Estimating age and the probability of being at least 18 years of age using third molars:

a comparison between Black and White individuals living in South Africa

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Abstract

Third molar development of 705 White and 563 Black South African individuals aged between 15 and 25 years were assessed from panoramic radiographs obtained from the School of Dentistry, University of Pretoria, South Africa. The maxillary and mandibular left third molars were scored according to a ten stage scoring system. Ancestry and sex differences in dental maturity were assessed and the likelihood of an individual being 18 years of age was determined for each developmental stage. Statistically significant differences were noted among ancestry groups for most developmental stages, with South African Black individuals consistently maturing earlier than the White individuals. Statistically significant differences were noted among sex groups for some of the stages, mostly those near the final stages of root development. The results indicate that male third molars completed their development faster than that of females. The likelihood of an individual being 18 years of age based on the third molar development stage for the maxilla and mandible on its own was also determined. Combined likelihood results, for the maxillary and mandibular left third molars for stage H, increased the likelihood of being 18 years to 95% for all the studied ancestry and sex groups.

Keywords

Third molars, South African Black and White individuals, root formation, dental maturation

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Introduction

Age estimation in children and young adults is a relevant medico-legal procedure due to the increase in persons devoid of identification documents – many of these related to issues of migration. Age estimation may be defined as investigations to assess/ estimate and to get an idea of the chronological age of an individual without a known age[1]. Because of the increase in crime, illegal immigration rates and the use of children to perform acts of child labour, the estimation of age for forensic purposes is often required to assess whether individuals should be viewed as adults in a court of law. In the South African context, the important ages regarding the criminal capacity of children are under 10 years, 10 - 14 years, and 14-18 years. The Bill of Rights and the Children's Act define a 'child' as a person under the age of 18 years and the distinction between 17 and 18 years is important with regard to legal and social responsibility.

The large economic differences between southern African states are responsible for the ingress of immigrants to stable economic countries such as South Africa[2], many of them under-aged individuals. Most crimes and most crimes in South Africa are committed by teenagers and young adults. According to research done by the Centre for Justice and Crime prevention (CJCP), the age at the first offense in South Africa is much younger compared with that in other countries. Young offenders reported that they committed their first crime at ages 10-15 years (43.5%); 16-18 years (35.9%) and 19-25 years (18.7%) respectively [3]. The population in South Africa is relatively youthful and 44% of the population is under 20 according to the 2011 census[4]. No national figures are available on crime numbers committed by young people but figures show that 98% of sentenced offenders are male. The National Institute for Crime Prevention and the Reintegration of Offenders' report of 2014 indicated that there were 53 871 prisoners between the ages of 18-25 in South Africa.

Examination of the dentition with accompanying radiographs is a suitable method for age estimation[5, 6]. Chronological age can be defined as the amount of time that has passed since birth. Biological age refers to an individual's degree of somatic development. Forensic anthropologists use the biological age estimate to predict chronological age[7]. Tooth development is relatively independent of exogenic factors such as disease or malnutrition, making it a better measure of chronological age than e.g. skeletal development [8]. Most methods used in forensic anthropology and odontology do, however, have limitations. Limitations include the difficulties in the standardization of different methods, the lack of consensus between different methods, mean error, age range discrepancies and the variation present among individuals and populations; the individual variation being the most important.

Estimating the age of an individual after 14 years of age becomes difficult and challenging. Most age estimation methods have both advantages and disadvantages and are more or less indecisive after the age of 14. Age estimation from dental age can be used to predict chronological age in young children before the completion of root formation[9] and the method by Demirjian is the method most commonly suggested in literature [10–12]. The left seven mandibular teeth are used in this method and the original model was developed from a French Canadian population[13]. Studies using the Demirjian method demonstrated differences between chronological age and estimated age. Most studies found an overestimation in their particular population [10, 14–16]. The only variable dental indicator left during adolescence is the third molar tooth[17]. Estimating chronological age from the third molar stages is thus suggested during late adolescence [9, 18, 19].

The aim of this study was to establish the relationship between the chronological and dental age in a South African sample of White and Black individuals as assessed from third molars, and the likelihood of being 18 years of age at a specific stage of development. Ancestry and sex differences in dental maturity were also assessed.

Materials and Methods

Panoramic radiographs of 1268 individuals taken from 2013 to 2016 with known age and sex were selected by using a quota sampling method from the School of Dentistry, University of Pretoria, for this study. The sample comprised of 705 White individuals (WSA) living in South Africa and 563 Black South African (BSA) individuals aged between 15 and 25 years. The different categories (sex and ancestry) were divided into groups according to their chronological age and each age was calculated to two decimals points. The 15 year-olds included individuals of ages ranging from 15.0 to 15.99, 16-year olds from 16.0 to 16.99, etc. The individuals treated at the School of Dentistry are of different social groupings and include individuals living in the city as well as referrals from neighbouring rural areas and thus include the entire socioeconomic spectrum. The identification of WSA and BSA was made according to self-classification information present in the patient's hospital records (Table 1). Exclusion criteria included the following: the presence of systemic diseases; presence of congenital anomalies; unclear panoramic radiographs and the absence of the left maxillary and mandibular third molars. A minimum of 30 panoramic radiographs for each age, sex and ancestry group were evaluated. Sampling was carried out until an entire age group had completely closed apices and the periodontal ligament had a uniform width around the root.

Table 1 - Age and sex distribution. Numbers in brackets represent samples with closed apices (Stage H) of the left third maxillary and mandibular molars respectively. Age 15 indicates all individuals aged 15.00-15.99 years, etc.

