The timing of mandibular tooth formation in two African groups.

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Tooth abbreviations:
I1 mandibular central incisor
I2 mandibular lateral incisor
C mandibular canine
P1 mandibular first premolar
P2 mandibular second premolar
M1 mandibular first molar
M2 mandibular second molar
M3 mandibular third molar

Tooth stage abbreviations:
Cr crypt
Ci initial cusp formation
Cco coalescence on cusps
Coc crown outline complete
C1/2 crown half complete
C3/4 crown three quart rs complete
Cc crown complete
Ri initial root formation
Rcl root cleft formation
R1/4 root length one quarter
R1/2 root length one half
R3/4 root length three quarters
Rc root length complete
A1/2 apex half closed
Ac apex closed

ABSTRACT
Background: Ethnic differences in the timing of human tooth development are unclear.
Aim: To describe similarities and differences in the timing of tooth formation in two groups of Sudanese children and young adults.
Subjects and methods: The sample consisted of healthy individuals from Khartoum, Sudan, aged 2-23 years. The Northern group was of Arab origin (848 males, 802 females) and the Western group was of African origin (846 males, 402 females). Each mandibular left permanent tooth from first incisor to third molar was assessed from dental radiographs into one of 15 development stages. Mean ages at entry for 306 tooth stages were calculated using probit regression in males/ females in each group and compared using a t-test.
Results: Mean ages were not significantly different in most tooth stage comparisons *between* ethnic groups for both males (61/75) and females (56/76) despite a tendency of earlier mean ages in the Western group. Mean ages for most tooth stage comparisons between males and females (137/155) were not significantly different *within* ethnic groups suggesting low sexual dimorphism.
Conclusion: The mean ages of most mandibular tooth formation stag s were generally not significantly different between ethnic groups or between males and females in this study.

INTRODUCTION

Human teeth grow in a highly organised sequence in relation to each other prior to their eruption into the oral cavity. Teeth appear in maxillary and mandibular bones as individual units and follow a sequence of development until all teeth are fully formed. Tooth formation from crown tip to root apex follows a predictable morphological path. How this relates to the timing of consecutive stage formation between human groups is less clear. Understanding the effects of biological factors on the timing of tooth formation is important in human biology, forensic anthropology, evolutionary, medical and anthropologic fields.

Maturing teeth are regulated by complex biological clocks in their trajectory to full maturity (Papagerakis et al., 2014). This is particularly evident in crown formation (Antoine et al., 2009). Children vary considerably with respect to maturing teeth in relation to chronological age by a number of years but are still considered biologically normal (Demirjian and Levesque, 1980, Levesque et al., 1981, Liversidge et al., 2006, Liversidge, 2011, Nystrom et al., 2007).

In light of the large age variation between individuals, the precise effect of biological factors such as sex and ethnicity on the timing of dental maturity events needs to be explored in large groups or populations across world regions. The effect of biological factors on the complex and lengthy process of forming teeth requires particular attention to methods of sampling and analysis (Smith 1991). Some of the methods of analysis claiming differences between groups have been called into question (Liversidge et al., 1999, Liversidge, 2012). In addition, there is evidence to indicate the overall timing of tooth formation is relatively unaffected by severe biological insults such as malnutrition despite affecting skeletal and somatic growth (Elamin and Liversidge, 2013, Garn et al., 1965). The mechanisms that insulate the forming teeth from severe environmental pressures such as malnutrition are not clear. Other evidence suggests that biological factors such a sex and ethnicity have less impact on tooth formation than previously thought (Dean et al., 2014, Liversidge, 2011).

Our understanding of the impact of sex and ethnicity on the timing of tooth formation has been complicated by a number of methodological factors. Most studies on the timing of tooth formation h ve samples of limited age ranges, small numbers and used non-cumulative statistical approaches. Samples that contain limited age ranges allow only a few tooth stages to be investigated and statistically significant differences may not necessarily amount to biological importance in light of the inherent variation seen between individuals (Smith, 1991). Part of the difficulty is due to maturation of the tooth being divided into many stages (usually 8 to 15). This reduces the number of children per stage despite a large sample size and wide age r nge. Another challenge is that teeth mature over a long period of time in relation to other body systems, developing from prior to birth into early adulthood when individuals undergo marked morphologic and skeletal change with genetic and other environmental factors playing a role.

Only a handful of studies describe the timing of individual tooth stages using appropriate statistical methods and dispersion parameters across age and these are listed in Table I (Garn et al., 1959, Moorrees et al., 1963, Haavikko, 1970, Fanning and Brown, 1971, Thompson et al., 1975, Anderson et al., 1976, Demirjian and Levesque, 1980, Levesque et al., 1981, Zhao et al., 1990, Liversidge and Speechly, 2001, Liversidge et al., 2006, Nyström et al., 2007, Liversidge, 2008, Liversidge, 2011,). Some directly compare ethnic/regional groups (Liversidge et al., 2006, Liversidge, 2008, 2011), one notes differences for the third molar (Liversidge, 2008)

whilst others showed similarities (Liversidge et al., 2006, Liversidge, 2011) in formation times. Most of these studies describe tooth formation in children of European origin and there are gaps in the literature describing the timing of tooth formation in other world groups, particularly those in Africa. The timing of formation of the mandibular third molar in South African Blacks (Liversidge, 2008) is the only tooth documented in this way from an African population.

Table I about here

The aim of our study was to investigate the effect of ethnic group and sex on the timing of mandibular tooth formation in two groups of dental patients in Sudan with a wide age range using well-defined ethnic grouping, age structure and statistical analysis.

MATERIALS AND METHODS

The subjects (2.83-23.96 years, *N*= 2898) for this investigation were part of a population survey that considered tooth formation, anomalies and disease in Khartoum, Sudan (Elamin, 2011). Sample selection followed the design from the Strengthening and The Reporting of Observational Studies in Epidemiology guidelines (STROBE) (von Elm et al., 2007). Arab tribes from the North of Sudan (Jaali, Mahasi, Shaigi, Bedairi, Halfawi and Dongalawi groups) and Western Sudanese tribes of African origin namely, Fur and Zagawa were studied (Figure 1).

Figure I here

Subjects from the Northern group were randomly selected from pre-schools, Khalwas (religious schools), mainstream schools and universities between January 2007 and May 2012 and stratified by school, using a cluster sampling method (Bennett et al., 1991). Schools, preschools, Khalwas and universities in the three localities (Bahri, Umdurman and Khartoum Ci y) in Khartoum were chosen from a list of schools in these localities obtained from the Ministry of Education and sampled where safety permitted. The Western group were drawn from schools and Khalwas located in and around camps for the internally displaced in Khartoum. Children were excluded if the date of birth was unknown or if they had craniofacial anomalies. The age and sex distribution of the group is shown in Table II. For practical reasons, radiographs were limited to individuals around 3 years and older. Ethical approval was granted by the Ethics committee at El Razi Dental School prior to the study (01/11/2006). Verbal and written consent were obtained from individuals and from parents of minors. A dental examination was carried out and where appropriate, a dental panoramic radiograph taken (Orthophos Model: D3200, Siemens, Germany). The same machine was used in this study but was moved between two locations, a dental school in southern Khartoum and a dental hospital in the northern part. The radiograph involv d taking a standard view with the head in the Frankfort plane. The film was manually developed by experienced dental staff in preparation for clinical use.

Figure 2 about here
Table II about here

The radiographs were digitised, decoded and randomised for blind scoring by a person other than the investigator. Age of each subject was converted to decimal age. Permanent mandibular left teeth were staged by the first author (FE) from the radiographs using the 14 crown and root stages after Moorrees et al. (1963) in addition to staging the crypt of the third molar i.e. 120 stages (Figure 2). We only assessed mandibular teeth as maxillary teeth are less clearly visualised on panoramic

radiographs due to superimposition of the hard palate. Intra-examiner reliability of stage assessment from 90 panoramic radiographs was assessed by Cohen's Kappa showing excellent agreement (K=0.91). SPSS, Release Version 17.0 (©SPSS, Inc., 2009, Chicago IL) was used to analyse data. Probit regression was used to calculate the cumulative mean age at entry or transition into tooth stages where at least 10 individuals per year of age were available.

