Estimating age in black South African children

SADJ March 2014, Vol 69 no 2 p56 - p61

A Uys[1], I Fabris-Rotelli[2], H Bernitz[3]

ABSTRACT

Forensic dentists are frequently required to determine the age at death of unidentified skeletons, or to age live individuals who have no record / documentation of their chronological age. In order to be of the greatest value, the method used should have the lowest possible standard deviation and be validated for the individual's specific population group. The method most frequently used in Forensic Dentistry for the estimation of age in children, was described by Demirjian *et al*. The maturity standards determined were based on samples of French Canadian origin and it has been recommended by several authors that correction factors be incorporated when applying this method to different population groups. The current research was carried out on a sample of 838 black South African children. A new model for age estimation in the said population was developed, to accurately determine the chronological age from dental development. A sample of 604 black South African children was used to test the validity of the method described by Demirjian.

Keywords: Forensic dentistry; age estimation; black South African children; panoramic radiographs.

INTRODUCTION

Age estimation plays an important role in several dental disciplines. In Forensic Dentistry, there is a frequent need to determine the age at death of unidentified skeletons, or individuals who have no record / documentation of their chronological age.[1-3] The importance of closely estimating the chronological age of suspects involved in serious crime, necessitates the use of highly reliable age estimation techniques. The critical ages for criminal liability in South African children are 10, 14 and 18 years. The law in South Africa states that a child who has not yet completed his or her tenth year, lacks criminal capacity and cannot be held criminally responsible. A child between the ages of 10 and 14 is presumed to lack criminal capacity, unless the prosecution can prove otherwise. At the age of 18 years, a person is regarded as an adult and creates no presumption of lack of capacity. In order to be of the greatest value, the age estimation method used should have the lowest possible standard deviation and be validated for the individual's specific population group.[2] The method most frequently used in Forensic Dentistry for the estimation of age in children was described by Demirjian *et al*.[4] Those maturity standards were determined on samples of French Canadian origin 4 and it has been recommended by several authors that correction factors be incorporated when applying this method to other population groups.[2,3,5-8]

1. **A Uys:** *BSc, BChD, Dip. Odont.(Materials), Dip. Odont.(Endo), MSc(Odont.)* Department of Oral Pathology and Oral Biology, University of Pretoria, South Africa.
2. **I Fabris-Rotelli:** *BSc (Hons), MSc, PhD.* Department of Statistics, University of Pretoria, South Africa.
3. **H Bernitz:** *BChD, Dip. Odont, MSc (Odont), PhD.* Manager of Forensic Dental Research, Dept of Oral Pathology and Oral Biology, University of Pretoria, South Africa.

Corresponding author

H Bernitz:
Department of Oral Pathology and Oral Biology, School of Dentistry, University of Pretoria, P.O. Box 1266, Pretoria 0001, Gauteng, South Africa.
Tel: +27 084 512 5258. E-mail: bernitz@iafrica.com

Factors that could affect the timing and rate of development and result in differences between specific population groups, include genetic factors and variation in age, gender and race.[9-11] It is important to understand these and other dynamics such as socio-economic status, nutrition and urban/rural considerations and to appreciate their potential influence on dental development.

In studies done by Phillips and Van Wyk Kotze[12,13] on selected racial groups of South African children, it was found that Demirjian's method of age estimation consistently overestimated the ages of children examined. This study was however restricted to Zulu and Xhosa children, did not differentiate between male and female children and had as few as two subjects per age group. A study on the development of the third molars in a black population sample by Olze *et al*.[14] also showed an accelerated development.

The aim of the present study was to develop a model to determine the chronological age from the developmental dental age stages. The reliability of the Demirjian method of age estimation was also evaluated on a sample of black South African children.

MATERIALS AND METHODS

A retrospective study was carried out on a sample of panoramic radiographs taken of 838 black South African children of known chronological age and gender (Table 1). The sample group consisted of 388 boys and 450 girls, ranging in age from 6.6 to 18.59 years and was adequate in size for assessing dental maturity curves.[15]

Pre-treatment panoramic radiographs and clinical records of black children were selected from the School of Dentistry, University of Pretoria, together with records of black patients from private orthodontic practices in the Pretoria region. Both film and digital panoramic radiographs were used. All participants were racially self-classified.

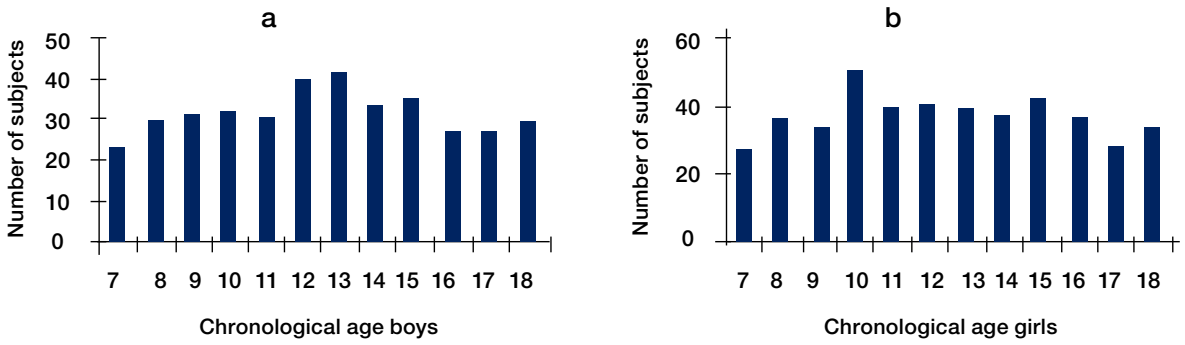

Table 1: The number of subjects and age distribution of the black South African (a) boys and (b) girls

