	.284		-1.955	.053
	Predicted Age Using Demirjian Method	.975	.025	.958	39.475	<.001

- a. Male, Dependent Variable: Chronological Age. With Adjusted R-square value = 0.942
- b. Female, Dependent Variable: Chronological Age with Adjusted R-square value = 0.919

The degree of over and under estimation for the males and also for females were not significant. However, there was more overestimation for the girls (57.14%) whilst the underestimation (47.83%) was more in the boys. (Table 3)

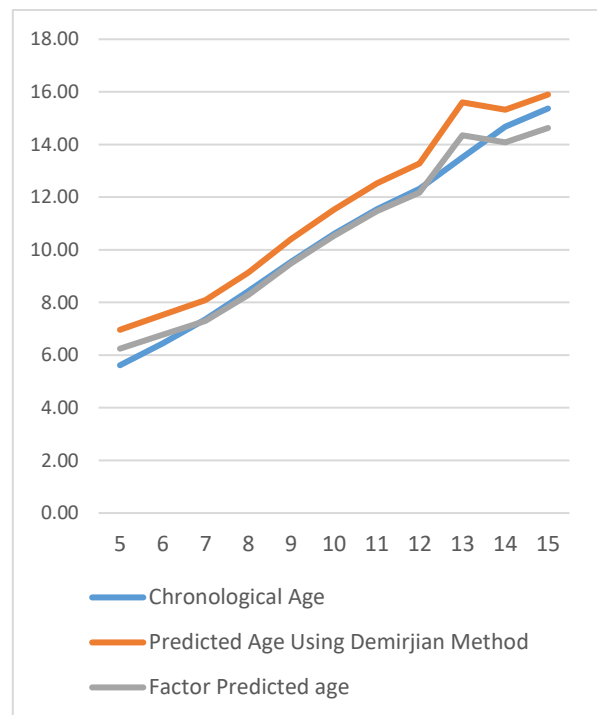


Figure 1: Comparison of the three estimated mean ages for Boys.

Regression models to estimate the correction factor for Males and Females

Using the CA as dependent variable and predicted ages as independent variables the Table 4. shows the coefficients of the independent variables with significant r-square value of 0.942 for boys and 0.919 for girls. The model for the prediction of the corrected factor for males is given by the equation: **Chronological Age= 0.938 x Dental Age - 0.285** That for females is given by: **Chronologic Age = 0.975 x Dental Age - 0.556**

Relationship between the three age categories

There was significant correlation among all the three age categories as shown in Figures 1- and 2-line graphs and scatter plots depicted by Figures 3 to 6, all with r-square values greater than 0.9.

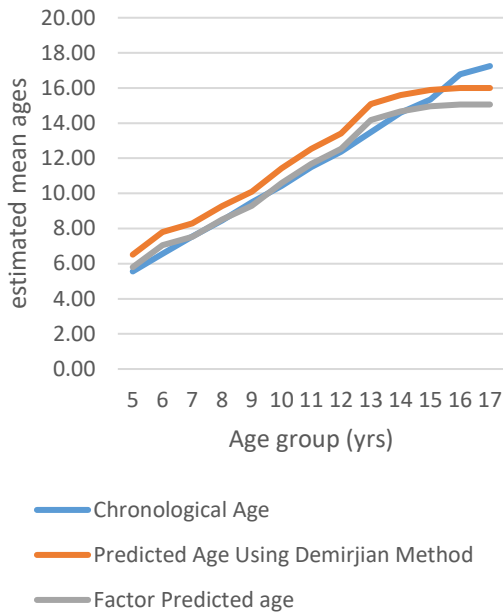


Figure 2: Comparison of the three estimated mean ages for Girls.