A total of 309 mean ages at entry were available to compare from a total of 420 possible comparisons in 4 groups of different ethnic origin and sex (males-female groups from North and West; male-male and female-female groups from both regions). Missing data in Tables III to IX are the tooth stages that develop before the third birthday, prior to the minimum age in our sample. Most tooth stages were observed across a wide age range and for most calculations at least 10 individuals were present in consecutive year age groups.

The number of available comparisons is shown in summary in Tables III and IV: 75 and 76 comparisons of Northern-Western males and females respectively, 80 comparisons Northern male-female and 75 Western male-female groups. The mean age of stage attainment for each tooth stage was compared between male (North/West) and female (North/West) groups of different ethnicity. Sex comparisons were carried out within ethnic groups using a t-test with a significance level of $p<0.05$.

RESULTS

A summary of significant/non-significant comparisons for all available mandibular tooth stages between ethnic groups and male/female groups is shown in Table III and IV respectively. Results for M3 are shown in Table V, M2 in Table VI, M1 in Table VII, P2 in Table VIII, P1 in Table IX, canine in Table X, I2 in Table XI and I1 in Table XII. Figures 3 to 8 show mean age at entry with 95% confidence interval of mean for stages of M3, M2 and C, comparing means in Northern and Western male groups and Northern male and female groups.

Other results of individual tooth stages including average age of individuals within a tooth stage and minimum and maximum age for tooth stages are available in Elamin (2011), although some root stages were re-assessed and ages checked subsequently for this paper. The reported standard deviation values for mean age at entry in this paper require a multiplication correction factor of $\pi/\sqrt{3}$ as mean ages were calculated using logistic regression (Greene and Hensher, 2010).

Figures 3 to 8 about here

Table III to XII about here

Ethnic comparisons

A high percentage of tooth stage comparisons of mandibular teeth were not significantly different. In males 61 out of 75 tooth stages (81%) were not significantly different. Of the 14 stages that were significant, mean age was earlier for 8 stages in the Western males compared to the Northern males. In females, 56 out of 76 tooth stages (74%) were not significantly different. Of the 20 stages that were significant, mean age was earlier for 7 stages in the Western group. The tooth stages involved were the lateral incisor apical root stages in males and premolars in both sexes. Mean ages of most root stages of both premolars in the Western females were later compared to Northern females. The reason for this is unclear. The Western female group was considerably smaller than other groups and late root stages of M3 are based on small numbers. These results are summarised in Table III and illustrated in Figures 3, 5 and 7 for M3, M2 and C respectively.

Sex comparisons

Most tooth stage comparisons of eight mandibular teeth were not significantly different. In the Northern groups 69 out of 80 tooth stages (86%) were not significantly different. Of the 11 stages that were significant, mean age was earlier for 8 stages in females compared to males. In the Western group, 68 out of 75 tooth stages (91%) were not significantly different. Mean age was earlier in the females for all 7 tooth stages that were significant in this group. These results are summarised in Table IV and illustrated in Figures 4, 6 and 8 for M3, M2 and C respectively.

DISCUSSION

Our results show that the timing of tooth formation is not significantly different in the vast majority of the 306 tooth stage comparisons. There was no clear pattern i.e. the stages that were significant were not specific to crown stage, root stage or tooth type, although mean ages in a number of root stages of successional teeth (canine and premolars) were delayed in the Western group compared to the Northern group. Mean ages were earlier in the Western group compared to the Northern group in around one third of comparisons.

Comparison between Northern and Western groups

Our main finding was that most mandibular tooth stages were not significantly different in timing in the two ethnic groups in Khartoum. Around 83% of comparisons in our study were not significantly different and there w_s no clear pattern in the tooth stages that were different. This finding is in agreement with two previous reports comparing the timing of age at entry of individual mandibular teeth between groups. The first study compared mean age entering D_mirjian stages in children from Australia, Belgium, Canada, England, Finland, France, South Korea and Sweden (Liversidge et al., 2006). About 13% of compari_ons were significantly different between groups with no clear pattern. The second (Liversidge et al. 2006) noted few differences between Whites and Bangladeshi groups in London (Liversidge, 2011). Comparing our results with the London groups show some stages in the Sudanese groups to be earlier (particularly incisors) and some later. Incisor stages assessment in some of the radiographs of the younger children in our study was difficult due to occasional poor image quality and this may have influenced our results.

Mean ages of M3 tooth stages were slightly later than one previous study of third molars in South African Blacks (Liversidge, 2008). Sub-Saharan African groups are known to have extensive genetic diversity (Tishkoff et al., 2009) and future studies on tooth formation in Africa are needed.

Several studies use non-cumulative methods of analyses and report ethnic differenc_s. Two studies compare timing of tooth formation directly. Harris and McKee describe mean age using Moorrees stages aged 3-13 years reporting earlier mean ages in middle southern USA black children compared to Whites (Harris and McKee, 1990). Another study in South African children found Blacks earlier than other groups (Phillips and van Wyk Kotze, 2009). Earlier mean/median age of third molars was reported in Black individuals in USA (Mincer et al., 1993, Harris, 2007, Blankenship et al., 2007) and in South Africans (Olze et al., 2004). Other studies compared mean age of third molars in German, Japan (Olze et al., 2007) and first nation people in Canada (Olze et al., 2010). Forensic age estimation from third molars in the living is reviewed by Olze et al.(Olze et al., 2004) who compare descriptive data in German, Japanese and South African groups. They note that mean ages of

some root stages in South Africans were earlier than Germans and mean ages in Japanese were later than Germans and they recommend population specific reference data. The use of mean/median ages to estimate age has been questioned and age of transition into maturity stages (including probit regression analysis) is now seen as more appropriate to estimate age and to compare groups (Boldsen et al., 2002, Konigsberg and Frankenberg, 2002, Konigsberg et al., 2008).

Comparison between Male-Females within groups

Our study found few statistical differences between mean ages of mandibular tooth stages in Northern male-female group and Western male-female group. The results from this study differ from previous findings of an advancement in root formation in females compared to males (Garn et al., 1958, Thompson et al., 1975, Moorrees et al., 1963, Anderson et al., 1976, Haavikko, 1970, Liversidge et al., 2006, Nystrom et al., 2007, Liversidge, 2012). Numerous previous studies report sexual dimorphism in timing between males and females in some teeth particularly canines and third molar root stages (Demirjian and Levesque, 1980, Levesque et al., 1981, Garn et al., 1959, Thompson et al., 1975, Liversidge et al., 2006, Liversidge, 2008, Nystrom et al., 2007, Moorrees et al., 1963, Anderson et al., 1976, Haavikko, 1970).

The reason for the lack of significant difference in the timing of tooth formation in males and females in our study is unclear. The size of the Western female group was considerably smaller than other groups. Sampling is possibly a factor when numbers are small however the cumulative statistical approach partly overcomes this difficulty.

This lack of significant difference in timing of tooth formation supports a recent histological study reconstructing longitudinal gr wth in enamel and dentine that reports no clear difference in modern male and female canine formation rates (Dean et al., 2014).

Strengths and limitations

A major strength of our study, which addresses some of the limitations of previous studies, was the structured design and statistical analysis to compare mandibular tooth formation at the population level in the Northern group. The stratified structured sampling strategy enabled comparisons to be representative. The study design included a large number of children per age group (3-23 years) selected to represent the Northern group. The age distribution of children in our sample was spread across a wide age range from as young as was practical up to dental maturity of the third molar. In order to assess the entire dentition, large sample sizes from very young to fully mature are required to validate the conclusions of effects of biological factors on the tim ng of tooth formation. This was accomplished for the Northern group.