All radiographs formed part of the patient's routine dental treatment and none were taken primarily for this research project. All the age estimations were carried out by the first author. Twenty cases were re-examined by the third author to determine the level of inter-examiner reliability. Exclusion criteria included the following: age above 18.59 years and under 6.6 years at the time the panoramic radiograph was taken; presence of systemic diseases; presence of congenital anomalies; unclear panoramic radiographs, and aplasia/absence of at least two corresponding teeth, bilaterally in the mandible. The subjects were grouped according to age in years, from 6.6 to 7.59, 7.6 to 8.59 and so on till 17.6 to 18.59.

The method of scoring used in this study is similar to that of Demirjian *et al*.[4] It is based on simplified chronological age estimation by restricting the number of tooth development stages to eight and scoring them from 'A' to 'H' (Figure 1).[5]

The stages represent the calcification of each tooth, from crown and root calcification to the closure of the apex. The left seven mandibular teeth were evaluated in the sample up to the age of 14.59 and scores were assigned. From age 14.6 to 18.59 the left and right mandibular third molars were included and also scored with the eight stage scoring system.

The description of the dental formation stage and criteria according to Demirjian *et al*.[4] can be summarized as follows:

STAGE DESCRIPTION

A The beginning of calcification is seen at the most superior area of the crypt. No calcification between fusion points is noted.

B The calcification points fuse together to form an occlusal surface.

C a. Occlusal enamel formation is complete. There is an extension of the enamel towards the cervical region.
b. The start of dentine formation is seen.
c. The shape of the pulp chamber is curved towards the occlusal border.

D a. The formation of the crown is complete down to the level of the CEJ.
b. In uniradicular teeth the superior border of the pulp chamber appears concave. Pulp horns are present giving the pulp an umbrella shape. A trapezoidal shape appearance of the pulp in molars is present.
c. The start of root formation can be seen in the form a spicule.

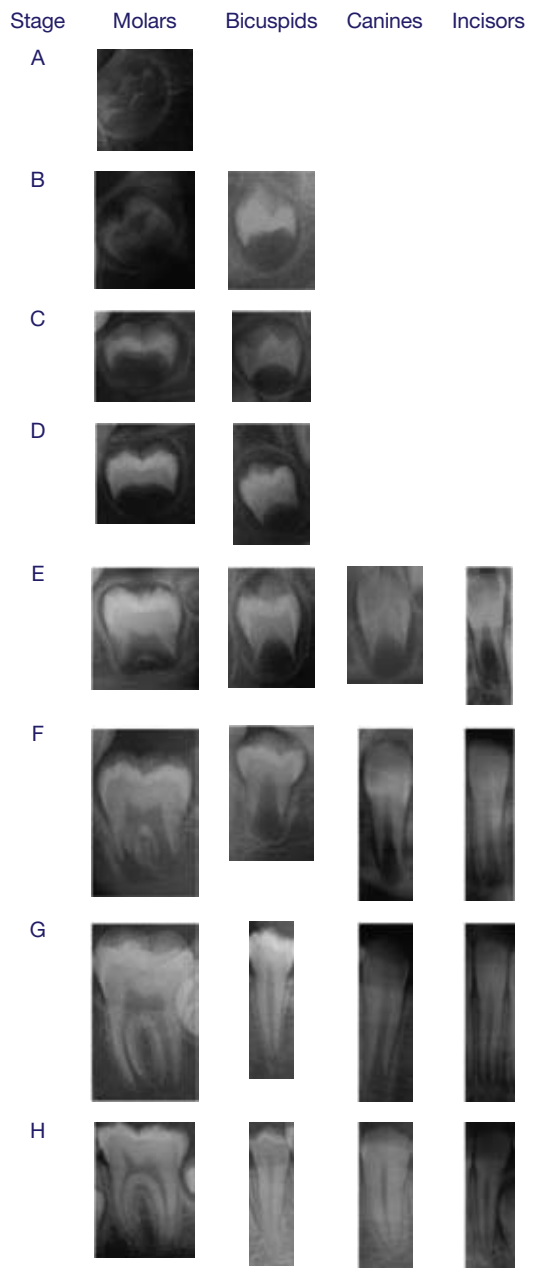

Figure 1: Examples of the developmental stage of the permanent dentition used in this study.

E Uniradicular teeth:
a. The pulp chamber walls are straight and the profile is only broken by the pulp horn. The pulp horn appears larger than in the previous stage.
b. The crown height is more than the root length.

Molars:
a. The start of the radicular bifurcation calcification can be seen in the form of a semi-lunar shaped calcification.
b. The crown height is more than the root length.

F Uniradicular teeth:
a. The pulp chamber walls form an isosceles triangle. The apex is funnel shaped.
b. The crown height is less or equal to the length of the root.

