Accuracy of the lower third molar radiographic imaging to estimate age among Ugandan young people

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Research note

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Abstract

Objective: Dental development is a useful method for age estimation. Although third molar eruption is commonly used to estimate age in Uganda, it is reported to be unreliable because of external influences. The more reliable radiographic techniques have inter-ethnic differences but data from sub-Saharan Africa are limited regarding estimating age in young adults. This study, therefore, aimed at determining the accuracy of Demirjian's classification of the lower third molar, a common dental age estimation method, in estimating key ages in a Ugandan population using Ugandan references. Dental records of 1021 Ugandans aged 10-22 years were assigned to two groups; reference and test. The reference data was retrieved from a database of a previous bigger research project. Results: The overall sample population comprised of 514/1021 (50.3%) males. The mean age was 15.8 (3.6) years. No significant sex differences in dental age were established in the reference sample (520 records). Accuracy values (area under the curve) at the 12-, 14-, 16- and 18-year-cut-offs were between 0.83 and 0.90 using the test sample (501 records). The results suggest that Demirjian's classification of the lower third molars is a useful method for age estimation in the young urban Ugandan population in the 10-22-year age-group.

Introduction

Assessment of dental development is a useful tool for age estimation among adolescents and young adults.[1] The need for age estimation arises where the birth documentation is absent or cannot be verified yet a subject's age is pivotal in decision making.[1, 2] Unpublished observations by Kutesa MA indicate the commonest method used for age estimation of young Ugandans as the visual inspection of third molar eruption—a cheap, fast and non-invasive method. However, studies from other parts of the world have reported this method as unreliable because the timing of tooth eruption is generally affected by not only genetic factors,[3-5] but also environmental, nutritional status, local and systemic diseases.

In contrast, radiographic techniques such as the Demirjian's method are not affected by environmental, nutritional and local factors like space availability and impaction.[4, 6, 7]. Their use has been simplified further by the orthopantomogram (OPG), a dental radiograph in which all teeth, whether erupted or un-erupted can be seen.

Studies on age estimation using radiographic techniques have revealed inter- ethnic differences [8-10] and hence the need for population-specific references. [11, 12] However, data from sub-Saharan Africa are limited regarding the optimal reference values for dental radiographic methods in estimating age in young adults, [9, 13-15] which age group has third molars as the only teeth available for dental age estimation.[16]

This study therefore, aimed to derive Ugandan dental age references using Demirjian's classification based on the lower third molars, and to determine the accuracy of this method as a tool for identifying Ugandans at key age cut-offs of 12, 14, 16 and 18 years.[17-20]

Methods

Dental records of 1021 young adults were used for this study. The records included digital orthopantomograms (OPGs) of 10-22-year old Ugandans from an urban/peri-urban population in Kampala from two types of populations. One from the general urban and peri-urban population previously recruited for another study among children, adolescents and young adults aged 5-25 years, with proof of their birth documentation. The second type of population was from patients attending three private urban clinics which were purposively selected on the basis of having patient records with digital OPGs. The records from the general population were assigned to the first group (reference sample) while the second referred to as the test sample consisted of those from the private clinics. The inclusion criteria were Ugandans by ethnicity through self-report, whose sex was recorded. A total of 1030 records were retrieved as determined from two separate sample size calculations. Records were picked randomly from each age group ensuring a minimum sample of 16 records per age group per sex. Groups with bigger numbers got more than 16 records sampled till the required sample size was attained.

Two separate sample sizes were calculated. For the reference sample, 525 using published criteria for reference material.[3, 16] and 505 for the test sample using a nomogram for sample size determination.[21] Each of the intermediate estimates were further increased by a factor of 0.2 to cater for the design effect from clustering within an individual,[22] and 5% to cater for missing teeth.