Most tooth stages are observed over a wide age among individuals in a given population. To overcome this, a sample has to ensure sufficient children *per age group,* a wide age range and a cumulative approach to avoid reporting differences that may have been influenced by the large variation in age that is seen between individuals or small groups.

The mean age entering a tooth stage for a group is the age at which fifty per cent of children reach or pass that particular stage. This cumulative statistical approach is robust and the calculation of mean age of each tooth stage uses all individuals who have reached or passed each specific tooth stage in consecutive age categories. For example, to calculate mean age entering stage X, the proportion of

individuals who have entered stage X (or later stages) is noted for consecutive age categories from the youngest to the age category where 99% of individuals have reached/passed stage X. This means that sufficient individuals are included in each analysis as the age range from 1% to 99% can include up to 9 consecutive age categories (for late root stages of M3).

A limitation of the study was that a convenience sample of the Western group was necessary due to the ongoing civil war, resulting in a different sample structure of considerably smaller size. Despite a reasonable number of Western males and females for ages 5 to 16 (see Table II) the younger and older age categories are not well represented. This resulted in some mandibular tooth stages containing small numbers in the unrepresented age categories. The number of individuals in the Western group over the age of 16 is small and similarity in the timing of later root stages of M3 between the sexes should be further investigated with larger numbers.

Another limitation, in common with many other studies using dental panoramic radiographs of living children, is the lack of very young children. The mean ages of most crown stages of permanent incisors, canines and first molars occur during the first three years.

A limitation of any maturity study is that maturation, a continuous process is divided into arbitrarily selected, discreet stages that are not equally spaced in time. A tooth must be allocated to a crown or root stage and some tooth stages rely on subjective estimation of final crown and root lengths, for example Cr ¾ and R¾ and these are more difficult to assign. Other difficulties include superimposition of the vertebral column with anterior teeth and the mandible n t being correctly positioned in very young children. These influence the clarity o the adiographic image. Other factors such as individual variation in crown height and root length as well as the duration of development of both crown and roots may explain some inconsistencies in the pattern of differences in our results.

Conclusions

Mean ages of 23% of 151 tooth stage comparisons of mandibular teeth between 2 and 23 years of age were significantly different between Northern and Western males and Northern and Western females. The age variation within each group was considerably greater han the age variation between groups for all mandibular tooth stages we could assess in this study.

Mean ages of 12% of 155 tooth stage comparisons of mandibular teeth between 2 and 23 years of age were significantly different between males and females in both Northern and Western groups. A pattern of sexual dimorphism in tooth formation was not apparent in our results. This is in contrast to most previous radiographic studies that report a clear pattern with earlier mean ages of canine root stages and lat M3 root stages in females compared to males.

This means that health care providers in the region can use these results of timing of mandibular teeth from the Northern group as a reference to assess dental maturity for dental treatment or to plan the timing of orthodontic treatment. More research is needed on the rate of tooth development, root proportions of mature teeth as well as timing and root stage at tooth eruption in these and other African groups.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest, financial or personal relations with other organisations or people who may influence the study findings inappropriately.

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Figure legends

Figure 1. Map of Sudan, pre-cessation into two countries in 2011, where th study was conducted.

Figure 2. Mandibular tooth formation stages after Moorrees t al (1963) with the addition of crypt stage for molars.

Figure 3. North-West male mean age comparisons for mandibular third molar (M3) stages across the age span of the developing tooth showing similarity between the groups. black diamond, north; unfilled diamond, west.

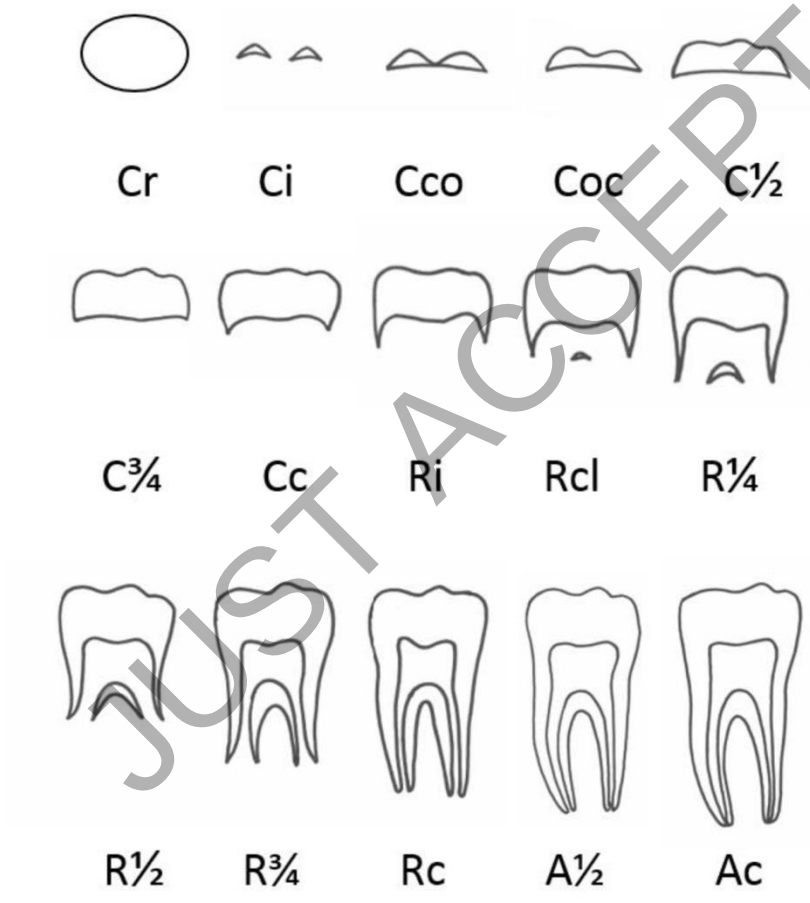
Figure 4. North male-female mean age comparisons for mandibular third molar (M3) stages across the age span of the developing tooth showing similarity between the groups. unfilled diamond, female; black diamond, male.

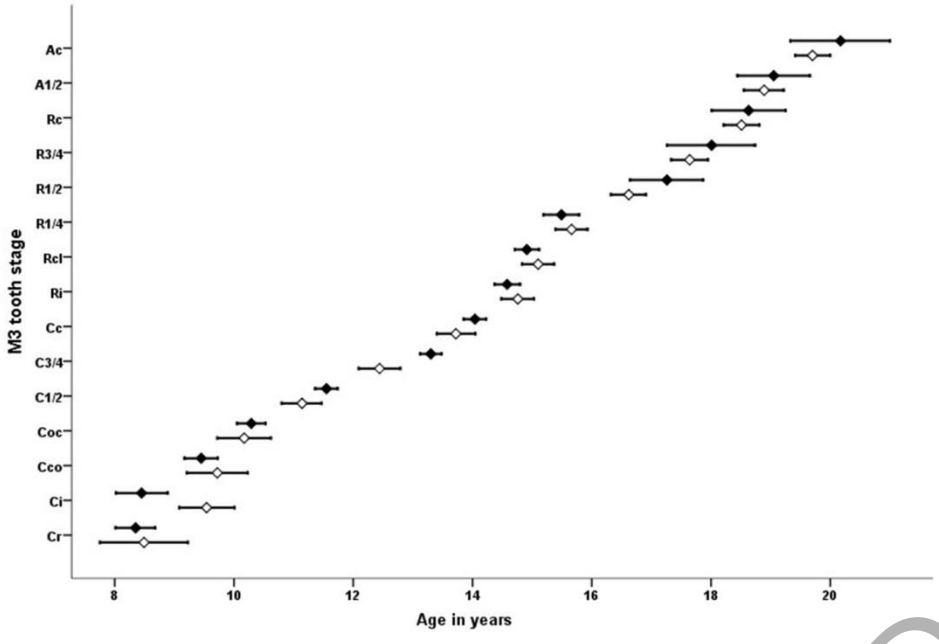
Figure 5. North-West male me n age comparisons for mandibular second molar (M2) stages across the age span of the developing tooth showing similarity between the groups. black diamond north; unfilled diamond, west.