Molars:
a. The radicular bifurcation calcification extends further down the root. The roots end in a funnel shaped outline.
b. The crown height is less or equal to the length of the root.

G a. The root canal walls are parallel with an open apex.

H a. The apex of the root is closed.
b. The periodontal ligament has a uniform width around the root apex.

For the evaluation of the reliability of the Demirijian method of age estimation a retrospective study was carried out on a sample of panoramic radiographs taken of 604 black South African children of known chronological age and gender. The sample group consisted of 279 boys and 325 girls ranging in age from 6 to 16.9 years and was adequate for assessing dental maturity curves.[15]

RESULTS

From the data collected, categorical generalized linear models (glms) were created separately for the boys and the girls as well as a combined model. In these, a value of 'H' (or 'md' for the mandibular molars) was used as the reference value. Intercept values for boys and for girls were calculated and are 13.78509647 and 14.0084378 respectively. The intercept value for the combined group is 14.0846688. The significant influence of each tooth when estimating age in the evaluated age range was determined and a p-value was calculated. The highlighted values (Table 2) demonstrate those teeth and development stages which exerted a significant influence on estimating the chronological age in the age group 7 to 18 years.

The mean difference between the dental ages as determined in black South African children compared with the dental ages determined for French-Canadian children ranged from -1.35 to -0.29 in boys and from -0.89 to 0.74 in girls, see Table 4.

In boys, all the age groups showed a negative mean difference. The negative values demonstrate that all the age groups from 6 to 15.9 were advanced in growth when compared with the French-Canadian children. Age group 16 for the boys was not analysed because all the children in the group had reached a dental score of 100 and the dental age could not be computed. There was a statistically significant difference between the chronological age and the dental age as calculated by Demirjian's method for all the age groups of boys except for age group 9 to 9.9. The greatest accelerated development was observed for age groups 6 and 11.

In girls, age groups 6 to 15 showed a negative mean difference (advanced dental age), and age group 16 a positive difference (retarded dental age).There was a statistically significant difference between the chronological age and the dental age as calculated by Demirjian's method for all the age groups except for age groups 14 and 15. The greatest acceleration was observed for age groups 6 and 12.

Box plots were constructed to contrast the chronological and dental ages of black South African children for males and females (Figure 2).

On average, the dental age of girls was 0.12 years ahead of boys when mean dental age was compared. These values are however not statistically significant. On average black South African boys were 0.8 years and the girls 0.5 years ahead of the French-Canadian children in dental development. The p-value determined with the Wilcoxon Matched Pairs Test for examiner reliability was 0.740368. This value is not significant and operator calibration was considered reliable.

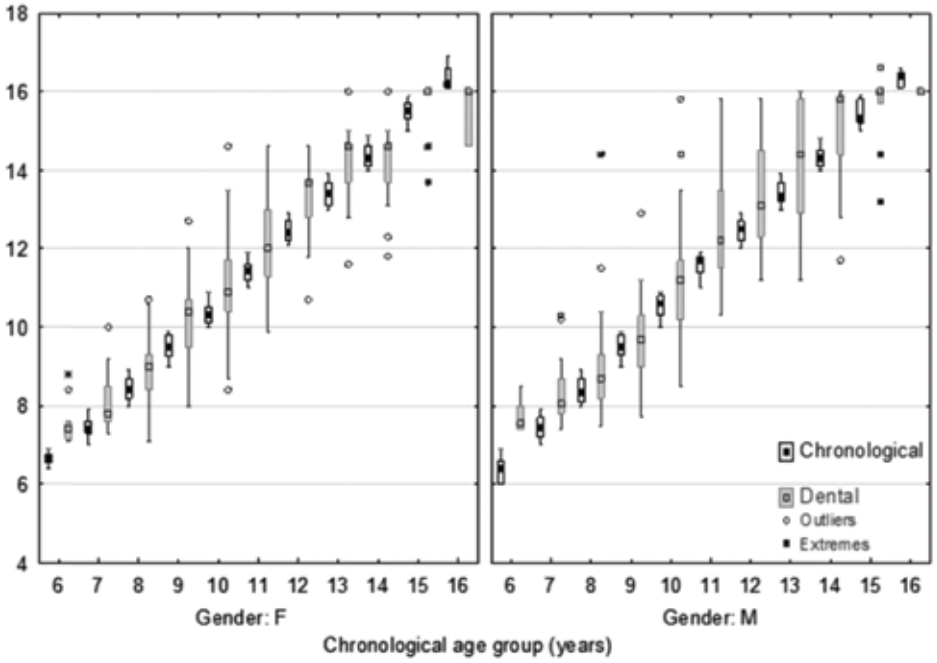

Figure. 2: Box plots demonstrating the chronological and dental ages of black South African children for females and males. The mean values are indicated by the squares, the rectangles indicate standard deviation and the thin lines indicate the total ranges. The outliers and extremes are indicated with ° and * respectively.

Table 2: Generalised linear model results obtained from the data collected for **black South African boys** Teeth are all mandibular.