All the 1030 digital images were de-identified and saved in the JPEG format using a unique research identifier number (UID) for future blinding of other data procedures. The other information on sex and age (difference between the date of birth and date of radiography) was saved as a separate excel file under each UID. The digital images were examined on a computer screen in a darkened room by two assesors: a dental radiologist and a dentist (CK and CLM, respectively). The maturation of the lower third molars was assessed and scored using the criteria according to Demirjian's classification with eight mineralisation stages A-H.[8, 23] For stages G and H, the distal root was scored. The teeth were *labelled* as tooth#48 for the lower right third molar and tooth#38 for the lower left third molar. The scores were entered on a paper data collection form against the relevant UID. The records with unclear images, third molars with short roots and those with both molars missing were dropped. The data on age, sex and Demirjian scores were merged, entered twice and validated using Epidata version 3.1. Finally, two separate data sets; the "reference data" and "test data" were obtained the details of which are in additional data files (see Additional file 1 and Additional file 2, respectively) .

The unit of analysis for the chronological age was computed in years with no decimal points. Each lower third molar was analysed as a separate entity. Stata software version 13.0 (Stata, College Station, Texas, USA) was used for analysis. Data from the reference sample was used to determine the median age of each Demirjian stage. This was derived as the dental age based on each lower third molar per sex. Mann-Whitney U test was applied to verify if there were sex differences in the dental ages. Having determined that there were no differences, both sexes were used to derive a combined dental age which was put in a table as the reference value. The test sample was used for the subsequent analysis. The chronologic age

was used as the “gold standard” while the dental age was the “test”. Sensitivity, specificity, ROC (Receiver Operator Curve) analysis at the different cut-off values of 12, 14, 16 and 18 years were obtained as described in a previous study.[24] For each age cut-off, any individual identified with the cut-off age and older was assigned a value of “1” (true), while those individuals younger than the cut-off were assigned “0” (false). The ROC analysis output was the Area under the Curve (AUC), which was used to interprete accuracy. The AUC ranges from 0 to 1, where “1” represents a perfect discrimination such that as the AUC tends to 1, this suggests increased test accuracy. Swets further described AUC values between 0.9 to 0.7 as useful for some purposes.[25] For inferential statistics, the p-value of 0.05 was the cut-off for statistical significance.

The research protocol was reviewed and approved by the research ethics committees of School of Biomedical Sciences, Makerere University, and Uganda National Council of Science and Technology.

Results

The intra-assessor and inter-assessor Kappa values were 0.91 and 0.87, respectively, both indicating very good agreement. The 1021 sample population had an almost equal number of both sexes (514/1021 (50.3%) males) with an overall mean age of 15.8 (standard deviation, SD=3.6) years and a median age of 16 (inter-quartile range, IQR=6) years. Table 1 provides a summary of the other descriptive statistics of the participant population by the two groupings; reference sample and test sample. In the reference group almost equal numbers of males and females were included, while for the test group, the males were slightly more than the females.

Table 1: Characteristics of 1021 young Ugandans whose dental records were included in the study

As shown in Table 2, reference values combined for the sexes were generated for the eight stages of Demirjian stages in the Reference sample. This was done only after finding that there were no significant sex differences. The reference values were similar for the right and left except at stages D and G where dental age was lower on the right than the left by a year and half a year, respectively.

Table 2: Reference values for dental age estimation among 520 young Ugandans using Demirjian’s classification

Demirjian’s classification. The difference between the sample number, 520 and number of teeth on each side (Right – 510 and left – 501) is accounted for by missing teeth or those that had not yet commenced mineralisation

Table 3 provides a summary of the sensitivity, specificity, false positives, false negatives, AUC, and their confidence intervals (CI), at the cut-offs of 12, 14, 16, and 18 years for both lower third molars. The AUC values for all cut-off ages *represent* the accuracy of Demirjian’s classification to identify correctly an individual as the given cut-off age. All AUC values were ranging from 0.83 to 0.90. Note that the highest

AUC and sensitivity in this table were at the 14-year cut-off while the lowest AUC and sensitivity were at the 14-year cut-off. The least specificity was at the 12-year cut-off.

Table 3: Accuracy of Demirjian's classification of the lower third molar in estimating age of young Ugandans.

Discussion

We set out to determine the accuracy of Demirjian's classification of the lower third molar in discriminating between individuals of specific legally important ages within the 10-22-year age-group in a Ugandan urban population. We found that the AUC at all cut-off ages based on the two lower third molars were useful for some purposes, using Swets' AUC scoring system.[25]

The highest sensitivity observed at the 14-year-cut-off shows that Demirjian's classification in this study population could most correctly identify individuals that have reached the age of 14 years. On the other hand, the highest specificity at the 16-year cut-off means that the third molars can be used to correctly classify individuals younger than 16 years. However, given that the same age group had both the lowest AUC and sensitivity shows that determining whether an individual has reached 16 years using this method alone should be done with caution.