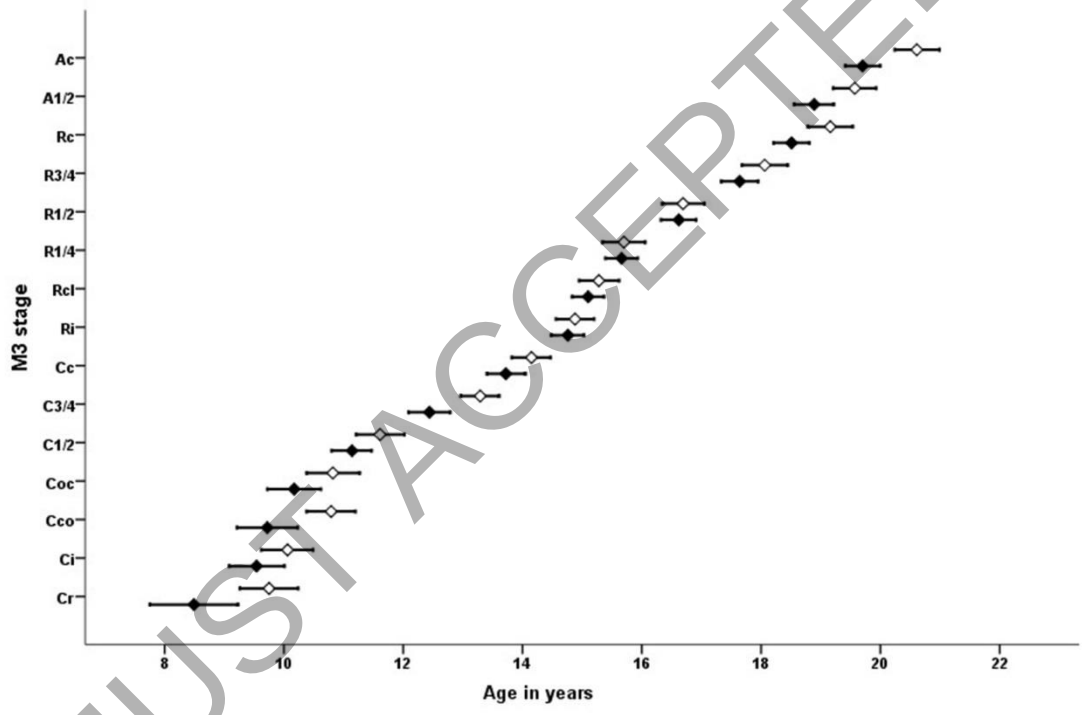
Figure 6. North male-female mean age comparisons for mandibular second molar (M2) stages across the age span of the developing tooth showing similarity between the groups. unfilled diamond, female; black diamond, male.

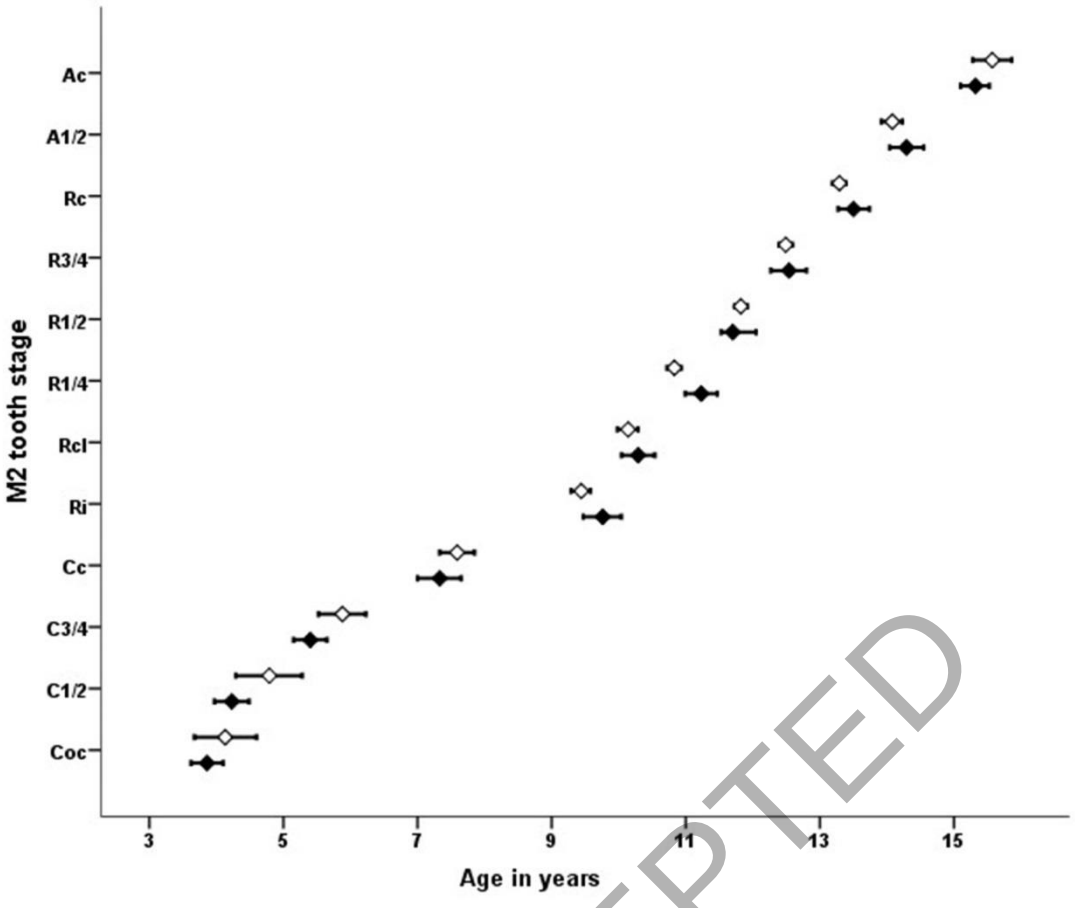
Figure 7. North West male mean age comparisons for mandibular canine (C) stages across the age span of the developing tooth showing similarity between the groups. black diamonds, north; unfilled diamonds, west.

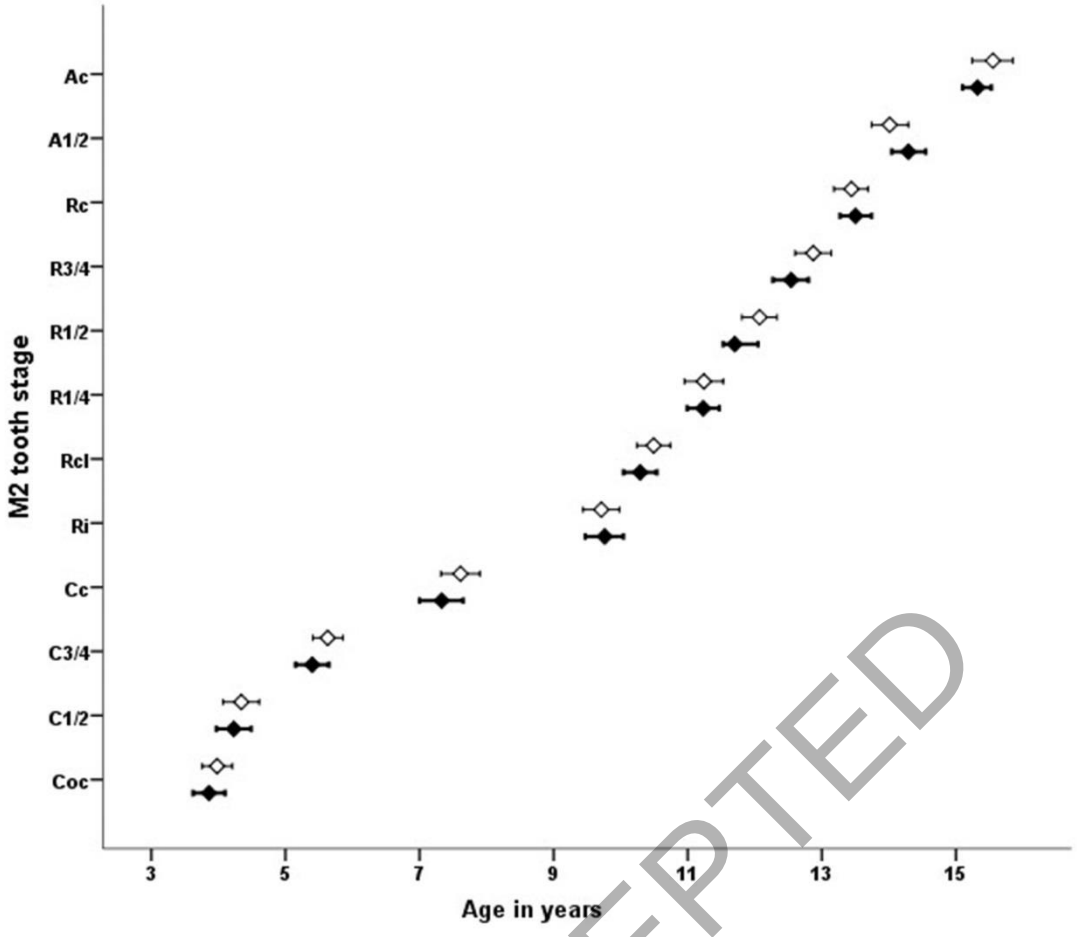
Figure 8. North male-female mean age comparisons for mandibular canine (C) stages across the age span of the developing tooth showing similarity between the groups. unfilled diamond, female; black diamond, male.