Paremeter	Estimate	Standard error	t Value	Pr > ltl
Intercept	13.78509647	0.26933701	51.18	<.0001
M2 C	-2.77755433	0.59870857	-4.64	<.0001
M2 D	-2.4095575	0.49219066	-4.9	<.0001
M2 E	-1.67383062	0.41763363	-4.01	<.0001
M2 F	-1.38590484	0.38418014	-3.61	0.0004
M2 G	-0.70142639	0.27095961	-2.59	0.01
M2 H	0	-	-	-
M1 F	-0.84602559	0.61652802	-1.37	0.1709
M1 G	-0.46671174	0.24820975	-1.88	0.0609
M1 H	0	-	-	-
P2 C	-1.09448488	0.70127502	-1.56	0.1195
P2 D	-0.54823805	0.50077223	-1.09	0.2744
P2 E	-0.78175533	0.450868	-1.73	0.0838
P2 F	-0.22407939	0.35530315	-0.63	0.5287
P2 G	-0.1877955	0.21958222	-0.86	0.393
P2 H	0	-	-	-
P1 C	0.97188929	1.28094375	0.76	0.4485
P1 D	-0.30993981	0.62499807	-0.5	0.6203
P1 E	-0.3368133	0.48973463	-0.69	0.4921
P1 F	-0.55655047	0.35870445	-1.55	0.1217
P1 G	-0.11790933	0.26261126	-0.45	0.6537
P1 H	0	-	-	-
C D	-0.42326342	0.62905225	-0.67	0.5015
C E	-0.63521477	0.44680374	-1.42	0.156
C F	-0.58851949	0.35036565	-1.68	0.0939
C G	-0.13325387	0.23047182	-0.58	0.5635
C H	0	-	-	-
I2 E	-1.31556451	0.83701629	-1.57	0.1169
I2 F	-1.36166313	0.35664982	-3.82	0.0002
I2 G	-0.91065913	0.2256397	-4.04	<.0001
I2 H	0	-	-	-
I1 F	-0.16942477	0.79821475	-0.21	0.832
I1 G	-0.04330825	0.45245829	-0.1	0.9238
I1 H	0	-	-	-
ManL 0	-0.04565727	1.87918633	-0.02	0.9806
ManL D	-0.33567492	1.6273703	-0.21	0.8367
ManL E	1.08434273	1.29387162	0.84	0.4026
ManL F	1.95834239	1.18616581	1.65	0.0996
ManL G	2.17507388	1.04851879	2.07	0.0388
ManL H	3.21259584	0.3794399	8.47	<.0001
ManL md	0	-	-	-
ManR 0	3.23084607	1.91805418	1.68	0.093
ManR D	2.3105608	1.60357157	1.44	0.1505
ManR E	0.676733	1.29985667	0.52	0.603
ManR F	0.77770292	1.15114107	0.68	0.4997
ManR G	0.89230769	1.00002548	0.89	0.3729
ManR H	0	-	-	-
ManR md	0	-	-	-

Table 2: Generalised linear model results obtained from the data collected for **black South African girls**. Teeth are all mandibular.

Paremeter	Estimate	Standard error	t Value	Pr > ltl
Intercept	14.01981945	0.2072171	67.66	<.0001
M2 C	-2.21797434	0.48775888	-4.55	<.0001
M2 D	-2.09707787	0.40171378	-5.22	<.0001
M2 E	-1.85730565	0.32800586	-5.66	<.0001
M2 F	-1.46743741	0.27745898	-5.29	<.0001
M2 G	-0.73243515	0.19817138	-3.7	0.0002
M2 H	0	-	-	-
M1 F	-0.6533467	0.48120074	-1.36	0.1753
M1 G	-0.41057046	0.20750419	-1.98	0.0485
M1 H	0	-	-	-
P2 C	-1.32256536	0.5563441	-2.38	0.0179
P2 D	-1.46518116	0.38823047	-3.77	0.0002
P2 E	-1.45578239	0.33507291	-4.34	<.0001
P2 F	-1.03402955	0.26822382	-3.86	0.0001
P2 G	-0.54257584	0.18272836	-2.97	0.0032
P2 H	0	-	-	-
P1 C	-2.55903815	1.10421616	-2.32	0.021
P1 D	-1.24600858	0.53091624	-2.35	0.0194
P1 E	-0.94483713	0.40190122	-2.35	0.0192
P1 F	-0.40825301	0.31986346	-1.28	0.2025
P1 G	-0.24302798	0.2103248	-1.16	0.2486
P1 H	0	-	-	-
C D	-1.00723282	0.7141909	-1.41	0.1592
C E	-0.90634421	0.40879406	-2.22	0.0272
C F	-0.56302318	0.3037539	-1.85	0.0645
C G	-0.36847365	0.2117281	-1.74	0.0825
C H	0	-	-	-
I2 E	-1.07584219	0.85712213	-1.26	0.2101
I2 F	-0.99212181	0.46784848	-2.12	0.0345
I2 G	-0.71742731	0.19809903	-3.62	0.0003
I2 H	0	-	-	-
I1 F	0.17979007	0.61299002	0.29	0.7694
I1 G	0.30457739	0.47175204	0.65	0.5189
I1 H	0	-	-	-
ManL 0	2.52227642	0.98409372	2.56	0.0107
ManL C	2.18519154	0.90059495	2.43	0.0157
ManL D	1.1087268	0.98007854	1.13	0.2586
ManL E	1.29346242	0.88219158	1.47	0.1434
ManL F	1.82549071	08361989	2.18	0.0296
ManL G	3.29155851	0.53691979	6.13	<.0001
ManL H	3.91392071	0.31742532	12.33	<.0001
ManL md	0	-	-	-
ManR 0	0.76815396	1.00125251	0.77	0.4434
ManR C	0	-	-	-
ManR D	0.92919399	0.95797258	0.97	0.3326
ManR E	0.33773238	0.87929271	0.38	0.7011
ManR F	0.21862205	0.80141737	0.27	0.7851
ManR G	-0.3428084	0.48307685	-0.71	0.4777
ManR H	0	-	-	-
ManR md	0	-	-	-

