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Odontology

Third molar development in a London population of White British and Black British or other Black ethnicity

Sally E. Andrews PhD[1] | Graham Robert MDS[2] | Pat Set FRCR[3] | Fiona Warburton MSc[2] | Fiona J. Gilbert FRCR[1]

[1]Department of Radiology, Addenbrooke's Hospital, University of Cambridge, Cambridge, UK

[2]Department of Orthodontics, King's College Dental Institute, London, UK

[3]Department of Radiology, Addenbrooke's Hospital, Cambridge, UK

Correspondence
Sally E. Andrews, PhD, Department of Radiology, Addenbrooke's Hospital, University of Cambridge, Box 218, Hills Road, Cambridge CB2 0QQ, UK.
Email: salgallia@gmail.com

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Abstract

Population differences in dental development between Black and White ethnic groups have been debated but not previously studied in the UK. Using inappropriate data for dental age estimation (DAE) could lead to erroneous results and injustice. Data were collected from dental panoramic radiographs of 5590 subjects aged 6–24 years in a teaching hospital archive. Demirjian stages were determined for left-sided teeth and third molars and data collected regarding hypodontia and third molar agenesis. Third molar development in self-assigned Black British, including other self-assigned Black ethnicity, was compared with that of self-assigned White British subjects. Data were compared for males and females in the two ethnic groups using *T*-tests for Demirjian Stages A–G of third molar development and Mann-Whitney tests for Stage H once a cut-off age at the maximum age for Stage G had been imposed. Third molar development occurred earlier in subjects of Black ancestry compared to those of White ancestry. While both ethnic groups showed large age ranges for every third molar stage, in female subjects these generally occurred at least 1.5 years earlier, and in males at least one year earlier. Hypodontia and third molar agenesis were more prevalent in White British, but the ethnic difference in third molar development persisted in subjects with complete dentitions. This is a large study that confirms ethnic differences in a London population, emphasises the difficulties of establishing the 18-year-old threshold using DAE, and confirms the risk of overestimating the age of individuals of Black ethnicity using White ethnic reference data.

KEYWORDS

18-year-old threshold, African ancestry, Black British and White British ethnic groups, Demirjian stages, dental age estimation, ethnicity, forensic odontology, London population, third molar development

Highlights

- Large UK study of dental development in subjects of Black ethnicity and White British ethnicity.
- Third molar development occurs significantly earlier in Black compared to White subjects.

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- Large age ranges seen in both ethnic groups for each Demirjian stage of third molars.
- Hypodontia and third molar agenesis are significantly more prevalent in the White British group.
- Overestimation of age of Black subjects is likely if White dental reference data is used.
- Difficulties of using dental age estimation to establish the 18-year-old threshold highlighted.

1 | INTRODUCTION

Although age itself is not always a valid measurement of maturity, the attainment of the 18-year-old threshold is an important stage in the lifetime of an individual. In the case of asylum seekers without documentation to prove their age, a decision as to whether adulthood has been reached carries potentially life-changing legal and social consequences [1]. Adult and child entitlements not only differ with respect to housing, care, and education but also to management if there is involvement with the criminal justice system. Incorrect age assessment risks further harm to vulnerable and already traumatised children if they are disbelieved about a fundamental part of their identity, assessed as being adult, and deprived of the support to which they are entitled. Methods including physical appraisal, psychosocial assessment, skeletal development, and dental development are used in determining the 18-year-old threshold but all are inevitably fallible. The benefit of the doubt must be applied when an age threshold decision is made [2,3].

Dental age estimation (DAE) is used in archaeological, forensic, and mass disaster investigations providing information to assist with identification of the deceased [4]. After about 16 years of age, the third molar is the only tooth still developing but, despite the wide acceptance, that there is no better biological marker of age than the third molar in late adolescence and young adulthood [5] accuracy of DAE is limited. As is to be expected with a biological growth process, there are wide age ranges at third molar developmental stages which inevitably reduce DAE accuracy. A little understood factor in DAE concerns the variation of timing of dental maturation in different population groups. This is the first study to compare dental development in a UK population of African ancestry and White British subjects in the same sample with the same methodology. Appropriate reference datasets are essential for any DAE undertaken and knowledge of the timing of dental development is also important in treatment planning and provision regarding, for example, orthodontic interventions and third molar surgery.