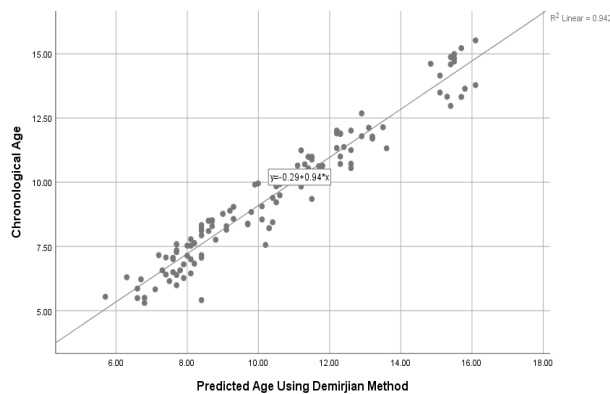


Figure 3: Scatter plot for CA and DAE- Boys

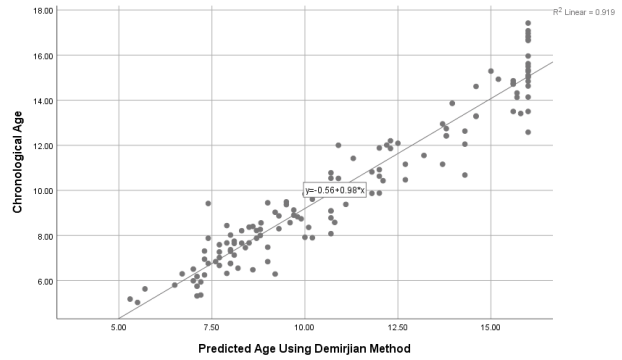


Figure 4: Scatter plot for CA and DAE- Girls.

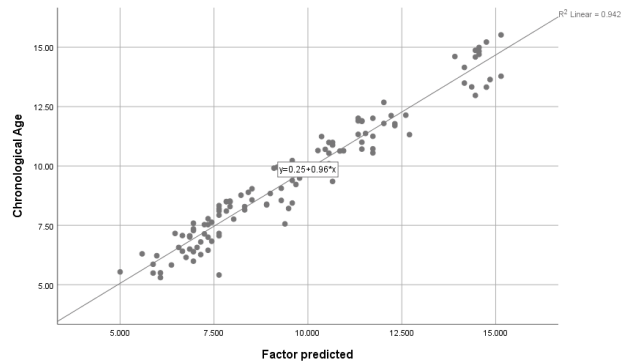


Figure 5: Scatter plot for CA and FPE - Boys.

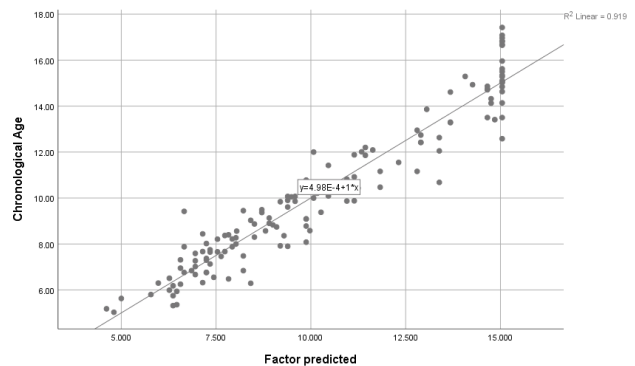


Figure 6: Scatter plot for CA and FPE - Girls.

Discussion

The Demirjian method for age-estimation is based on dental developmental stages and is accepted generally for this purpose⁵.The initial study was conducted on a French-Canadian population and the outcome is known to be population-type and ethnic-origin dependent. A systematic review and meta-analysis conducted by Jayaraman et al⁶ in 2013 on the initial Demirjian methodology concluded that there is an inherent tendency towards dental age overestimation. In the original French-Canadian standards, the difference between the dental age and chronological age ranged from .17 to .33 years in the boys and from -.02 to .48 in the girls. In our study, the respective differences ranged from .02 to 2.64 in boys and .01 to 3.62 in girls. In (Table 2), there was an overestimation of 57.14% in girls

compared with 52.17% in boys and underestimation of 47.83% in boys as against 42.96% in girls. These over and underestimations were however not statistically significant. A Norwegian study⁷, found that both sexes were more advanced in dental maturity except in the 8.5 years old girls. In that study still, the largest discrepancy between estimated age and chronological age was observed amongst girls in the 12-year age group. Similar studies undertaken by Moness Ali et al⁸ on Egyptian children, Prabhakar et al⁹ on Indian children in Davangere, as well as a comparative study by Davidson et al¹⁰ on Somali and White Caucasian children living in Sheffield recognized an overestimation using the Demirjian method. Likewise, results observed in studies on children from Western China¹¹, Turkey¹² and of Dutch origin¹³ indicated advanced dental age. A recommendation to adapt an applicable correction factor to different population types and ethnicity was advanced when using the Demirjian method. However, studies on Kuwaiti¹⁴ and Hungarian¹⁵ children reported delayed dental maturation and age relative to CA. In a study to compare the Demirjian and Willem's methods for age assessments, Essan et al¹⁶ working on a Black Southern African population noted a significant overestimation of age with the former in both male and females. Still in a meta-analysis study by Essan et al¹⁷ comparing different populations using the two assessment methods, significant overestimation was noted in the males 3-15 years and 4-16 years female brackets by the Demirjian methodology. The conclusion in this study was that whereas Willems method provided a more accurate estimate of CA, Demirjian method had a broad application in terms of determining dental maturity scores. Two important conclusions to be derived from this meta-analysis are that for end results dependent on dental maturity as in orthodontic decision-making, Demirjian may be preferable and for higher accuracy chronological age estimation, population-specific correction factor need be applied.