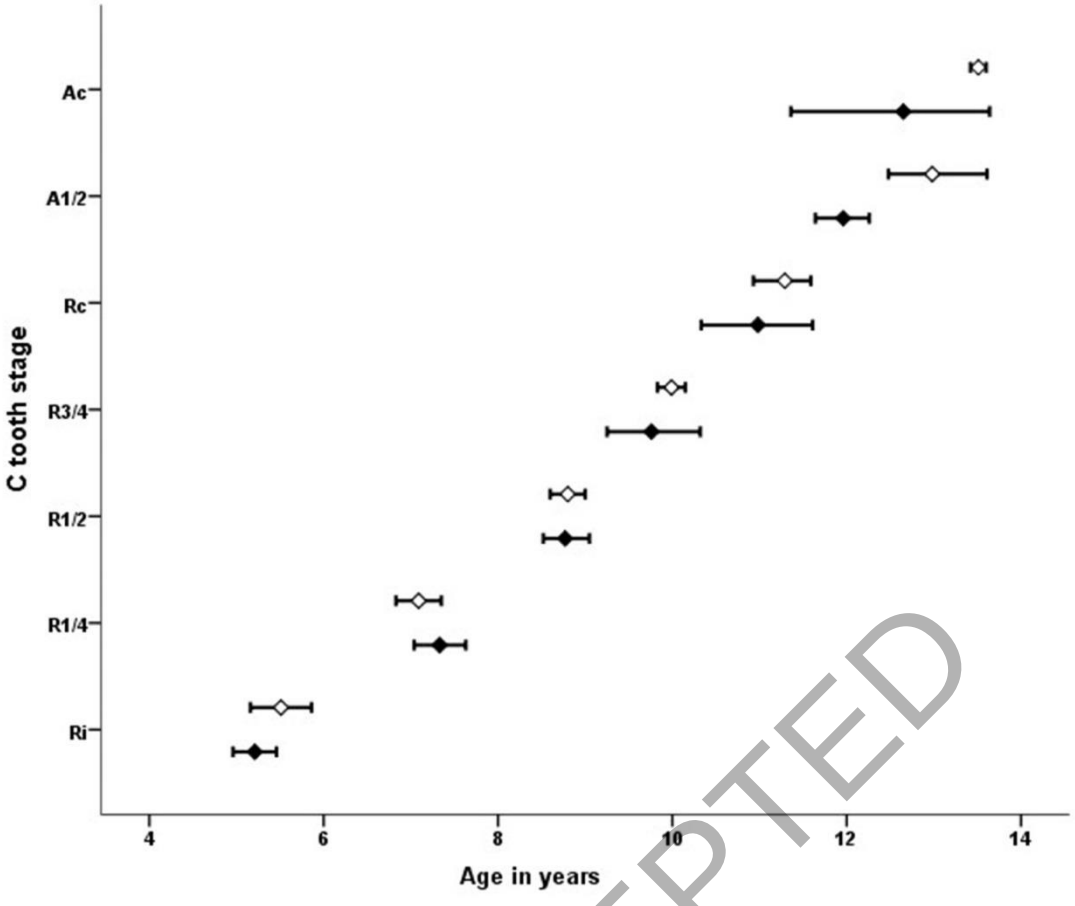












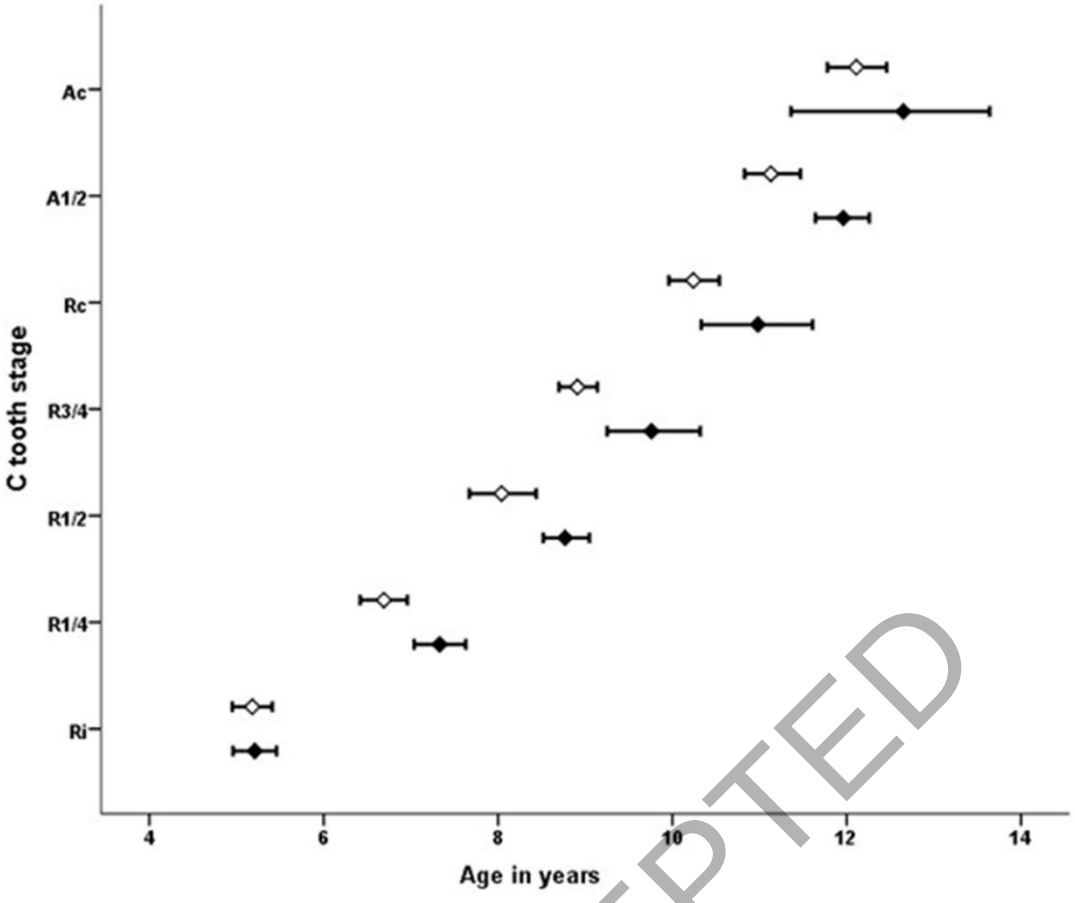


Table I. Radiographic studies that describe timing of individual permanent tooth maturation.