There is increasing evidence that population differences exist despite some claims that differences do not make a significant impact on dental age estimation [6,7]. A difference in the timing of dental development between those of African and Caucasian ancestry has been suggested since before DAE became a recognised radiographical technique [8] and is of interest not only because these differences have been little investigated but also because most unaccompanied asylum-seeking children arriving in the UK have African countries as their place of origin [9].

Clinical studies have indicated that third molars may mature at an earlier age in those of Black ethnicity compared to White ethnicity [8,10–12], with one suggested explanation being a fibrous African diet [13]. However, if third molars are developing earlier for whatever reason, age could be overestimated if dental age assessment is made using Caucasian reference data. Clinical studies have been criticised for not taking root development into account as well as limitations regarding unknown incidence of third molar agenesis and impactions. The radiographic investigation of ethnic differences between those of Black ethnicity and White ethnicity has been sparsely represented in the literature. An ethnic difference was demonstrated in a radiographic study using Demirjian tooth development stages (TDS) between the third molars of Americans of Black ancestry and White ancestry [14], between those of Black Africans in South Africa and White and Bangladeshi children from London [15], between Afro-Trinidadians and UK Caucasians [16]. In all these studies, those of African ancestry were found to develop third molars in advance of the comparison groups. There have been criticisms of results such as these not only in terms of the obvious difficulties in defining ethnicity but also the possible socio-economic, geographical [17], dietary [13], and other variables between populations and disparate locations, and also the possibility of apparent differences being attributable to data management biases. The A.B.F.O. (American Board of Forensic Odontology) study [18] concluded an insignificant difference between Black Americans and White Americans although suggested that this may have been because the sample size was small. Small differences in the timing of third molar root development were found in a study of world groups, with Sub-Saharan Africans ahead of a UK White group for example, but it was concluded that a reference dataset with a wide age range and uniform age distribution is more important in DAE using the third molar than a population-specific sample [7].

This study addresses the above concerns and samples from a large local population in London are analysed to establish if the ethnic differences in the third molar are real.

2 | MATERIALS AND METHODS

Ethical permission for this study was granted by the Health Research Authority (HRA) and the Guy's and St Thomas' NHS Foundation Trust (GSTFT) Ethics Committees through the Integrated Research Application System (IRAS ID 239922). Subjects attending GSTFT King's College Dental Institute, South London, are drawn from the richly diverse local ethnic community in the Borough of Southwark and surrounding region. In South London, the proportion of White British residents was 40% in the 2011 census with Southwark having the largest Black African population in the UK (16.1%) and more than a quarter (27%) of residents identifying as 'Black' [19].

Subjects with an existing digitised dental panoramic radiograph/tomograph (DPT) in the GSTFT Romexis database were identified and included in the sample if their self-assigned ethnicity had been given as White British, Black British, or any other Black ethnicity denoting African ancestry on completing the hospital registration requirements. All those reporting their ethnicity as Black were counted as Black British for the purposes of this study. A preliminary check of the DPT was carried out to ensure compliance with the inclusion criterion of the third molar region of at least one side being shown. Radiographs had been taken for diagnosis or treatment and therefore showed pathological features such as caries, impacted teeth, ectopic teeth, hypodontia, supernumerary teeth, maxillofacial trauma, and surgical procedures. No attempt was made to categorise the reason for taking the DPT. The identification of developing teeth or agenesis was generally straightforward but other radiographs could be checked to clarify less obvious features of the dentition such as whether premolars were developmentally absent or had been removed for orthodontic reasons. Exclusion criteria were uncertainty of tooth identification, or an undated or poor copy of a DPT. Care was taken to ensure that each individual was represented by only one DPT to ensure cross-sectional study compliance. Partial DPTs, designed to include only the area to be investigated but avoid unnecessary irradiation, were included as long as the third molar region was shown on at least one side.

A sample size calculation carried out in Gpower (v 3.1.5) found that 50 males and 50 females in both White British and Black British ethnic groups within each half-yearly age group between the ages of 6.00 and 23.99 years would be required to find a difference of 0.75 years (SD of 1.32) with 80% power at the 5% level of significance. DPTs have been added to the Romexis database since 2005, and by 2020, it contained approximately 47,000 DPTs. Around one third of these DPTs belong to individuals whose ethnicity was not disclosed. Of those with a DPT in the Romexis database by 2020, it is estimated that approximately all the individuals with self-assigned Black ethnicity had been incorporated into the study sample. However, there were insufficient numbers of subjects with Black ethnicity of all ages to allow the target of 50 individuals in each half-yearly group to be reached and the target for 6-year-olds was not reached for either the White British or Black British groups. The latter is explained by few 6-year-olds requiring a DPT for diagnostic purposes and also because there are alternative radiographic views to the DPT, which may be preferable for young children. Further power calculations demonstrated that having at least 25 subjects in each Black British half-yearly group is sufficient for effective comparison. This target was achieved for Black British of 9 years of age and above.