	Black South Africans		White South Africans	
Age (last birthday)	Females	Males	Females	Males
15	33	30	31	33
16	30	35(4, 1)	36(2, 1)	30
17	31(6, 3)	30(7, 7)	32(5, 2)	33(2, 1)
18	30(10, 8)	30(15, 12)	34(7, 7)	34(17, 11)
19	30(20, 14)	32(19, 17)	32(12, 7)	31(19, 13)
20	30(16, 14)	37(31, 29)	36(26, 19)	31(29, 27)
21	30(29, 26)	30(28, 27)	32(23, 21)	30(27, 25)
22	31(30, 30)	32(31, 31)	32(27, 25)	31(29, 27)
23	31(31, 31)	31(31, 31)	34(29, 29)	32(29, 30)
24	-	-	30(28, 28)	31(30, 30)
25	-	-	30(30, 30)	30(30, 30)
Total	276	287	359	346
Total	563		705	

The maxillary and mandibular left third molars were scored according to a ten stage scoring system from 'A' to 'H'[9]. To improve the evaluation of third molar development stages a modified version of the Demirjian et al. [13] root formation was used. Two additional stages were added namely stages F1 and G1(Fig. 1) [9]. Stage F1 represents a root length that is twice the crown length and the roots still have a funnel shaped opening at the apex. Stage G1 represents a tooth with parallel root walls, where the apices are not completely closed and the periodontal ligament space at the apex is $\geqslant$1.0mm. These additional stages were found to be of particular value to fine-grade the final stages [9].

All the examinations were carried out by the first author. One hundred and thirty randomly selected cases were re-examined by the first author to determine intra- examiner reliability. Fifty randomly selected cases were also re-examined by the second author to determine the level of inter-examiner reliability. Cohen's kappa coefficient was determined to assess both intra- and inter-observer repeatability.

Median, max. - and min.- values, together with means and standard deviations were calculated for ages at each stage of development for males and females separately, using Matlab and Excel. Skewness was calculated for each stage classification and for each population group. Outliers were not excluded from the calculations. Both Wilcoxon rank sum tests and t-tests were conducted but the Wilcoxon rank sum test was preferred since we were unable to properly establish the normality of the distributions with the relatively small samples, notably in early categories/stages. A non-parametric Kruskal Wallis test was also performed (as a one-way ANOVA) to indicate significant differences for each stage.

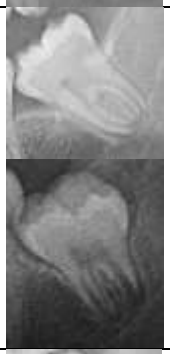
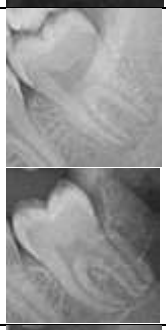
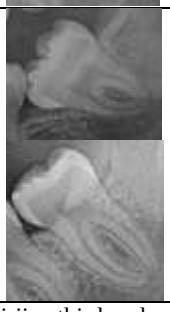
Stage	Radiograph of third molars	Criteria
F		The root length is at least as long as the crown length. The root endings have a funnel shape.
F_1		The root length is twice the length of the crown. The root endings still have a funnel shape.
G		The walls of the radicular pulp (root canal) chamber are parallel, and the apical foramen remains open.
G_1		The walls of the radicular pulp (root canal) are parallel, and the apical foramens are not completely closed. The periodontal ligament space surrounding the apical ending is ≥1mm.
H		The apical ends of the roots are completely closed. The periodontal ligament surrounding the roots is uniform in width.

Fig.1 – Demirjian third molar development staging F-H as modified by Solari et al.[9]

The likelihood of an individual being at least 18 years at a specific third molar stage was calculated. A similar method to that of Liversidge et al. [19] was used where by the number of observed individuals, per category, older than age 18 were divided by the total number of observations in that category to establish likelihood estimates. The combined likelihood was estimated by the number of individuals who were classified jointly in both stages. The number of individuals older than 18 in that stage combination was then divided by the

total number of individuals in that stage combination.

Ethical clearance was obtained from the University of Pretoria, Faculty of Health Sciences (Ethics reference number: 263/2015).

Results

The results for the intra-observer repeatability indicated substantial agreement for scoring the mandibular and maxillary teeth with a Cohen's kappa value of 0.8511 and 0.9263 respectively. The results for inter-observer repeatability indicated substantial agreement between observers for the evaluation of the maxillary third molars, with a Cohen's kappa value of 0.6287, and moderate agreement for the mandibular third molars with a Cohen's kappa value of 0.5107. The highest rates of disagreement between the observers for both the maxillary and mandibular third molars were between stages F and F1 and between G and G1 in the mandible.

The data were separated into ancestry groups and sex and then further subdivided into the maxilla and mandible. Table 2 displays the median ages of the left maxillary and mandibular third molar tooth development stages for each ancestry group. The analysis began at a stage D because of the small sample size for stage B and C for our age range of 15 to 25 years. Statistically significant differences were noted among ancestry groups for 11 out of the 28 stages (Table 2), with the South African Black individuals consistently maturing earlier than the White individuals. The median ages when BSA females were compared to WSA females were lower for BSA females for stages E, F1, G, G1 and H in the maxilla and for stages E, F, F1, G, G1 and H in the mandible. The median ages when BSA males were compared to WSA males were lower for BSA males for stages E, F1, G and H in the maxilla and for stages E, F1, G and H in the mandible (Table 2).

Statistically significant differences were noted among sex groups for some of the stages, mostly those near the final stages of root development (Table 3). This indicates that male third molars completed their development faster than that of females. The median ages when BSA males were compared to BSA females were lower for BSA males for stages D, F, F1, G and H in the maxilla and for stages E, F1, G and H in the mandible. The median ages when WSA males were compared to WSA females were lower for WSA males for stages E, F, F1, G, G1 and H in the maxilla and for stages D, E, F1, G, G1 and H in the mandible (Table 3).