Country	Authors	N male, female	Age range	Teeth*	Statistics	Dispersion
Canada	Anderson et al. 1976	121,111	3-20	1	mean age L	SD
	Thompson et al. 1975	121,111	3-20	2	mean age L	-
	Demirjian + Levesque 1980	2705,2732	2-19	3	% smoothed curves	-
	Levesque et al. 1981	2278,2367	7-25	8	% smoothed curves	-
China	Zhao et al. 1990	465,438	3-16	3	50th percentile	-
Finland	Haavikko 1970	615,547	2-21	2	50th percentile	10^{th},90^{th} percentile
	Nyström et al.2007	966,1004	0-25	2	50th percentile	-
South Africa, UK	Liversidge 2008	390,335	5-23	8	mean, logistic regression	SD†, SE
UK	Liversidge + Speechly 2001	263,258	4-9	3	mean, probit regression	SD
	Liversidge 2011	529,521	2-22	2	mean, logistic regression	SD†, SE
USA	Garn et al. 1958	255	0-15	6	mean age L	-
	Garn et al. 1959	255	0-15	5	50th percentile	5^{th},15^{th},85^{th},95^{th} percentile
	Fanning 1961	48,51	3-12	3,7	mean age L	SD‡
	Fanning + Brown 1971	151,139	0-22	4	mean age L	3^{rd}, 97^{th} percentile
	Moorrees et al. 1963	184,161	0 22	2,7	mean age L	SD‡
Various	Liversidge et al. 2006	4522,4480	2-16	3	mean, logistic regression	SE

Age range in years, * 1 all maxillary and mandibular, 2 all mandibular, 3 all mandibular except M_3, 4 mandibular C, P_1, P_2, M_1, M_2,M_3, 5 mandibular C, P_1, P_2, M_1, M_2, 6 mandibular P_1,P_2, M_1, M_2, 7 maxillary incisors, 8 M_3, L longitudinal, SD standard deviation, SE standard error, † needs correcting factor, ‡ illustrated as error bar

Table II. Age and sex distribution of study sample. The Northern group was of Arab origin and the Western group was of African origin.

	North group			West group		
Age	F	M	Total	F	M	Total
2+	1	4	5	-	-	-
3+	31	37	68	4	4	8
4+	28	32	60	4	6	10
5+	31	47	78	30	21	51
6+	71	68	139	23	54	77
7+	62	56	118	22	61	83
8+	60	32	92	28	35	63
9+	45	35	80	52	45	97
10+	30	30	60	25	49	74
11+	20	29	49	57	150	207
12+	28	19	47	52	130	182
13+	18	41	59	26	113	139
14+	30	50	80	14	86	100
15+	31	34	65	16	43	59
16+	37	36	73	12	21	33
17+	61	52	113	6	7	13
18+	55	65	120	4	3	7
19+	34	48	82	9	11	20
20+	35	41	76	5	4	9
21+	34	39	73	9	2	11
22+	41	31	72	3	1	4
23+	19	22	41	-	-	-
Total	802	848	1650	402	846	1248

M male, F female, 2+ includes individual aged from 2.00 to 2.99 years etc.

Table III. Ethnic group comparisons. Summary of 75 comparisons of mean age entering mandibular tooth stages in North-West males and 76 in North-West females showing predominant similarity between ethnic groups. Missing tooth stages occurred at a younger age than our sample and could not be calculated.

Male Comparisons*	I1	I2	C	P1	P2	M1	M2	M3
Cr								NS
Ci								↑
Cco								NS
Coc					NS		NS	NS
C1/2					NS		NS	NS
C3/4				NS	NS		NS	↓
Cc			NS	NS	↑		NS	NS
Ri			NS	↑	↓	NS	NS	NS
Rcl			--	--	--	NS	NS	NS
R1/4	NS	NS	NS	↑	NS	NS	↑	NS
R1/2	NS	NS	NS	NS	↓	NS	NS	NS
R3/4	NS	NS	NS	↓	NS	NS	NS	NS
Rc	NS	↑	NS	NS	NS	NS	NS	NS
A1/2	NS	↑	↓	↓	NS	NS	NS	NS
Ac	NS	↑	NS	NS	NS	NS	NS	NS
Female Comparisons*	I1	I2	C	P1	P2	M1	M2	M3
Cr								NS
Ci								NS
Cco							NS	NS
Coc					NS		NS	NS
C1/2					NS		NS	NS
C3/4				NS	NS		NS	NS
Cc			NS	NS	NS		NS	NS
Ri		NS	NS	NS	NS		↑	NS
Rcl		--	--	--	--	NS	↑	NS
R1/4	NS	NS	NS	↓	↓	NS	NS	NS
R1/2	NS	NS	NS	↓	↓	NS	↑	NS
R3/4	NS	NS	NS	↓	↓	NS	↑	NS
Rc	NS	NS	↓	NS	NS	NS	NS	↑
A1/2	NS	NS	NS	↓	↓	NS	NS	↑
Ac	NS	NS	↓	↓	↓	↓	NS	↑

* significan difference in mean age entering tooth stage ($p<0.05$).

↑ significant advance in mean age for Western group *(Northern group is reference)*

↓ significant delay in mean age for Western group *(Northern group is reference)*

NS Non-significant differences ($p>0.05$)

-- No cleft stage for anterior teeth

Table IV**.** Male-female comparisons**.** Summary of 80 comparisons of mean age entering mandibular tooth stages in North male-female and 75 West male-female groups showing predominant similarity between males and females. Missing tooth stages occurred at a younger age than our sample and could not be calculated.

North Comparisons*	I1	I2	C	P1	P2	M1	M2	M3
Cr								NS
Ci							NS	NS
Cco					NS		NS	NS
Coc					NS		NS	NS
C1/2				NS	NS		NS	NS
C3/4				NS	NS		NS	NS
Cc			NS	NS	↓		NS	NS
Ri		NS	NS	NS	↓	NS	NS	NS
Rcl		--	--	--	--	NS	NS	NS
R1/4	NS	NS	↑	NS	NS	NS	NS	NS
R1/2	NS	NS	↑	NS	NS	NS	NS	NS
R3/4	NS	NS	↑	NS	NS	NS	NS	NS
Rc	NS	NS	NS	NS	NS	NS	NS	NS
A1/2	NS	↑	↑	↑	↑	NS	NS	NS
Ac	NS	↑	NS	NS	NS	NS	NS	↓
West Comparisons*	I1	I2	C	P1	P2	M1	M2	M3
Cr								NS
Ci								NS
Cco							NS	NS
Coc					NS		NS	NS
C1/2					NS		NS	↑
C3/4				NS	NS		NS	↑
Cc			NS	NS	NS		NS	↑
Ri			NS	NS	NS		↑	NS
Rcl			-	--	--	NS	NS	NS
R1/4	NS	NS	NS	NS	NS	↑	NS	NS
R1/2	NS	NS	NS	NS	NS	NS	NS	NS
R3/4	NS	NS	↑	NS	NS	NS	NS	NS
Rc	NS	NS	NS	NS	NS	NS	NS	NS
A1/2	NS	NS	NS	NS	NS	NS	NS	NS
Ac	NS	NS	↑	NS	NS	NS	NS	NS

* significant difference in mean age entering tooth stage ($p<0.05$).
↑ significant advance in mean age for females *(Males are reference group)*
↓ significant delay in mean age for females *(Males are reference group)*
NS Non-significant differences ($p>0.05$)
-- No cleft stage for anterior teeth

Table V. Comparison of mean age in years, standard deviation (SD), 95% confidence interval (95% CI) for entering mandibular M3 stages in Northern and Western Sudanese groups. N=Number of individuals in the group