The final sample (Table 1) totalled 5590 subjects. There were 50 male and 50 female White British subjects in each half-yearly group between the ages of 7.00 and 23.99 years; and at least 25 male and 25 female Black British subjects between the ages of 9.00 and 23.99 years (Figure 1).

Having established the sample in a Microsoft Excel file, a printed list was used to assist in retrieval of the DPTs from the Romexis system later without recourse to subjects' personal details and also ensuring that the DPTs would be examined in a randomised order. Dental details were then entered into a Microsoft Access database using forms established by the DARLInG [20] team for use in reference data collection. All the DPTs were examined by one observer (SG) while unaware of the subject's name, age, sex, and ethnicity.

TABLE 1 Sample size

	Male	Female	Total
White British	1775	1780	3555
Black British	953	1082	2035
Total	2728	2862	5590

Note: Table showing whole sample size of male and female subjects grouped by ethnicity.

All teeth in the permanent dentition were categorised as follows: present, extracted, developmentally missing, in an area not shown by the radiograph, or present but poorly imaged preventing assignment of a tooth development stage (TDS). Hypodontia is defined as one or more developmentally missing teeth not including third molars, and third molar agenesis (TMA) is defined as one or more developmentally missing third molars. A dentition status for each subject was allocated. If the DPT showed areas where all permanent teeth could be accounted for, the categories were as follows: complete dentition if all teeth including third molars were present; hypodontia with, or without, TMA; or TMA only. Hypodontia and TMA were assessed by the observer in relation to the developmental status of other teeth on the DPT, and on other radiographs if available, and if there was doubt about the conclusion, the dentition status was recorded as unsure. In allocating these categories, the observer relied upon their knowledge and experience of developing dentitions and radiographic interpretation to assess the dentition as a whole, the age of the subject being unknown. If the DPT did not show the whole dentition or the reason for missing teeth was unclear, the dentition status was recorded as unsure or, in cases such as cleft palate visible on the DPT, recorded as other. The Demirjian system [21] of eight stages, identified by the letters A–H, was employed to assess the stage of tooth maturation and, according to accepted practice in DAE and DARLInG studies, data collected for the left-sided permanent teeth shown on the DPT with the addition of information about third molars on the right side if shown. The line drawings, descriptions, and radiographic examples as originally described for the Demirjian stages [21] were used to determine the TDS with the addition of Stage A including the presence of a well-defined crypt even if cusp tips within it were not readily discernible. Examples of the radiographic appearance of the eight stages in the lower left third molar (LL8) taken from the sample are shown in Figure 2.

Finally, personal details of sex and ethnicity as recorded in the initial sample list completed the Access database. Analysis on this dataset was carried out using Stata (StataCorp 2013. Statistical Software: Release 13.0: Stata Corporation). Summary data for each TDS were calculated in Stata together with comparisons using Student *t* tests for Stages A–G to compare the age at assessment for TDS in third molars between the two ethnic groups, and the