Table 4 demonstrate the likelihood of an individual being 18 years of age based on the left third molar development stage for the maxilla and mandible separately. When a 95% probability is considered for stage H, only the BSA males for the maxilla and mandible respectively were below the level. A combined likelihood for the maxilla and mandible for each ancestry group for stage H increased the likelihood to above 95% for all the groups (Table 5). Fig. 2 shows the age dispersion for a particular stage.

Table 2 – Median, mean, minimum, and maximum ages and standard deviations (SD) of third molar crown-root formation at the given stages of development for Black South African (BSA) and White South African (WSA) individuals.

Stages		D	E	F	F_1	G	G_1	H
Maxilla								
Males								
BSA	Median	16	16.05	16.61	16.23	17.22	18.68	21.28
	Mean	15.89	15.81	16.54	16.45	17.43	18.53	21.06
	SD	0.85	0.67	1.20	1.19	1.69	1.49	1.87
	Min	15.00	15.01	15.00	15.00	15.09	15.76	16.32
	Max	17.18	16.77	20.02	18.77	22.61	21.27	23.84
WSA	Median	15.84	16.36	15.73	16.85	17.6	18.18	21.85
	Mean	15.95	16.46	16.16	17.17	18.37	18.62	21.73
	SD	0.81	1.19	1.18	1.50	2.26	1.63	1.91
	Min	15.02	15.00	15.00	15.18	15.59	16.17	17.26
	Max	18.11	19.61	18.77	21.19	23.59	24.09	24.90
Median difference in months (years)		1.92* (0.16*)	-3.72 (-0.31)	10.50 (0.88)	-7.50 (-0.63)	-4.56 (-0.38)	6.0 (0.5)	-6.90* (-0.58*)
Females								
BSA	Median	16.05	15.97	16.89	16.34	17.33	18.23	21.67
	Mean	16.14	16.29	16.82	16.78	17.81	18.45	21.29
	SD	0.99	1.20	1.18	1.31	1.94	1.48	1.76
	Min	15.00	15.00	15.00	15.00	15.00	15.33	16.37
	Max	18.30	19.68	19.51	20.26	22.02	21.48	23.86
WSA	Median	15.77	16.73	16.43	17.35	18.93	18.85	22.60
	Mean	16.25	17.07	17.26	17.65	19.37	18.94	22.45
	SD	1.20	2.03	2.29	2.14	2.24	1.59	2.22
	Min	15.00	15.01	15.00	15.44	15.59	15.76	16.17
	Max	19.10	23.51	24.69	23.35	24.02	22.77	25.99
Median difference in months (years)		3.36* (0.28*)	-9.06 (-0.76)	5.52* (0.46*)	-12.12* (-1.01*)	-19.20 (-1.6)	-7.38 (-0.62)	-11.16* (-0.93*)
Mandible								
Males								
BSA	Median	16.11	15.51	16.84	16.56	17.6	19.43	21.42
	Mean	16.12	15.74	16.71	16.79	17.94	19.03	21.23
	SD	0.68	0.71	1.30	1.36	1.65	1.57	1.76
	Min	15.00	15.01	15.00	15.00	15.27	16.18	16.51
	Max	17.18	17.09	20.02	20.34	22.61	21.36	23.84
WSA	Median	15.59	15.97	16.59	17.36	17.67	19.01	22.18
	Mean	15.69	16.26	16.56	17.27	17.93	19.30	21.97
	SD	0.57	1.11	1.18	1.00	1.72	1.83	1.82
	Min	15.02	15.17	15.00	15.43	15.59	16.17	17.26
	Max	16.77	19.61	19.44	18.77	23.25	24.09	24.90
Median difference in months (years)		6.30 (0.53)	-5.52 (-0.46)	3.00 (0.25)	-9.60* (-0.8*)	-0.84 (-0.07)	5.04* (0.42)	-9.06* (-0.76*)
Females								
BSA	Median	16.02	16.31	16.36	16.59	17.94	19.02	21.85
	Mean	16.05	16.43	16.71	17.18	18.19	19.12	21.55
	SD	0.86	1.39	1.26	1.73	1.70	1.22	1.64
	Min	15.00	15.00	15.00	15.00	15.00	16.51	17.43
	Max	18.30	19.68	20.26	20.77	22.02	21.93	23.86
WSA	Median	15.77	16.34	16.43	17.72	18.75	20.27	23.01
	Mean	16.21	17.04	17.05	18.29	18.81	20.30	22.77
	SD	1.02	1.96	2.07	2.12	1.56	1.84	2.07
	Min	15.00	15.00	15.00	15.44	15.76	16.17	16.84
	Max	18.52	23.51	24.69	23.35	23.02	24.02	25.99
Median difference in months (years)		3.00 (0.25)	-0.42 (-0.04)	-0.84 (-0.07)	-13.50* (-1.13*)	-9.75 (-0.81)	-15.00 (-1.25)	-13.92* (-1.16*)

*statistically significant at $p < 0.05$

Table 3 – Median ages and median differences comparison of third molar crown-root formation at the given stages of development for males and females.