	North Females (N=802)		West Females (N=401)		North Males (N=848)		West Males (N=846)	
Stage	Mean, SD	95% CI	Mean,SD	95% CI	Mean, SD	95% CI	Mean, SD	95% CI
Cr	8.19,1.41	7.95,8.45	8.23,1.68	7.28,9.18	8.49,2.05	7.75,9.23	8.35,2.66	8.01,8.68
Ci	8.88,1.18	8.65,9.14	8.75,2.06	8.34,9.16	9.54,3.76	9.08,10.01	8.45,1.45	8.02,8.89
Cco	9.28,1.19	9.04,9.59	9.50,1.32	9.13,9.87	9.72,2.06	9.21,10.23	9.45,1.36	9.17,9.73
Coc	9.77,1.26	9.50,10.10	10.11,1.54	9.79,10.44	10.17,2.12	9.72,10.62	10.29,1.50	10.05,10.53
C1/2	10.71,1.57	10.11,11.49	11.23,1.48	10.95,11.51	11.14,1.74	10.80,11.47	11.55,1.63	11.36,11.74
C3/4	12.27,1.81	11.79,12.71	12.26,1.18	12.02,12.51	12.44,1.86	12.09,12.79	13 30 1.41	13.12,13.48
Cc	13.56,1.96	13.11,13.97	13.04,1.45	12.71,13.36	13.72,1.72	13.40,1405	14.04,1.25	13.85,14.23
Ri	14.47,1.87	14.06,14.85	14.23,1.23	13.86,14.59	14.76,1.29	14.48,15.03	14.58,1.18	14.37,14.80
Rcl	14.95,1.77	14.56,15.31	15.25,1.47	14.80,15.71	15.10,1.36	14.83,15.37	14.91,1.12	14.71,15.12
R1/4	15.70,2.14	15.34,16.06	15.49,1.21	15.07,15.92	15 66,1.38	15.39,15.93	15.49,1.36	15.19,15.79
R1/2	16.69,2.50	16.34,17.05	16.27,1.12	15.82,16.72	16.62,1.77	16.32,16.91	17.26,1.63	16.64,17.87
R3/4	18.06,2.73	17.68,18.45	17.28 0.85	16 70,17.86	17.64,2.03	17.33,17.95	18.01,1.36	17.26,18.74
Rc	19.16,2.39	18.78,19.54	18.11,1.00	17.55,18.66	18.51,1.86	18.21,18.81	18.63,1.19	18.01,19.25
A1/2	19.57,2.28	19.21,19 93	18.44,0.80	17.95,18.93	18.89,1.70	18.55,19.22	19.05,0.98	18.44,19.66
Ac	20.61,1.94	20.24,2.99	19.43,1.34	18.72,20.14	19.70,1.54	19.41,20.00	20.17,1.47	19.33,21.00

Table VI. Comparison of mean age in years for entering mandibular M2 stages in Northern and Western Sudanese groups.

	North Females (N=802)		West Females (N=402)		North Males (N=848)		West Males (N=846)	
Stage	Mean, SD	95%CI	Mean, SD	95%CI	Mean ,SD	95%CI	Mean, SD	95%CI
Ci	3.48,0.22	3.25,3.71			3.03,0.94	2.59,3.47		
Cco	3.78,0.56	3.56,3.99	3.90,0.52	3.36,4.44	3.44,0.94	3.12,3.76		
Coc	3.98,0.69	3.76,4.21	4.19,0.33	3.81,4.57	3.86,0.76	3.62,4.10	4.13,0.54	3.67,4.60
C1/2	4.34,0.98	4.07,4.61	4.66,0.96	4.15,5.17	4.23,0.96	3.97,4.49	4.79,0.89	4.29,5.28
C3/4	5.63,0.89	5.41,5.86	5.58,1.14	5.39,5.76	5.40,1.18	5.15,5.65	5.88,1.07	5.52,6.23
Cc	7.61,1.50	7.32,7.90	7.52,1.14	7.14,7.90	7.33,1.83	7.00,7.65	7 59,119	7.33,7.85
Ri	9.71,1.38	9.44,9.98	9.00,0.81	8.76,9.25	9.76,1.52	9.47,10.04	9.44,0 63	9.29,9.58
Rcl	10.49,1.30	10.24,10.74	9.84,0.65	9.65,10.02	10.29,1.25	10.04,10.54	10.14,0.67	9.98,10.29
R1/4	11.24,1.61	10.95,11.53	10.79,0.72	10.62,10.95	11.23,121	10.99,11.47	10.83,0.62	10.72,10.93
R1/2	12.07,1.19	11.81,12.33	11.60,0.49	11.45,11.75	11.79,112	11.53,12.05	11.82,0.65	11.73,11.92
R3/4	12.87,1.23	12.60,13.14	12.33,0.63	12.17,12.49	12.54,1.18	12.27,12.80	12.49,0.60	12.39,12.59
Rc	13.44,1.18	13.18,13.69	13.09,0.56	12.89,13.28	13.50,1.09	13.27,13.74	13.29,0.76	13.19,13.39
A1/2	14.01,1.12	13.74,14.29	14 30 1.12	13 93,14.67	14.29,1.03	14.04,14.55	14.08,1.01	13.92,14.23
Ac	15.55,1.67	15.24,15.85	15.62 1.09	15.19,16.06	15.32,1.00	15.10,15.53	15.57,1.27	15.28,15.86

Abbreviations see Table V

Table VII. Comparison of mean age in years entering mandibular M1 stages in Northern and Western Sudanese groups.

	North Females (N=802)		West Females (N=402)		North Males (N=848)		West Males (N=846)	
Stage	Mean,SD	95% CI	Mean,SD	95% CI	Mean,SD	95% CI	Mean,SD	95% CI
Cc	2.97,0.57	2.30,3.65						
Ri	4.07,0.23	3.90,4.25			4.18,0.42	3.95,4.41	4.10,0.18	3.71,4.32
Rcl	4.20,0.21	4.04,4.37	4.33,0.50	3.71,4.96	4.51,0.34	4.31,4.71	4.58,0.41	4.10,5.07
R1/4	5.22,0.31	5.03,5.41	4.86,0.32	4.53,5.19	5.23,0.32	5.06,5.41	5.39,0.13	5.20,5.57
R1/2	6.00,0.41	5.80,6.20	6.09,0.15	5.92,6.27	6.08,0.47	5.88,6.27	6.12,0 23	5.94,6.30
R3/4	6.47,0.97	5.76,6.91	6.80,0.31	6.51,7.09	7.06,0.47	6.84 7.28	6.81 0.57	6.55,7.08
Rc	7.34,0.88	6.92,7.77	7.18,0.81	6.89,7.45	7.27,0.89	6.27 8.26	7.03,1.31	5.84,7.86
A1/2	7.60,0.71	6.45,9.02	8.31,1.23	7.36,8.88	7 89,1 07	7.29,8.69	8.29,1.27	8.04,8.52
Ac	8.08,0.58	7.94,8.24	9.71,1.09	9.45 9.96	8 99,1 30	8.18,10.14	9.50,1.07	8.95,9.95

Abbreviations see Table V

Table VIII. Comparison of mean age in years entering mandibular P2 stages in Northern and Western Sudanese groups.