M2 = Second molar; M1 = First molar; P2 = Second premolar; P1 = First premolar; C = Canine; I2 = Lateral incisor; I1 = Central incisor; Man L = Third molar left; Man R = Third molar right; Man L0 = Third molar left absent; Man 0 = Third molar right absent; C, D, E, F, G, H = Dental development stages; md = indicates missing data.

DISCUSSION

The inclusion of all the South African black ethnic groups across the socio-economic spectrum was achieved by including 838 subjects, some of whom were receiving private orthodontic treatment, together with individuals from a large State teaching hospital.

Numerous studies have demonstrated that correction factors should be used on different population groups for reliable chronological age estimation. Odontogenesis is under strong genetic control and a high correlation exists with an individual's chronological age.[16] Advanced growth in the black South African population can relate to the short formation times for enamel and dentine in this group.[17] Crown formation times for anterior teeth were consistently shorter in southern Africans compared with that of northern Europeans.[17] The formation of molar enamel was found to be less different between diverse genetic groups and these differences were very small.[17] The enamel formation time of Southern Africans seems to be shorter when compared with Northern Europeans; this might explain the overestimation of dental age in a black South African population.[18]

Because of the difference in tooth formation rates, the technique as described by Demirjian *et al*.[4] should not be used on a South African black population as the sole aging technique. When the dental ages of the sample of 604 black South African children were compared with the data of the French-Canadian children the mean difference between chronological age and dental age of South Africa black children was 0.8 years in boys and 0.5 years in girls.

In girls statistically significant differences were found in age groups 6, 7, 8, 9, 10, 11, 12 and 13 at the $p<0.05$ level. The girls demonstrated a more advanced dental maturity for all these ages. For age groups 14 and 15 there were no statistically significant differences. A possible explanation could be that the French-Canadian girls caught up to the black South African girls during these ages, or that black South African girls develop fast from age 6 to 13 but slow down when they reach age 14 and 15 years. No individuals were discarded from the results for being regarded as outliers. This was to ensure inclusion of all children with advanced, normal and delayed ages.

The scatterplots constructed from our data (Figure 3) demonstrate a broader band between the 5th and 95th percentile lines for boys when compared with the girls. This represents a greater variation in dental age for the boys, and this was present for the entire age range. Biological differences between boys and girls are the likely cause of this variation. A larger variation for other parameters has been found for boys. These development parameters include height for age.[18] Most of our subjects fell within the 95th percentile range. For boys most of the outliers were between the ages of 10 and 13 years and for girls between the ages of 9 to 14 years.

On average, girls' dental maturation was 0.12 of a year ahead of the boys although these values were not statistically significant. This is in accordance with earlier maturation of other parameters of development in girls such as height, sexual maturity and skeletal age.

This necessitates an accurate and easy to use method to determine chorological age from dental development. The dental formation stage for each tooth was recorded separately for boys and girls. From our data it was possible to create generalized linear models to determine the chronological age of black South African children. Stage 'H' represents the final closure of root apices for each of the teeth evaluated and is used as a reference value (or 'md' for the mandibular molars) in the model. Each age category contained an adequate number of individuals to create an accurate model for this population group. Whilst this large sample ensured a comprehensive data base, it is recognised that there may be differences between tribal groups.[12,13]

The steps to be followed in estimating chronological age from dental development are illustrated in examples one and two.

Example 1

Step 1: Determine the developmental stage of each of the mandibular left seven teeth according to the method of Demirjian *et al*.[4]

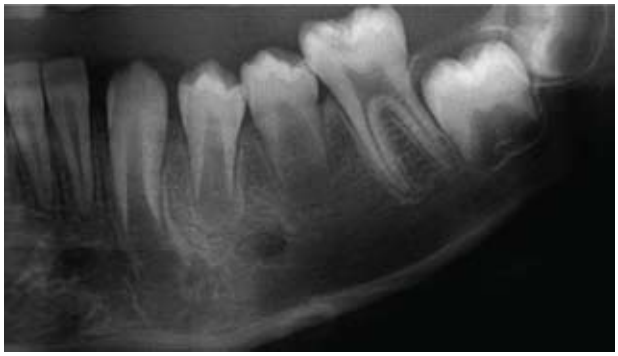

Figure 4: Example of a cropped panoramic projection taken from a boy and displaying the left seven mandibular teeth. The chronological age of this boy was 10.83 years or 10 years and 10 months.