Stages	D	E	F	F_1	G	G_1	H
Maxilla							
BSA							
Males	16.00	16.05	16.61	16.23	17.22	18.68	21.28
Females	16.05	15.97	16.89	16.34	17.33	18.23	21.60
Median difference in months	-0.60	0.96	-3.42	-1.38	-1.26	5.40	-4.74
(years)	(-0.05)	(0.08)	(-0.29)	(-0.12)	(-0.11)	(0.45)	(-0.40)
WSA							
Males	15.84	16.36	15.73	16.85	17.6	18.18	21.85
Females	15.77	16.73	16.43	17.35	18.93	18.85	22.60
Median difference in months	0.84	-4.38	-8.40	-6.00	-15.90	-7.98*	-9.00*
(years)	(0.07)	(-0.37)	(-0.70)	(-0.50)	(-1.33)	(-0.67*)	(-0.75*)
Mandible							
BSA							
Males	16.11	15.51	16.84	16.56	17.6	19.43	21.42
Females	16.02	16.31	16.36	16.59	17.94	19.02	21.85
Median difference in months	1.08	-9.54	5.76	-0.36	-4.08	4.92*	-5.16
(years)	(0.09)	(-0.80)	(0.48)	(-0.03)	(-0.34)	(0.41*)	(-0.43)
WSA							
Males	15.59	15.97	16.59	17.36	17.67	19.01	22.18
Females	15.77	16.34	16.43	17.72	18.75	20.27	23.01
Median difference in months	-2.22	-4.44	1.92	-4.26	-12.96*	-15.12	-10.02*
(years)	(-0.19)	(-0.37)	(0.16)	(-0.36)	(-1.08*)	(-1.26)	(-0.84*)

Black South African (BSA) and White South African (WSA) individuals. *statistically significant at $p < 0.05$

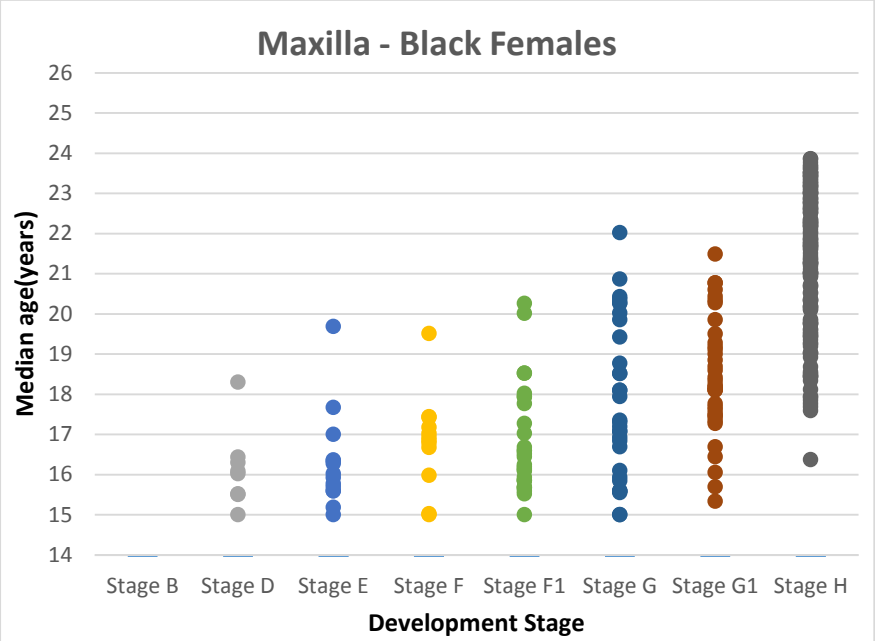
Table 4 - Likelihood of an individual being 18 years of age based on the third molar development stage for the maxilla and mandible.

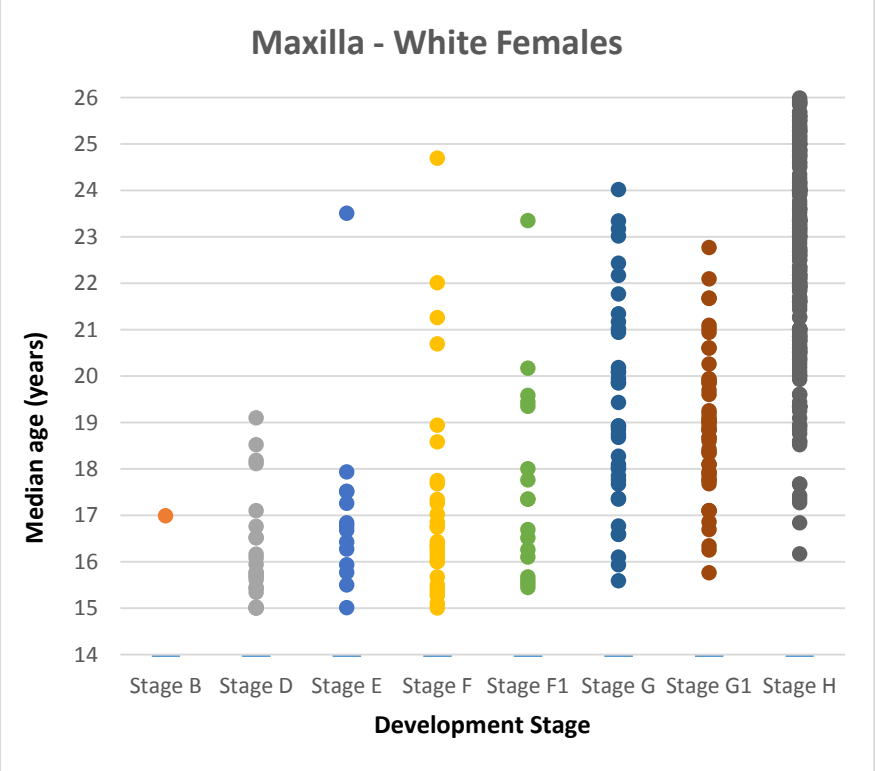
	Stage						
Ancestry, Sex, Location	D	E	F	F_1	G	G_1	H
BSA Female Maxillary	0.125	0.071	0.083	0.167	0.438	0.649	0.951
BSA Female Mandibular	0.077	0.100	0.087	0.303	0.475	0.839	0.976
BSA Male Maxillary	0.000	0.000	0.063	0.200	0.294	0.647	0.934
BSA Male Mandibular	0.000	0.000	0.211	0.200	0.463	0.762	0.948
WSA Female Maxillary	0.174	0.071	0.207	0.353	0.711	0.708	0.963
WSA Female Mandibular	0.095	0.304	0.138	0.400	0.684	0.872	0.982
WSA Male Maxillary	0.059	0.118	0.125	0.211	0.353	0.613	0.989
WSA Male Mandibular	0.000	0.100	0.154	0.273	0.355	0.725	0.994