	North Females (N=802)		West Females (N=402)		North Males (N=848)		West Males (N=846)	
Stage	Mean, SD	95% CI	Mean,SD	95% CI	Mean, SD	95% CI	Mean, SD	95% CI
Cco	3.40,0.70	2.85,3.96			3.66,0.50	2.99,3.72		
Coc	3.98,0.52	3.66,4.30	4.02,0.79	2.61,4.55	3.57,0.40	3.30,3.82	4.15,0.39	3.69,4.60
C1/2	4.26,0.56	3.95,4.57	4.43,0.66	3.34,4.85	4.15,0.45	3.90,4.40	4.20,0.47	3.51,4.89
C3/4	5.25,0.59	4.99,5.52	5.18,0.61	4.52,5.44	5.21,0.94	4.97,5.42	5.16,0.65	4.64,5.68
Cc	6.50,0.71	6.24,6.76	6.48,1.10	6.12,6.80	5.95,1.18	5.66,6.12	6.85,0.61	6.58,7.12
Ri	8.73,0.97	8.42,9.04	8.16,0.67	7.80,8.53	7.91,1.56	7.63,8 22	8 45,0.50	8.24,8.66
R1/4	9.00,1.20	8.77,9.25	9.54,0.54	9.32,9.96	9.33,1.26	9.05,9.64	9.78,0.54	9.61,9.96
R1/2	9.83,1.41	9.55,10.14	10.58,0.58	10.37,10.80	10.18,0.63	9.97,10.40	10.79,0.53	10.64,10.94
R3/4	11.02,1.33	10.71,11.37	11.80,0.43	11.61,11.99	11 43,1 64	11.07,11.77	11.82,0.64	11.68,11.96
Rc	12.18,1.45	11.44,12.90	12.70,0.46	12.48,12.92	12.66,1.33	12.33,12.96	12.87,0.60	12.73,13.02
A1/2	12.96,1.38	12.60,13.31	14.27,0.78	13.95,14.61	13.77,1.13	13.50,14.03	14.50,0.60	13.90,14.20
Ac	14.19,1.54	13.82,14.56	15.30 1.32	14.88,15.83	14.29,0.78	12.75,15.39	14.82,1.03	14.40,15.38

Abbreviations see Table V

Table IX. Comparison of mean ages in years for entering mandibular P1 stages in Northern and Western Sudanese groups.

	North Females (N=802)		West Females (N=402)		North Males (N=848)		West Males (N=846)	
Stage	Mean, SD	95%CI	Mean,SD	95%CI	Mean,SD	95%CI	Mean,SD	95%CI
C1/2	2.99,1.18	2.31,3.68						
C3/4	4.20,0.91	3.93,4.46	3.66,1.21	2.51,4.80	4.14,0.86	3.58,4.56	3.93,1.38	2.98,4.87
Cc	5.47,0.80	5.26,5.69	4.97,1.41	4.41,5.52	5.23,0.90	5.00,5.43	5.23,1.25	4.72,5.73
Ri	6.54,1.16	6.30,6.78	6.82,1.18	6.43,7.20	6.04,1.47	5.32,6.57	6.99,1.14	6.71,7.26
R1/4	7.76,0.92	7.58,7.95	8.32,1.16	7.97,8.66	8.03, 1.30	7.78,8.30	8.66,0.83	8.46,8.86
R1/2	8.69,1.07	8.19,9.30	9.70,0.98	9.49,9.91	9.68,1.23	9.26,10.16	10.00,0.92	9.82,10.18
R3/4	9.63,1.65	9.14,10.28	10.82,1.00	10.63,11.01	10.53,0.87	10.26,10.79	10.97,1.01	10.83,11.12
Rc	10.92, 1.46	10.12,11.89	11.97,0.72	11.77,12.16	11.61,0.41	10.69,12.38	12.07,1.12	11.93,12.21
A1/2	11.88, 1.35	11.54,12.24	12.95,0.92	12.72 13.17	12 62 1.37	12.30,12.92	13.13,1.09	12.98,13.28
Ac	12.76, 1.31	12.41,13.14	13.94,0.96	13.61,14.26	13.46,1.36	12.52,14.17	13.90,0.87	13.75,14.05

Abbreviations see Table V

Table XI. Comparison of mean ages in years for entering mandibular C stages in Northern Sudanese and Western Sudanese groups.

	North Females (N=802)		West Females (N=402)		North Males (N=848)		West Males (N=846)	
Stage	Mean,SD	95%CI	Mean,SD	95%CI	Mean, SD	95%CI	Mean,SD	95%CI
C3/4					2.97,0.89	2.52,3.42		
Cc	3.93,1.00	3.62,4.24	4.19,0.74	3.10,4.67	4.05,1.21	3.73,4.37	4.52,0.65	4.05,4.98
Ri	5.18,0.87	4.95,5.41	5.08,1.34	4.57,5.58	5.21,1.10	4.96,5.46	5.51,0.80	5.16,5.86
R1/4	6.69,1.43	6.42,6.96	6.90,0.92	6.54,7.25	7.33,1.52	7.04,7.63	7.09,1.07	6.83,7.35
R1/2	8.04,1.13	7.67,8.44	8.19,1.09	7.39,8.89	8.77,0.24	8.52,9.05	8.80,0.87	8.60,9.00
R3/4	8.91,1.03	8.70,9.14	8.89,1.18	8.54,9.24	9.76,1.47	9.25,10.32	9.99,0.92	9.83,10.15
Rc	10.24,1.25	9.96,10.54	10.83,1.00	10.64,11.02	10.98, 0.98	10.33 11.61	11.29 1.32	10.93,11.59
A1/2	11.13,1.30	10.83,11.47	12.47,0.63	12.30,12.66	11.96, 1.27	11.64,12.26	12.98,0.83	12.48,13.61
Ac	12.11,1.24	11.78,12.46	12.97,0.49	12.81,13.17	12.65, 0.97	11.36,13.64	13.51,0.39	13.42,13.60

Abbreviations see Table V

Table XI. Comparison of mean ages in years for entering mandibular I2 stages in Northern and Western Sudanese groups.

	North Females (N=802)		West Females (N=402)		North Males (N=848)		West Males (N=846)	
Stage	Mean, SD	95%CI	Mean, SD	95%CI	Mean,SD	95%CI	Mean, SD	95%CI
Ri	3.61, 0.83	3.29,3.93	3.83,0.62	3.19, 4.47	3.27,1.18	2.84,3.70		
R1/4	4.80,0.89	4.56,5.04	4.63,0.72	4.17,5.09	4.78,1.07	4.52,5.03	4.77,0.91	4.27,5.28
R1/2	5.97,0.92	5.75,6.19	5.88,0.83	5.58,6.18	5.90, 1.14	5.63,6.16	5.40,1.25	4.95,5.86
R3/4	7.16,1.29	6.90,7.42	7.09,0.74	6.76,7.43	7.00, 0.95	6.80,7.20	6.70,1.10	6.42,6.98
Rc	7.37,0.84	7.20,7.54	8.25,1.05	6.98,7.59	7.54, 1.00	7.33,7.76	7.12,0.96	6.90,7.32
A1/2	7.68,0.84	7.21,8.18	7.94,1.25	7.60,8.25	8.52, 1.42	8.21,8.84	7.81,1.19	7.57,8.05
Ac	8.07,0.86	7.89,8.26	8.31,1.27	7.98,8.60	9.12, 1.37	8.82,9.48	8.31,1.08	8.08,8.54

Abbreviations see Table V

Table XII. Comparison of mean age in years entering mandibular I1 stages in Northern and Western Sudanese groups.

	North Females (N=802)		West Females (N=402)		North Males (N=848)		West Males (N=846)	
Stage	Mean,SD	95% CI	Mean,SD	95% CI	Mean,SD	95% CI	Mean,SD	95% CI
R1/4	4.00,0.43	3.75,4.24	3.83,0.34	3.19,4.47	3.58,0.72	3.18,3.98	3.46,0.75	2.24,4.68
R1/2	5.15,0.48	4.92,5.38	4.83,0.29	3.02,6.63	5.02,0.57	4.77,5.27	4.77,0.50	4.27,5.28
R3/4	6.17,0.61	5.93,6.41	5.88,0.46	5.58,6.18	6.16,0.64	5.92,6.39	5.40,0.69	4.95,5.86
Rc	6.75,0.91	6.56,6.94	6.59,0.77	6.32,6.86	6.54,0.43	6.42,6.67	6.18,1.15	4.38,6.74
A1/2	7.07,0.91	6.62,7.48	7.03,0.94	6.73,7.32	6.67,0.56	6.52,6.81	6.85,100	6.60,7.07
Ac	7.36,0.86	7.19,7.54	7.42,1.14	7.09,7.72	7.20,0.89	7.02 7.40	6.87 0.97	6.63,7.09

Abbreviations see Table V