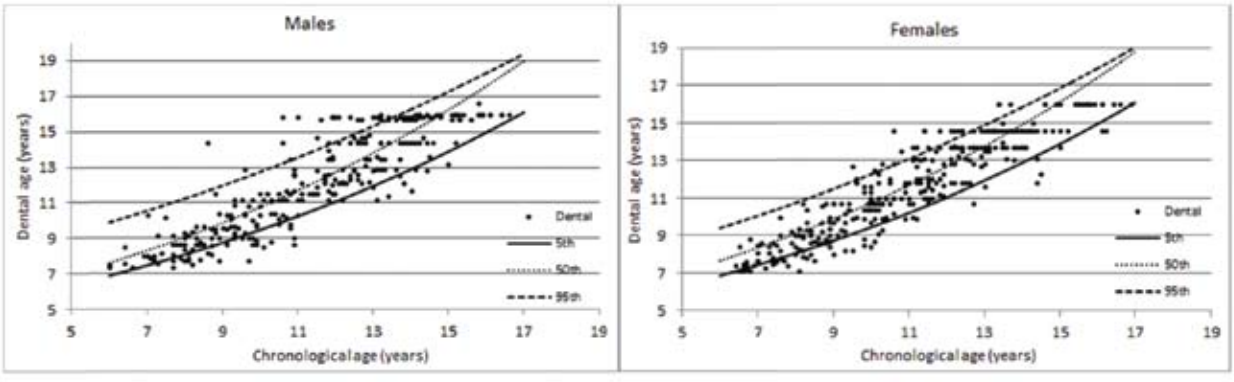

Figure. 3: Scatterplots to demonstrate the calculated dental age by actual chronological age for black South African children (a) boys and (b) girls. The 5th, 50th and 95th percentile lines are drawn.

Pepsodent®

Oral Care Science with Real Life built in

Unilever

*Helps REPAIR tiny invisible holes before they become cavities**.*

*With active Micro Calcium and Fluoride, **Pepsodent** Cavity Fighter is scientifically proven to deliver 50% more calcium* in the mouth, helping to repair tiny, invisible holes before they become big problems.*

Recommend with Confidence.

*Compared to normal calcium levels in the mouth.
**Refers to remineralisation of weak spots in tooth enamel. Brush twice a day and visit your dentist regularly.

fdi FDI World Dental Federation

FDI recognizes that twice daily brushing with a fluoride toothpaste such as Pepsodent is beneficial to oral health.

Tooth number	I_1	I_2	C	P_1	P_2	M_1	M_2
Stage	H	H	F	F	F	H	E

Step 2: Table 2(a) is now used to determine the intercept and the values for each tooth.

The categorical generalised linear model equation is:

$$y = \text{intercept} + M_2^i + M_1^j + P_2^k + P_1^l + C^m + I_2^n + I_1^o + \text{ManL}^p + \text{ManR}^q$$

The values from Table 2 can now be inserted into the equation:

$$y = \text{intercept} + M_2^i + M_1^j + P_2^k + P_1^l + C^m + I_2^n + I_1^o + \text{ManL}^p + \text{ManR}^q$$

=13.78509647-1.67383062+0-0.22407939-0.55655047-0.58851949+0+0
=10.74 years

In this study third molar teeth were not included in the ages 6.6 – 14.59 years. Hence the ManL^p + ManR^q values must be omitted from the equation for individuals younger than 14 years. Up to the chronological age of 14.59 years, dental age can be determined without the inclusion of the third molars. The lower left seven mandibular teeth have not all reached maturity and a dental stage can be assigned to each individual tooth. From the age of 14.6 years we found that most of the seven left mandibular teeth have reached maturity in our population group. This finding correlates with other studies which found data to be applicable only up to the age of 14 years.[19] The mandibular left and right third molars were therefore included from age 14.6. The maxillary third molars were not assessed because on a panoramic radiograph images of the zygomatic arch, hard palate and coronoid process are superimposed on the images of those teeth making accurate assessment of the root formation unreliable.

Example 2

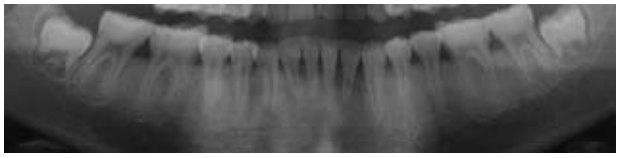

Figure 5: Example of a cropped panoramic projection taken from a girl and displaying the left and right eight mandibular teeth: The chronological age of this girl was 15.33 years or 15 years and 4 months.

M_3	I_1	I_2	C	P_1	P_2	M_1	M_2	M_3	Tooth
E	H	H	H	H	H	H	H	E	Stage

A dental stage was allocated to each of the eight left mandibular teeth and the right mandibular third molar. The left mandibular teeth with the exception of the left third molar all displayed full root closure and a stage H was assigned to them. The left and right third molar teeth demonstrated the beginning of inter-radicular bifurcation formation. The root length is also less than the crown length. Stage E was assigned to both the third molars.

Using the categorical generalized linear model equation and values from Table 2b (girls) the dental age can be determined as follow:

$$y = \text{intercept} + M_2^i + M_1^j + P_2^k + P_1^l + C^m + I_2^n + I_1^o + \text{ManL}^p + \text{ManR}^q$$
$$= 14.01981945+0+0+0+0+0+0+0+1.29346242+0.33773238$$
$$= 15.65101425$$
$$= 15.7 \text{ years}$$

Reproducibility of any age estimation technique is essential. The small differences in results between examiners for this study indicated a high level of agreement. Differences

Table 3: Combined results obtained with a generalized linear model from the data collected for black South African children. All teeth assessed are mandibular.