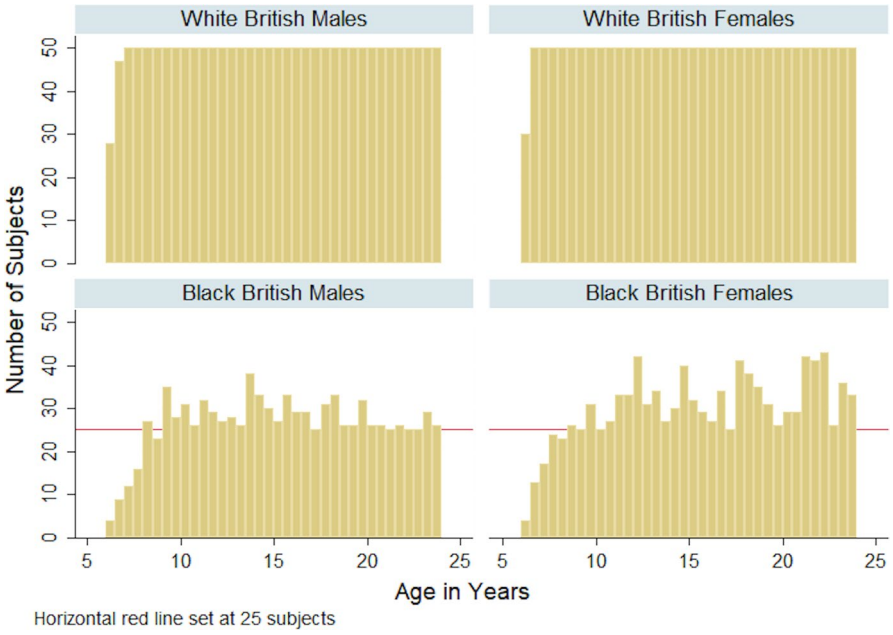

FIGURE 1 Radiographs taken from sample to illustrate the lower left third molar at each of the eight TDS

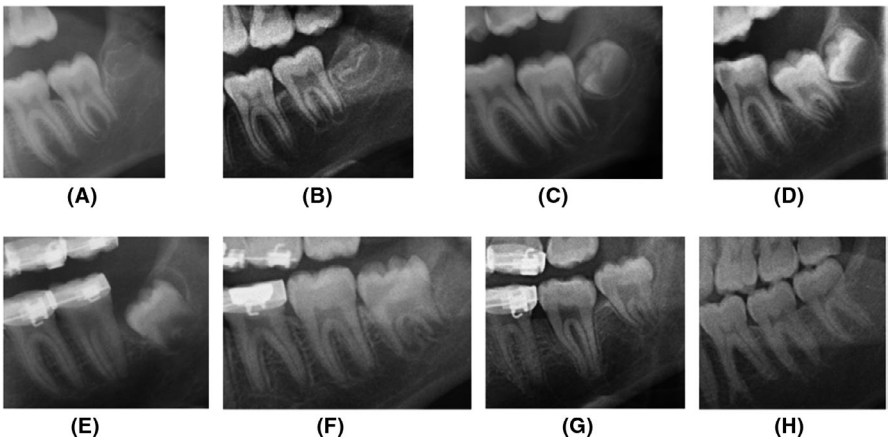

FIGURE 2 Graph to show age distribution of the whole sample divided into four sections; males and females of each ethnic group

Bonferroni correction was imposed. Stage H persisting throughout life, Stage H data are inevitably non-parametric, so a Mann-Whitney test was applied after censoring at the maximum age for Stage G as described by Roberts et al. [22]. The cut-off is applied having discarded any subject whose age at Stage G is more than +3SD from the mean [22]. The basis for this for the relevant third molar in the relevant group is the assumption that only Stage H exists after the maximum age for Stage G has been reached. The median ages for censored Stage H data were calculated, and Mann-Whitney tests were used for comparison. Having analysed the data, it was decided to test the conventional assumption in DAE that TDS data are normally distributed using Shapiro Wilk tests.

The percentages of TDS A–H seen in 17-year-old males, separated by ethnicity, was found. This was repeated for 18-year-old males.

The prevalence of hypodontia and TMA was investigated and their relevance to the timing of third molar development was illustrated by statistical analysis as described above for subjects with different dentition statuses. Only 12.00–19.99 year-olds ($n = 2595$) for whom all third molars were accountable were included in the TMA calculations. This age group was chosen to avoid the chance of undeveloped third molars in younger subjects, and extracted third molars in older subjects, being counted as agenetic. The chance of similar confusion in teeth involved in hypodontia was deemed resolved as the "unsure" dentition category was used in any cases of doubt. It is conceded that very late initiation of premolars, for example, does occur and therefore, although unlikely because of the "unsure" category, it cannot be ruled out that there may be some of these unusual cases within the hypodontia sample. A comparison of third molar development in subjects with complete dentitions in the two ethnic groups was also carried out.