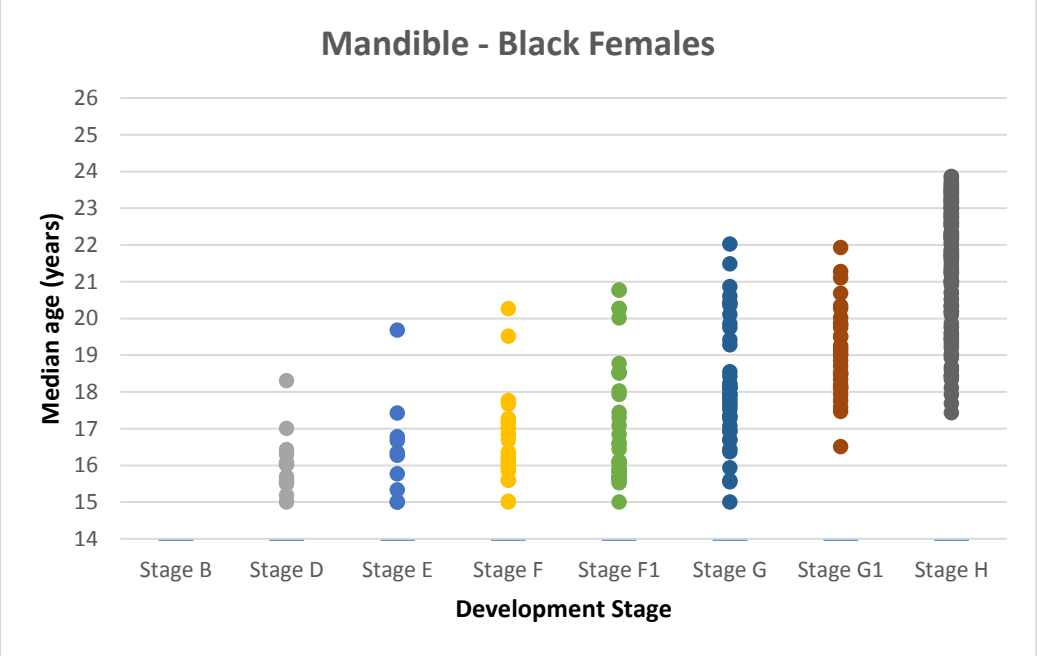
Black South African (BSA) and White South African (WSA) individuals.

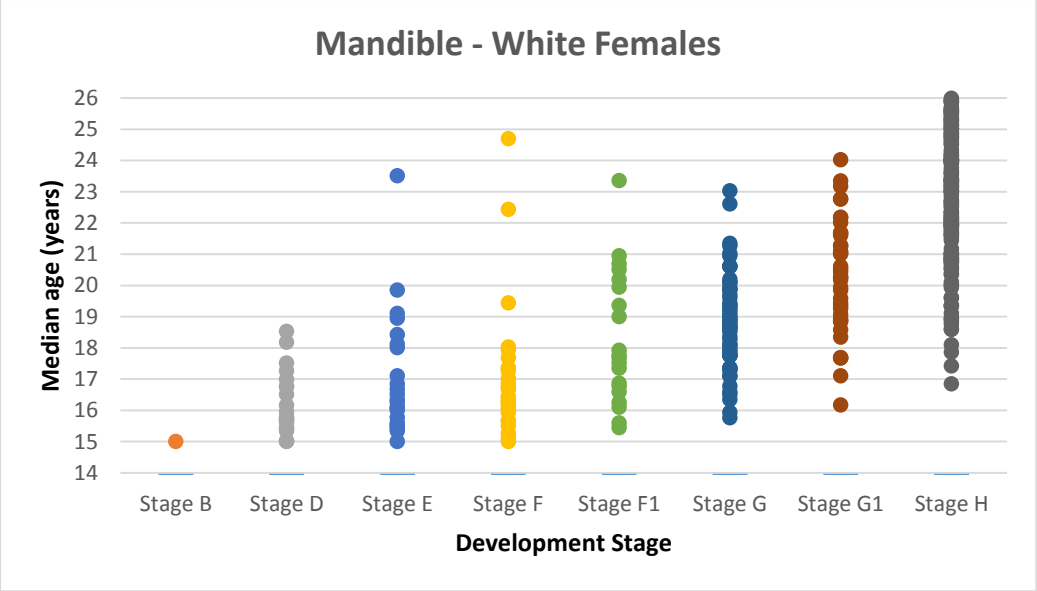
Table 5 – Combined likelihood for the maxilla and mandible for stage H.