Our study was designed to calculate the correction factor applicable to Ghanaian children and adolescents. This is the first such study from Ghana. The sample population employed from Accra, is representative of the Ghanaian population due to its cosmopolitan nature. A bias however would exit based on socio-economic stratification and health behavioural pattern. Unlike in the higher socio-economic group that would tend to attend the Dental School clinic for regular dental care, the lower social group would prefer to go to the government general hospital clinics mainly for acute care.

A strong correlation was exhibited between chronological and dental age and even more so between factor-corrected and chronological age. Both the overestimations in this study as compared to the Demirjian and the underestimations observed were statistically insignificant. Across the spectrum for boys, from above 15 years, dental maturity scores were above the upper limit of the Demirjian chart readings for 18

years. This may be interpreted as a period of accelerated dental maturity or growth spurt in boys. The pattern shown in girls after 15 years is however that of a dip and underestimation by both Demirjian and factor-corrected estimates but still remain within limits of statistical insignificance. This may be indicative of slowing of growth spurt or dental maturation for girls above 15 years of age. Our observation on boys above 16 years was not reported on in the original Demirjian method which was designed for children and adolescents of up to 18 years globally. This raises the question of an additional age limitation on the applicability of the Demirjian methodology on our study population probably as a result of variability in population-type.

Compared with similar studies done in sub-saharan Africa by Rizig et al¹⁸ in Sudanese children from Darfur, Demirjian underestimated the mean ages by .70 years in males and 1.42 in females. This under-estimation significantly manifested in the age group of 10-11 and 9-10 in males and females respectively. In the study conducted in Cotonou, Benin by Bigot et al¹⁹ there was an overestimation of .68 years in boys and 1.07 in girls using the Demirjian method and it remained stable for between 3 – 15 years for both gender. A correction factor was subsequently applied. For a study population of Kenyan children using the Willem's method however (Kihara et al, 2017)²⁰ a statistically significant overestimation was reported in boys but not in girls. In that study, it was however concluded that the overestimation was well within the ranges found in other populations and also applicable for estimation in the study population. From the review so far, the general conclusion is that the Demirjian method is accepted as a standard for age-estimation. However, for even population groups of similar origins as in sub-saharan Africa, there can arise unpredictable differences as noted with the study in Darfur¹⁸. Research methodology variations, ethnicities and still subtle environmental factors may account for these observations and hence the need for individual population-based correction factor estimations.

Socially in Ghana, age estimation services are needed in cases of child labour and trafficking after these children are rescued and being rehabilitated back into society. Deployment for purposes of age corroboration in sports and critically for differentiating between participants for age-limiting events pegged at below or above 18 years remain highly desirable services. For this study, age estimation by the Demirjian method closely matched the chronological age. The overestimation and underestimation profiles were not statistically significant. The factor-predicted estimates however more closely matched the chronological age profile and highly recommended. The Demirjian method was not applicable to boys above 16 years due to dental maturity scores far above the dental age chart. It is recommended that more studies be conducted for 15 to 18 years boys' group to test this observation. Other large city population studies in Ghana are needed to test the

validity and applicability of the predicted correction factor as arrived at in this study nationwide. Summary of limitations in this study includes the socio-economic background of the study population attending our clinics mainly for orthodontic considerations in this age group. They are in the mid-level and above social grouping. Ghana historically has a multi-ethnic population but despite no hinderance to inter-marriage, may still harbour significant ethnic variations as confounding factors.