The least accuracy could be due to the fact that between the stages F and G which are representative of the 16-year-cut-off, there is a span of 3-3.5 years compared to the other cut-offs with 1-2 years representing the sequential stages. This ambiguity of the root stages has been alluded to as stemming from Demirjian's method having only four root stages (E-G) representing a wide range of age distribution (14-20 years).[26] Although having relatively fewer root stages makes Demirjian's technique easy to use and reproducible, this may affect the accuracy of age estimation.[27] For this reason, Demirjian's method was modified to incorporate two extra root stages at F and G in order to improve on the precision of this method.[16] Therefore, to improve on the accuracy at the 16-year-cut off in this population might require the adoption of these extra stages.

The findings from this study further support the emphasis made by other authors on the need for country-specific references with respect to the use of this method for age estimation.[11, 12] From our observations summarised in Table 2, we note that the urban Ugandan population appears to mature faster than the black South Africans using the same method.[9, 15] Therefore, this Ugandan population also matures dentally faster than the Caucasians and Mongolians.[9, 26] These intra-racial differences in dental development further justify the need for population specific cut-off reference values to address various medico-legal scenarios.

Considering the fact that over 60% of minors in Uganda lack birth documentation,[28] age estimation becomes a necessary practice in the Ugandan setting. For purposes of achieving more credible estimates especially for high stake purposes, a cost-benefit analysis would be recommended to inform the planning and policy-making forage estimation processes. This would demand that more resources are allocated to

this area of expertise as well as local research so that we reap the maximum benefits of such techniques. This could be achieved if efforts are combined with different advocacy and human rights groups, sports bodies whose work involves age determination of subjects.

In conclusion, these results of this study suggest that Demirjian's classification for the lower third molars is useful for age estimation for the specific legal ages in the 10-22 year age-group in the urban Ugandan population. The findings also reveal that determining age at the 16-year cut-off might require the modified Demirjian method with additional root stages.

Limitations

The study limitations include: - the fact that that the samples obtained were from urban and peri-urban populations, which may not be a fair economic representation of the whole Ugandan population. This may make it difficult to extrapolate the study findings to the whole of the Ugandan population. However, the urban and peri-urban dwellings in Kampala are composed of a predominantly transitional population consisting of individuals who are part of the rural to urban migration from different parts of the country. Thus, while the study population differs from the rural population economically, it is fairly representative of the Ugandan population with respect to the genetic mix represented by different tribal groups.

Furthermore, the use of secondary data in this study limited determining the effect of previous systemic illnesses and malnutrition on mineralisation. However, previous research demonstrated that malnutrition has no effect on mineralisation.[6]

List Of Abbreviations

AUC - Area under the curve

CI - Confidence interval

F-Pos - False positive

F-Neg - False negative

IQR - Inter-quartile range

LQ - Lower quartile

OPG - Orthopantomogram

ROC - Receiver Operator Curve

SD - Standard deviation

UQ - Upper quartile

Declarations

Ethics approval and consent to participate

Protocols to collect archived patients' records including a request to waive consent were submitted to the research ethics committee of School of Biomedical Sciences, Makerere University (SBS-216). The protocol was also submitted to Uganda National Council of Science and Technology (HS1727).Data was collected after approval and waiver of consent were obtained.

Consent for publication

Not applicable.

Availability of data and material

The data sets supporting the conclusions of this article are included within the article and its additional files.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

CLM conceived and refined the research idea, drafted the initial proposal, and was involved in the whole research process till drafting of the manuscript. AK was instrumental in devising the research methodology and contributed to the drafting of the manuscript. CK made radiological assessments and was a major contributor in the manuscript writing. IGM and WB were involved in drafting and critically *analysing* the manuscript for publication. All co-authors gave the final approval of the version to be published.