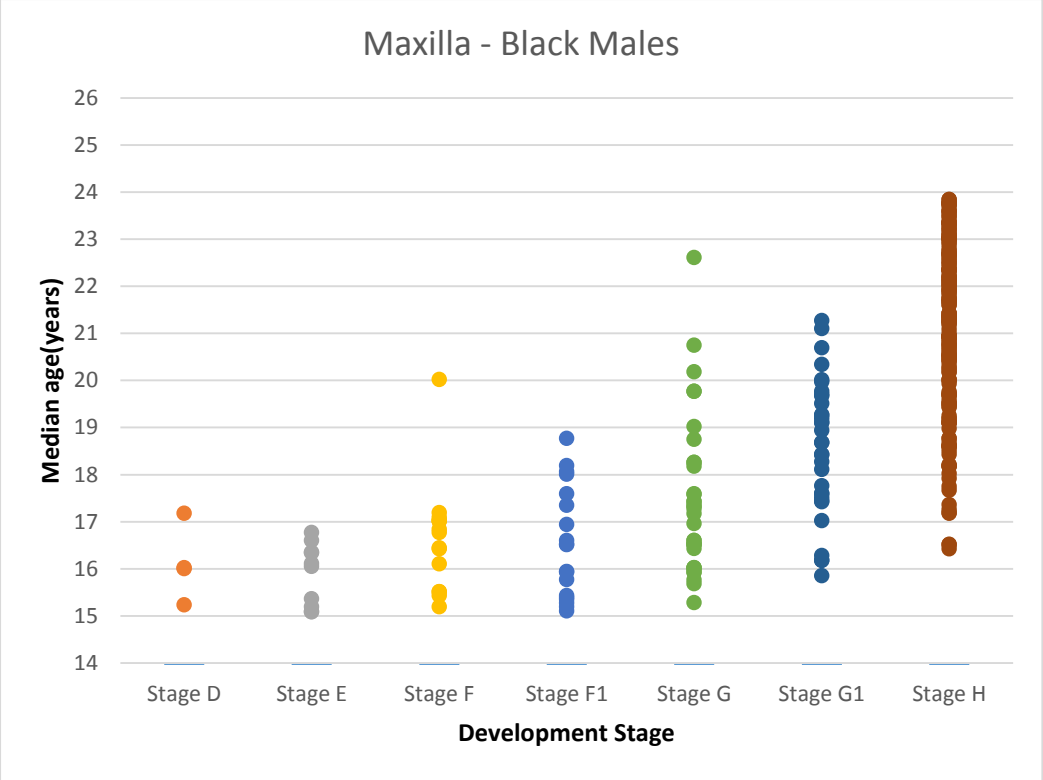
	Black South African Female	Black South African Male	White South African Female	White South African Male
Combined likelihood - Stage H	0.9839	0.9542	0.9876	0.9938

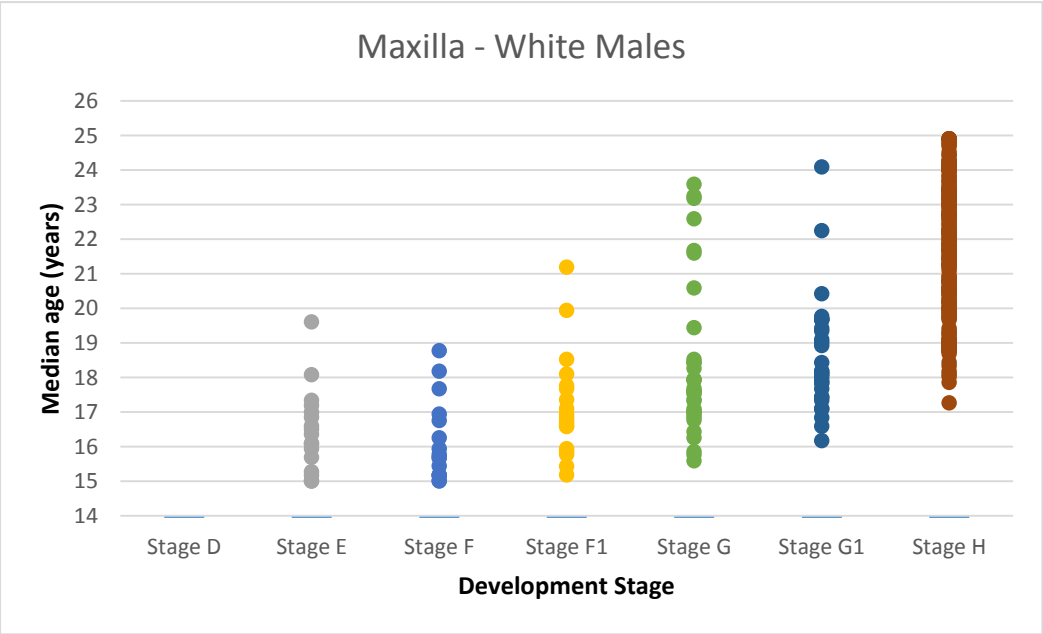





Mandible - Black Females
Median age (years)
26
25
24
23
22
21
20
19
18
17
16
15
14
Stage B
Stage D
Stage E
Stage F
Stage F1
Stage G
Stage G1
Stage H
Development Stage


Mandible - White Females
Median age (years)
26
25
24
23
22
21
20
19
18
17
16
15
14
Stage B
Stage D
Stage E
Stage F
Stage F1
Stage G
Stage G1
Stage H
Development Stage


Maxilla - Black Males
26
25
24
23
22
21
20
19
18
17
16
15
14
Median age(years)
Stage D
Stage E
Stage F
Stage F1
Stage G
Stage G1
Stage H
Development Stage


Maxilla - White Males
26
25
24
23
22
21
20
19
18
17
16
15
14
Median age (years)
Stage D
Stage E
Stage F
Stage F1
Stage G
Stage G1
Stage H
Development Stage