Paremeter	Estimate	Standard error	t Value	Pr > ltl
Intercept	14.0846688	0.16796028	83.86	<.0001
M2 C	-2.53754702	0.37044443	-6.85	<.0001
M2 D	-2.29276364	0.30948401	-7.41	<.0001
M2 E	-1.88385945	0.25577836	-7.37	<.0001
M2 F	-1.49809668	0.22307494	-6.72	<.0001
M2 G	-0.77961456	0.15930551	-4.89	<.0001
M2 H	0	-	-	-
M1 F	-0.8122284	0.35532169	-2.29	0.0225
M1 G	-0.44415204	0.15910543	-2.79	0.0054
M1 H	0	-	-	-
P2 C	-1.35157087	0.42650305	-3.17	0.0016
P2 D	-1.09104087	0.3057864	-3.57	0.0004
P2 E	-1.22951655	0.26982543	-4.56	<.0001
P2 F	-0.70205063	0.21392226	-3.28	0.0011
P2 G	-0.35415463	0.14115507	-2.51	0.0123
P2 H	0	-	-	-
P1 C	-0.71407209	0.82478709	-0.87	0.3869
P1 D	-0.8660546	0.40092206	-2.16	0.0311
P1 E	-0.6950141	0.30895134	-2.25	0.0247
P1 F	-0.45330275	0.2388662	-1.9	0.0581
P1 G	-0.20540622	0.16453618	-1.25	0.2123
P1 H	0	-	-	-
C D	-0.25954793	0.43518228	-0.6	0.5511
C E	-0.5212319	0.29013297	-1.8	0.0728
C F	-0.50846484	0.22609665	-2.25	0.0248
C G	-0.24733199	0.15213877	-1.63	0.1044
C H	0	-	-	-
I2 E	-1.36485912	0.51373794	-2.66	0.008
I2 F	-1.20157172	0.26615675	-4.51	<.0001
I2 G	-0.76026594	0.14824088	-5.13	<.0001
I2 H	0	-	-	-
I1 F	0.00282503	0.42948817	0.01	0.9948
I1 G	0.02633654	0.27959621	0.09	0.925
I1 H	0	-	-	-
ManL 0	2.26008856	0.80587691	2.8	0.0052
ManL C	2.21005419	0.94138115	2.35	0.0191
ManL D	1.31599213	0.77565815	1.7	0.0902
ManL E	1.52179244	0.68668069	2.22	0.027
ManL F	2.09748778	0.6386161	3.28	0.0011
ManL G	2.8539578	0.48038654	5.94	<.0001
ManL H	3.51974377	0.24308075	14.48	<.0001
ManL md	0	-	-	-
ManR 0	0.87447207	0.82045058	1.07	0.2868
ManR C	0	-	-	-
ManR D	0.73122565	0.75904284	0.96	0.3357
ManR E	0.13761288	0.68636941	0.2	0.8411
ManR F	0.2181947	0.61299674	0.36	0.722
ManR G	0.08322099	0.44310777	0.19	0.8511
ManR H	0	-	-	-
ManR md	0	-	-	-

M2 = Second molar; M1 = First molar; P2 = Second premolar; P1 = First premolar; C = Canine; I2 = Lateral incisor; I1 = Central incisor; Man L = Third molar left; Man R = Third molar right; Man L0 = Third molar left absent; Man 0 = Third molar right absent; C, D, E, F, G, H = Dental development stages; md = indicates missing data.

between examiners occurred primarily in teeth 44(P_1) and 45(P_2) in stages G and H. The p-value determined with the Wilcoxon Matched Pairs Test for examiner reliability was 0.740368. This value is not significant and operator calibration was considered reliable. The given stages allow for variation in interpretation and assessment. Qualitative assessment in the outer ranges of each formative stage can create small differences when using this method. When using the proposed method the percentage of variance in the chronological age that is explained by the dental development model for boys is more than 91% and for girls more than 93%. In the combined group (Table 3) the variance explained is more than 92%. Radiographic studies are able to record both the sequence of tooth mineralization and the timing of the various stages of tooth mineralization of individual teeth.[20] Radiography does not have the resolution to differentiate between microscopic changes in tooth growth.[21] Digital panoramic images proved easier to assess than film images. Fine anatomic detail, especially around the apex, was better displayed, making staging of the apex more accurate. Microscopy of histological sections is of course not possible in the living individual.

CONCLUSION

To determine the age of an individual requires an impartial, practical and reliable method. The method must be safe to use on living individuals. This study of a large sample representative of the range of the black population in the country provides a practical method to determine with reasonable precision the chronological age in black South African children.

Further studies may include as modifiers genetic factors and variation in age, gender and race, as well as socio-economic status, nutrition and urban/rural considerations.

Declaration: No conflict of interest declared.

Table 4: t-Test demonstrating the mean differences between the chronological ages and dental ages for black South African boys and girls according to Demirjian (reference data based on French Canadian children). The p-value in the second last column was determined using the Wilcoxon matched pairs test.