Conclusion

For this study, age estimation by the Demirjian method closely matched the chronological age. The overestimation and underestimation profiles were not statistically significant. The factor-predicted estimates obtained even more closely matched the chronological age profile and highly recommended. The Demirjian method was not applicable to boys above 16 years due to dental maturity scores far above the dental age chart. It is recommended that more studies be conducted for the 15 to 18 years boys' group to test this observation. Other large city population studies in Ghana are needed to test the validity and applicability of the predicted correction factor as arrived at in this study nationwide.

Declaration

Conflict Of Interest

No author had any conflict-of-interest situation to disclose.

References

1. Maresh MM. Linear growth of long bones of extremities from infancy through adolescence. *AMA Am J Dis Child.* 1955; 89:725-742.
2. McKern TW, Steward TD, United States Army Quartermaster Research & Development Command, Quartermaster Research & Development Center (U.S.). Environmental Protection Research Division. Skeletal age changes in young American males: Analysed from the standpoint of age identification. Headquarters, Quartermaster Research and Development Command. 1957.
3. Greulich WW, Pyle SI. Radiographic atlas of skeletal development of the hand and wrist. Stanford University Press, Stanford, CA. 1959. p30.
4. Annan K. Ending child trafficking and slavery in Ghana. *Nat Hum Behav.* 2017;5. doi.10.1038/s41562-017-0080
5. Demirjian A, Goldstein H, Tanner JM, A new system of dental age assessment- *Hum Biol.* 1973; 45: 211-227.
6. Jayaraman J, Wong HM, King NM, Roberts GJ. The French-Canadian data set of Demirjian for dental age estimation: A systematic review and meta-analysis. *J Forensic Legal Med.* 2013; 20:373-381.
7. Nykanem R, Espeland L, Kyvaal SI, Krogstad O. Validity of the Demirjian method for dental age estimation when applied to Norwegian children. *Acta Odontol Scand.* 1998; 56: 238-244.
8. Monnes Ali AM, Ahmed WH, Khattab NM. Applicability of Demirjian's method for dental age estimation in a group of Egyptian children. *BDJ Open.* 2019; 5:2. doi.org/10.1038/s41405-019-0015-y
9. Prabhakar AR, Panda AK, Raju OS. Applicability of Demirjian's method of age assessment in children of Davangere. *J Indian Soc Pedod Prev Dent.* 2002; 20:54-62.
10. Davidson LE, Rodd HD. Interrelationship between dental age and chronological age in Somali children. *Community Dent Health.* 2002; 18: 27-30.
11. Chen JW, Guo J, Zhou J et al. Assessment of dental maturity of western Chinese children using Demirjian's method. *Acta Stomatol Croat.* 2008; 42:11-18.
12. Uysal T, Sari Z, Ramoglu SI, Basciftci FA. Relationships between dental and skeletal maturity in Turkish subjects. *Angle Orthod.* 2004;74:657-664
13. Leurs IH, Wattel E, Artman IHA, Ety E, Prah Andersen B. Dental age in Dutch children. *Euro J Ortho.* 2005; 27:309-314.
14. Qudeimat MA, Behbehani F. Dental age assessment for Kuwaiti children using Demirjian's method. *Ann Hum Biol.* 2009; 36: 695-704.
15. Nyarady Z, Mornstad H, Olasz L, Szabo G. Age estimation of children in south-western Hungary using the modified Demirjian method. *Fogorv Sz.* 2005; 131:22-29.
16. Esan TA, Schepartz LA, Accuracy of the Demirjian and Willems methods of age estimation in a Black Southern African population. *Legal Med* 2018; 31:82-89.
17. Esan TA, Yengopal V, Schepartz LA. The Demirjian versus the Willems method for dental age estimation in different populations: A meta-analysis of published studies. *PLoS ONE.* 201; 12: e0186682. <https://doi.org/10.1371/journal.pone.0186682>
18. Rizig AO, Elamin F, Zeidan ZA et al. Age estimation and dental maturity for Sudanese children using Demirjian's system. *J Med Med Sci.* 2012; 4: 123-127.
19. Bigot CE, Adjadohoun SB, Djossou D et al. Estimation of the chronological age by Demirjian method among children in Cotonou. *Int J Med Imaging.* 2022; 10:5-9. doi:10.11648/j.ijml.20221001.12
20. Kihara EN, Gichangi P, Liversidge HM et al. Dental age estimation in a group of Kenyan children using Willem's method: A radiographic study. *Ann of Hum Biol.* 2017; 44. doi.org/10.1080/03014460.2017.1371794.