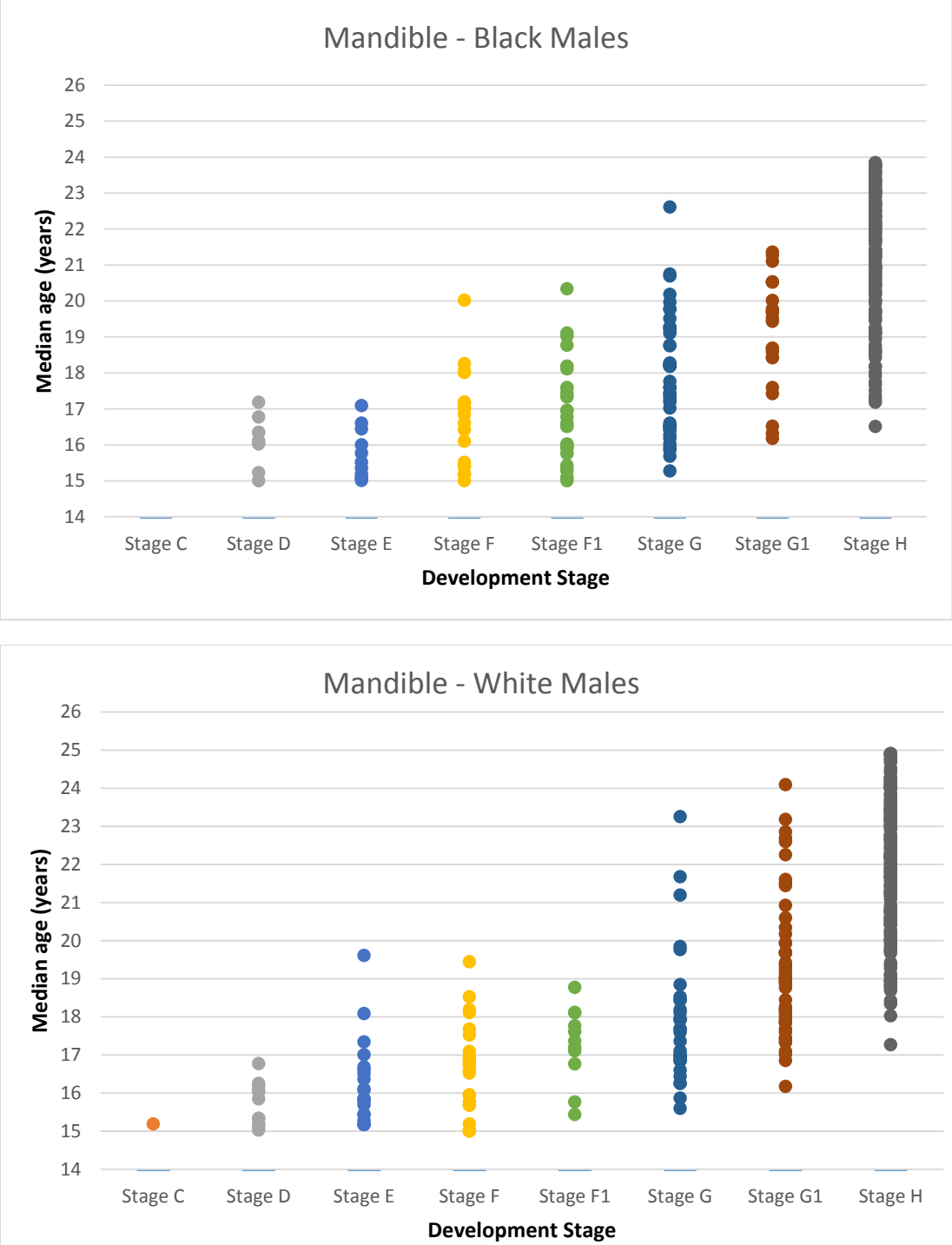


Fig. 2 – Dot plots of the median ages at which developmental stages D through H were attained in the maxilla and the mandible.

Discussion

A limitation to the reliability of age estimation is the individual variation of tooth development between individuals from birth to adulthood. After the age of 14 years, age estimation becomes difficult due to the fact that most teeth are already fully developed [20]. Third molars are generally the only teeth still developing and

useful to determine the probability of an individual being 18 years of age. The staging used by Demirjian et al. [13] proved to be accurate for the use in forensic age estimation by other researchers [21], and we similarly found it to be useful, easy to observe and detailed enough for this purpose. A ten stage scoring system was used to achieve higher accuracy in separating the stages of development towards apex closure [9]. Demirjian et al.[13] did not describe F1 and G1 as permanent molar stages but the additional stages have been found to be of particular value for third molar development evaluation by other researchers[9]. The two addition stages, F1 and G1, proved to be valuable in this study in determining the likelihood of being eighteen. The increase in likelihood between stages F, F1, G, G1 and H is shown in Table 4.

In our study we found that third molar development terminates earlier in BSA females than in WSA females and stage H is reached, on average, 11.16 months earlier in the maxilla and 13.92 months earlier in the mandible in BSA. BSA females reached 11 out of the 14 evaluated stages before the WSA females with 6 stages being statistically significant. BSA males reached stage H an average of 6.90 months earlier in the maxilla and 9.06 months earlier in the mandible when compared to WSA males. BSA males reached 8 out of the 14 evaluated stages before WSA males with 5 stages being statistically significant. For both the maxillary and mandibular third molars the pattern of stage development was similar. Stages F1, G and H were reached earlier by BSA males compared to WSA males with only stage G1 reached earlier by WSA males. This suggests that an earlier or later initiation of root formation between ancestral groups may be present. Completion of certain stages may take longer followed by periods of growth acceleration. The development of a tooth is a complex process controlled by a specific sequence of cellular and molecular networks acting at specific times[22].