Age	Mean chronological age (± SD)	Mean Dental age (± SD)	Mean difference	*p*-value	*n*
Boys					
6	6.38 (0.35)	7.73 (0.44)	-1.35	0.028	6
7	7.46 (0.31)	8.41 (0.85)	-0.95	0.001	18
8	8.41 (0.30)	8.97 (1.26)	-0.56	0.004	34
9	9.50 (0.28)	9.79 (1.02)	-0.29	0.165	31
10	10.53 (0.31)	11.11 (1.58)	-0.58	0.040	34
11	11.56 (0.31)	12.67 (1.53)	-1.11	0.000	34
12	12.49 (0.28)	13.50 (1.35)	-1.01	0.000	37
13	13.42 (0.30)	14.34 (1.51)	-0.92	0.001	36
14	14.32 (0.25)	15.02 (1.22)	-0.70	0.007	25
15	15.43 (0.32)	15.74 (0.74)	-0.31	0.010	19
16	16.32 (0.22)	16.00 (0.00)		0.043	5
Girls					
6	6.65 (0.15)	7.53 (0.53)	-0.88	0.002	12
7	7.43 (0.26)	8.09 (0.63)	-0.66	0.000	27
8	8.44 (0.31)	8.94 (0.82)	-0.50	0.000	41
9	9.47 (0.30)	10.23 (1.19)	-0.76	0.002	32
10	10.34 (0.28)	10.96 (1.17)	-0.62	0.001	49
11	11.44 (0.27)	12.18 (1.18)	-0.74	0.001	46
12	12.44 (0.27)	13.33 (0.99)	-0.89	0.001	35
13	13.42 (0.29)	14.19 (0.88)	-0.77	0.000	37
14	14.33 (0.28)	14.38 (1.09)	-0.05	0.346	23
15	15.47 (0.29)	15.68 (0.71)	-0.21	0.098	16
16	16.34 (0.31)	15.60 (0.68)	0.74	0.018	7

S.D.: standard deviation; p<0.05 is statistically significant;
n: number of subjects.

References

1. Mani S, Naing L, John J, Samsudin A. Comparison of two methods of dental age estimation in 7-15 year-old Malays. Int J Paediatr Dent 2008;18:380-8.
2. Chaillet N, Nyström M, Demirjian A. Comparison of dental maturity in children of different ethnic origins: International maturity curves for clinicians. J Forensic Sci 2005; 50:1164-74.
3. Willems G, Van Olmen A, Spiessens B, Carels C. Dental age estimation in Belgian children: Demirjian's technique revisited. J Forensic Sci 2001;46:893-5.
4. Demirjian A, Goldstein H, Tanner J. A new system of dental age assessment. Hum Biol 1973;45:211-21.
5. Maber M, Liversidge H, Hector M. Accuracy of age estimation of radiographic methods using developing teeth. Forensic Sci Int 2006;159:S68-S73.
6. Chen J, Guo J, Zhou J, Liu R, Chen T, Zou S. Assessment of dental maturity of western Chinese children using Demirjian's method. Forensic Sci Int 2101;197:119e1-119e4.
7. Rozyło-Kalinowska I, Kiworkowa-Raczkowska E, Kalinowski P. Dental age in central Poland. Forensic Sci Int 2008;174:207- 16.
8. Nykänen R, Espeland L, Kvaal S, Krogstad O. Validity of the Demirjian method for dental age estimation when applied to Norwegian children. Acta Odontol Scand 1998;56:238-44.
9. Roberts D. Genetics of growth. Brit Med Bull 1981;37:239-46.
10. Thesleff I. The genetic basis of normal and abnormal craniofacial development. Acta Odontol Scand 1998;56:321-5.
11. Thesleff I. Epithelial-mesenchymal signalling regulating tooth morphogenesis. J Cell Sci 2003;116:1647-8.
12. Phillips V, van Wyk Kotze T. Dental age-related tables for children of various ethnic groups in South Africa. J Forensic Odontostomatol 2009;27(2):29-44.
13. Phillips V, van Wyk Kotze T. Testing standard methods of dental age estimation by Moorrees, Fanning and Hunt and Demirjian, Goldstein and Tanner on three South African children samples. J Forensic Odontostomatol 2009;27(2):20-8.
14. Olze A, Schmeling A, Taniguchi M, Maeda H, van Niekerk P, Wernecke K. Forensic age estimation in living subjects: the ethnic factor in wisdom tooth mineralization. Int J Legal Med 2004;118:170-3.
15. Flood SJ, Mitchell WJ, Oxnard CE, Turlach BA, McGeachie J. To evaluate the utility of smaller sample sizes when assessing dental maturity curves for forensic age estimation. Forensic Sci Int 2011;56:1604-9.
16. Grøn AM. Prediction of tooth emergence. J Dent Res 1962;41:573-85.
17. Tompkins R. Human population variability in relative dental development. Am J Phys Antropol 1996;99:79-102.
18. Reid D, Dean M. Variation in modern human enamel formation times. J Hum Evol 2006, 50:329-46.
19. Haavikko K. Tooth formation age estimated on a few selected teeth. A simple method for clinical use. Proc Finn Dent Soc 1974;70:15-9.
20. Beynon A, Clayton C, Ramirez Rozzi F, Reid D. Radiological aspects of the developing dentition in modern humans and great apes. J Hum Evol 1998;35:351-70.
21. Wood R. Forensic aspects of maxillofacial radiology. Forensic Sci Int 2006;159:47-55.