Cohen's Kappa test in Stata was used to check intra-rater agreement of the observer (SG, seven years' experience of developmental staging) using three separate samples (10, 6, and 20 DPTs) assessed several months apart, the first before the start of the study, and repeated twice during the study (Kappa scores 0.9452, 0.9031, and 0.9069); and with 98 DPTs in a test prepared and analysed by a third party (Fraser McDonald and FW,

TABLE 2 Results for third molars Stages A–H for males (means and *T* tests for TDS A–G; means, medians in parentheses, and Mann-Whitney tests for censored TDS H)

	Results for third molars Stages A–H for males											
	Black British					Difference		White British				
TDS	*n*	Mean (median)	SD	Min	Max	between means	*p* Value	*n*	Mean (median)	SD	Min	Max
UR8A	16	8.97	1.34	6.97	12.35	0.44	0.3593	33	9.41	1.63	6.80	15.31
UR8B	51	9.21	0.96	7.39	11.63	1.54	<0.0001	114	10.75	1.78	7.69	15.85
UR8C	97	10.65	1.55	7.69	14.64	1.58	<0.0001	157	12.23	1.82	8.48	17.39
UR8D	124	12.65	1.52	8.25	16.36	1.05	<0.0001	133	13.70	1.71	7.81	21.74
UR8E	84	14.01	1.59	10.07	20.04	1.19	<0.0001	106	15.21	1.85	10.77	19.66
UR8F	75	15.91	1.37	13.09	19.53	1.01	<0.0001	92	16.92	1.63	13.15	21.57
UR8G	74	17.07	1.58	12.89	21.27	1.09	<0.0001	90	18.16	1.44	14.88	21.90
UR8H	133	19.19 (19.31)		15.75	21.25	0.70	<0.0001	216	19.89 (20.17)		9.58	21.89
UL8A	14	8.99	1.00	7.55	10.63	0.92	0.0962	43	9.91	1.95	7.41	15.85
UL8B	51	9.28	1.18	7.39	13.68	1.29	<0.0001	93	10.57	1.57	8.17	15.40
UL8C	100	10.64	1.48	8.18	15.68	1.65	<0.0001	162	12.29	1.98	6.85	18.35
UL8D	122	12.69	1.56	8.25	17.16	1.17	<0.0001	138	13.85	1.85	7.81	18.60
UL8E	90	14.23	1.61	11.24	19.83	0.66	0.0091	106	14.88	1.84	10.77	20.49
UL8F	71	15.88	1.42	13.09	20.04	0.99	0.0001	101	16.87	1.63	13.15	21.57
UL8G	69	17.05	1.57	12.92	20.47	1.05	<0.0001	94	18.11	1.52	14.46	21.90
UL8H	126	18.61 (18.79)		12.89	20.45	1.35	<0.0001	233	19.96 (20.16)		9.58	21.89
LL8A	33	8.49	1.01	6.21	10.46	1.41	<0.0001	107	9.90	1.75	6.80	15.09
LL8B	66	9.46	1.24	7.58	13.62	1.94	<0.0001	125	11.40	1.81	7.52	16.70
LL8C	128	11.21	1.63	8.36	15.69	1.62	<0.0001	184	12.83	1.79	8.48	17.87
LL8D	82	12.86	1.48	8.25	16.36	1.38	<0.0001	67	14.23	1.74	10.29	19.28
LL8E	100	14.44	1.55	11.37	19.53	1.33	<0.0001	134	15.77	1.82	10.81	21.57
LL8F	72	16.05	1.29	13.09	19.39	1.37	<0.0001	87	17.42	1.51	13.15	20.83
LL8G	77	17.39	1.52	14.21	22.65	1.41	<0.0001	80	18.80	1.50	15.76	23.41
LL8H	211	19.96 (20.19)		12.89	22.63	0.97	<0.0001	288	20.60 (20.80)		16.28	22.84
LR8A	34	8.63	1.25	6.21	11.99	1.41	<0.0001	109	10.04	1.83	6.80	16.68
LR8B	73	9.43	1.19	7.69	13.62	1.92	<0.0001	123	11.35	1.87	7.52	16.70
LR8C	119	11.33	1.53	8.61	15.69	1.47	<0.0001	188	12.80	1.71	8.48	17.68
LR8D	86	12.97	1.65	8.25	16.73	1.42	<0.0001	76	14.39	1.63	10.77	18.39
LR8E	92	14.35	1.39	11.37	18.37	1.61	<0.0001	105	15.96	1.93	10.81	21.57
LR8F	72	16.07	1.31	13.09	19.39	1.24	<0.0001	103	17.31	1.60	13.15	20.83

(Continues)

TABLE 2 (Continued)