Published data from other African groups are scarce and therefore comparisons are difficult. These findings do however correspond to the results found by Liversidge[18] where maturation occurred earlier in Black South African children compared to White and Bangladeshi children in London and Cape Coloured children in Cape Town. American Black individuals also reached each tooth development stage significantly earlier compared to American white individuals[23, 24]. Olze et al.[25] compared a German sample with a Black African sample and found a clear tendency for the Black African sample to reach mineralisation at an earlier stage. The median age for reaching stage H in our study is about a year higher compared to a German study including all third molars present[26]. The differences could be due to using an eight stage classification system compared to a ten stage classification system, the inclusion of all third molars compared to just the left third molars, and the use of conventional and digital radiographs compared to using only digital radiographs. The median ages for reaching stage H for WSA males and females were very similar to the results found for

German and Japanese individuals[27]. The median age for reaching stage H differs between Black South African males and females in this study compared to Black South African individuals used in previous studies[27, 28]. The differences could be explained by the small sample sizes used for some of the groups in previous studies and by only making use of conventional radiographs. Reference data should be adjusted to accommodate different ancestry groups because of the variation within the chronology of tooth formation.

This study shows that third molar development terminates on average earlier in BSA males compared to BSA females. In the maxilla stage H is reached 4.74 months earlier and in the mandible 5.16 months earlier. WSA males also reached, on average, each development stage earlier than WSA females. WSA males, compared to WSA females, reached stage H an average of 9.0 months earlier in the maxilla and 10.02 months earlier in the mandible. These findings in the studied population regarding sexual dimorphism corresponds to the findings in other populations where third molar maturity appears to be more advanced in boys[9, 29–32]. In contrast, Liversidge [18] found the mean age was reached earlier for almost all stages in Black African girls compared to boys and the sex difference was significantly different for only the crown complete stage where boys were 0.73 year later than girls. These conflicting results could be due to the small number of individuals used by Liversidge [18] in some of the age categories, but may also reflect variations between populations. Olze et al. [28] also found that, on average, female teeth developed 1.5 years earlier than those of males in a Black African population. Mean ages were found not to be statistically significant between males and females across all the third molar maturity index ranges in a Black African population in Botswana[33]. These discrepancies between different studies need further investigation and may suggest that there are other factors that play a role. Sexual dimorphism as far as dental development is concerned appears to be greater in the WSA population than in the BSA. Because of the observed sexual dimorphism in various groups, age estimation standards must be sex specific [30].

The results for the inter-observer repeatability indicated substantial agreement between observers for the evaluation of the maxillary third molars and only a moderate agreement for the mandibular third molars which are easier to rate. The mandibular third molars are generally easier to rate due to the fact that there is no anatomical structures superimposed over the area of evaluation. The quality of the panoramic radiographs used was very high. Only digital panoramic radiographs were used with the added advantage of using the software tools to create clear images and optimal viewing conditions making evaluation of the upper maxillary third molars easier. Stage F and F1 had a high rate of disagreement between the observers for both the maxillary and mandibular third molars. This could be due to the difficulty in exactly determining the length of the root in

relation with the crown to assign a specific stage, especially in cases where the mesial and distal root lengths are different. Stage G and G1 in the mandible also had a high rate of disagreement. Most disagreement between observers was to decide if the apical foramen was closed enough to categorize the tooth as a stage G1instead of a stage G. The transition from stage G to G1 created difficulty in accurately staging some teeth.

In this paper the likelihood of an individual being 18 years of age based on the third molar development stage for the maxilla and mandible was determined. The likelihood for an individual being 18 years of age increased considerably form stage F to stage G and from stage G to H for all ancestry and sex groups. The additional stages F1 and G1 make the transition of likelihood ratios between stages more gradual. The likelihood ratios between ancestry and sex groups were different for all development stages. Our results also differ from other population groups[34]. This indicates population variability and the need for ancestry and sex specific data when assessing age. When a 95% confidence is considered for the maxilla and mandible respectively for stage H, the majority of the females and WSA males are above, or very close to, age 18 with correspondingly high likelihoods. Combined results for the maxilla and mandible for stage H increased the likelihood of being 18 years to above 95% for all ancestry and sex groups. Therefore, a combined likelihood of the maxillary and mandibular third molar is considered to be a reliable indicator to determine if an individual is older than 18 years of age.

When estimating the age of a South African individual from BSA or WSA ancestry, the combined likelihood for the left maxillary and mandibular third molar must be considered for stage H to increase the likelihood of being at least eighteen years of age to above 95%. However, the study data cannot serve as the only criterion to estimate age and additional methods must be applied to estimate age more accurately. Ancestry and sex differences should be taken into consideration when estimating age. This research represents the largest comparison of these two ancestral groups to date.

Conclusions

Third molar development of 1268 South African individuals with known age, sex and ancestral origin was studied to determine if the rate of development differed between ancestry- and sex groups. It also aimed to present the likelihood of being 18 at a given developmental stage. Results of the study indicated that third molar development of BSA individuals is completed at earlier chronological ages compared to that of WSA individuals. The individual median ages at which BSA individuals achieve stage H development were significantly different to the WSA individuals, indicating that ancestry-specific data should be used. The use of

ancestry-specific data is necessary to prevent the overestimation of the age of BSA individuals. The third molars of males from BSA- and WSA- individuals matured earlier than those of females and these results are conflicting to previous studies done on similar population groups. The individual median ages at which WSA males achieved development stages were statistically significantly different to WSA females for certain stages, indicating that sex-specific data should ideally be used.

Third molar development can be used as a reliable method to determine the likelihood of being 18 years of age if the probability and 95% confidence interval is considered for stage H. Considering that no accurate non-invasive method is currently available to estimate age in living individuals the development of the third molars is a useful and reliable method of age estimation.

Compliance with ethical standards

The study was conducted in accordance to the ethical standards laid down by the Declaration of Helsinki[35].Approval for the study was granted by the University of Pretoria, Faculty of Health Sciences (Ethics reference number: 263/2015).

Conflict of interest

The authors declare that they have no conflict of interest

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