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Tables

Table 1: Characteristics of 1021 young Ugandans whose dental records were included in the study

		Reference group		Test group	
		Number of participants (%)	Mean years (S.D)	Number of participants (%)	Mean years (S.D)
Total		520 (100)	15.9 (3.8)	501 (100)	15.7 (3.5)
Females		262 (50.4)	15.9 (3.7)	245 (48.9)	15.7 (3.5)
Males		258 (49.6)	15.9 (3.9)	256 (51.1)	15.7 (3.4)
Age-group (yrs)	**10 - 12**	128 (24.6)		115 (23.0)	
	13 - 15	124 (23.8)		120 (24.0)	
	16 - 18	115 (22.1)		144 (28.7)	
	19 - 22	153 (29.4)		122 (24.3)	

Key: S.D is the standard deviation. A total of 1030 dental records were retrieved, six were excluded for having unclear lower third molars and three had both lower third molars with very short roots. The overall mean age was 15.8 (3.6) years.

Table 2: Reference values for dental age estimation among 520 young Ugandans using Demirjian's classification

Demirjian Stage	Tooth 48 (n=510)				Tooth 38 (n=501)			
	No.	*Median*	*LQ,UQ*	*Mean (SD)*	*No.*	*Median*	*LQ,UQ*	*Mean (SD)*
A	*2*	***10***	*10, 10*	*10 (0.0)*	*1*	***10***	*-*	*10 (0.0)*
B	*16*	***10***	*10, 11.5*	*10.9 (1.4)*	*13*	***10***	*10, 11.5*	*10.8 (1.2)*
C	*83*	***11***	*11, 12*	*11.7 (1.5)*	*85*	***11***	*11, 12*	*11.7 (1.5)*
D	*61*	***12***	*11, 14*	*12.6 (1.6)*	*62*	***13***	*11, 14*	*12.6 (1.5)*
E	*68*	***14***	*13, 15*	*13.9 (1.5)*	*62*	***14***	*13, 15*	*13.9 (1.6)*
F	*59*	***15***	*14, 16*	*15.4 (1.6)*	*63*	***15***	*14, 17*	*15.4 (1.7)*
G	*96*	***18.5***	*17, 20*	*18.4 (1.6)*	*93*	***19***	*17, 20*	*18.5 (1.6)*
H	*125*	***21***	*19, 22*	*20.1 (1.8)*	*122*	***21***	*19, 22*	*20.3 (1.7)*

Key*: LQ and UQ represent lower quartile and upper quartile respectively. A-H are the eight stages of Demirjian's classification. The difference between the sample number, 520 and number of teeth on each side (Right – 510 and left – 501) is accounted for by missing teeth or those that had not yet commenced mineralisation*

Table 3: Accuracy of Demirjian's classification of the lower third molar in estimating age of young Ugandans.

Age cut-off (years)	Tooth	No.	F-Pos	F-Neg	Sensitivity	Specificity	AUC (95% CI)
12	**38**	496	14	34	92.00%	80.28%	0.86 (0.81 to 0.91)
	48	494	14	30	92.91%	80.28%	0.87 (0.82 to 0.91)
14	**38**	496	25	9	97.41%	83.22%	0.90 (0.87 to 0.93)
	48	494	25	9	97.41%	82.88%	0.90 (0.87 to 0.93)
16	**38**	496	6	82	68.82%	97.42%	0.83 (0.80 to 0.86)
	48	494	7	83	68.68%	96.94%	0.83 (0.80 to 0.86)
18	**38**	496	40	20	88.02%	87.84%	0.88 (0.85 to 0.91)
	48	494	43	24	85.88%	86.73%	0.86 (0.83 to 0.90)

Key: No. is number of observations. The difference between the test sample number, 501 and number of teeth on each side (Right – 494 and left – 496) is accounted for by missing teeth or those that had not yet commenced mineralisation. F-Pos and F-Neg is False positive and False negative respectively

Additional File Legend

File name - Additional file 1

File format -xls

Title of data - Reference data of Ugandan young people

Description of data - This data file presents age, sex and Demirjian's classification of the lower third molar among Ugandan young people. The data was used to obtain reference values of dental age.

File name - Additional file 2

File format -xls

Title of data - Test data of Ugandan young people

Description of data - This data file presents age, sex and Demirjian's classification of the lower third molar among Ugandan young people. This data was used to test the accuracy of the reference values of dental age obtained using Demirjian's classification of the lower third molar.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- supplement1.xls
- supplement2.xls