	Results for third molars Stages A–H for males											
	Black British					Difference between means	*p* Value	White British				
TDS	*n*	Mean (median)	SD	Min	Max			*n*	Mean (median)	SD	Min	Max
LR8G	78	17.16	1.58	12.89	21.07	1.57	<0.0001	81	18.74	1.59	15.76	23.41
LR8H	125	19.15 (19.34)		15.75	21.06	1.72	0.0077	307	20.87 (21.07)		16.28	23.40

Note: Summary data for and comparison of TDS data in males. Letters A–H denote Demirjian Stage. For example, UR8A denotes upper right third molar at Demirjian Stage A.
Abbreviations: 8, third molar; LL, lower left; LR, lower right; UL, upper left; UR, upper right.

respectively) at the end of the study. For this last test, images were viewed in a Microsoft Word document for the second assessment because COVID-19 restrictions imposed working from home. This test was analysed using a more exacting weighted Kappa test, and third molars in each quadrant were scored separately. A limitation of this test was the inability to view fine detail on the images in the second assessment as the Romexis viewer could not be used. However, the result was substantial agreement for the lower third molars and almost perfect agreement for the upper third molars (Kappa scores: UR8: 0.8621; UL8: 0.8189; LL8: 0.7256; LR8: 0.7011). Inter-rater agreement was tested during the study with a TDS rater of seven years' experience (Dr Maxi Malekniazi) and 50 DPTs. Kappa scores indicated almost perfect reproducibility (Kappa score 0.9365).

3 | RESULTS

The summary statistics for each TDS of third molars for males and females of each ethnicity are shown in Tables 2 and 3, which consistently show an ethnic difference for every TDS with the mean age for each TDS occurring earlier in the Black British group compared to the White British group. Student's *t* test shows that these differences are all highly significant with $p < 0.0001$ for all stages B–G in males and females. Although there is a significant ethnic difference for upper third molars at Stage A in females ($p < 0.01$), this is not demonstrated in males, but this may be explained by the smaller numbers, especially of male subjects, with upper third molars at Stage A. Applying the censoring method to the Stage H data, one subject whose age at this stage was 3SD outside 3SD, the mean was discarded from the Stage G data, a White British male aged 23.41 years with LL8 at Stage G. Applying the Mann-Whitney Test for the non-parametric censored data of Stage H, highly significant differences are seen in both males and females for all four third molars. For Stages A–H, in males and females, the Bonferroni correction was used to adjust for multiple testing, giving a *p* value of 0.0016 to denote statistical significance. Although t tests have been conventionally used to compare TDS A–G data, Shapiro-Wilk tests show that it is not always normally distributed as is often assumed. Regarding the lower left third molar (LL8), for example, eight TDS out of the total of thirty-two TDS A–G in the four groups (males and females in each of two ethnic groups) were found to depart significantly from a normal distribution ($p \leq 0.05$). Whilst raising wider questions about data used in RDS for DAE, which are assumed to normally distributed, *t* tests that test normal data are still useful to investigate the ethnic differences in the present study.

Timing of development of all third molars occurred at an earlier mean age in the Black British group for every TDS. The ethnic difference was greater in females than it was in males. It was also more pronounced regarding lower third molars compared to upper third molars. The average mean age difference for Stages A–H being, for lower third molars in males, 1.49 years, and in females, 1.68 years.

TABLE 3 Results for third molars Stages A–H for females (means and *T* tests for TDS A-G; means, medians in parentheses, and Mann-Whitney tests for censored TDS H)

	Results for third molar Stages A–H for females											
	Black British					Difference		White British				
TDS	*n*	Mean (median)	SD	Min	Max	between means	*p* Value	*n*	Mean (median)	SD	Min	Max
UR8A	23	8.47	1.20	6.84	10.70	1.00	0.0125	49	9.47	1.69	6.86	13.48
UR8B	49	9.10	1.49	6.60	12.22	1.84	<0.0001	80	10.95	2.24	7.23	18.47
UR8C	96	10.61	1.51	7.81	14.94	1.35	<0.0001	152	11.96	1.99	8.18	18.46
UR8D	140	12.86	1.81	9.31	18.74	0.80	0.0002	153	13.67	1.87	9.64	20.23
UR8E	105	14.22	1.82	10.08	18.70	1.26	<0.0001	146	15.48	2.11	11.66	21.21
UR8F	76	15.92	1.75	11.70	19.59	1.15	<0.0001	104	17.07	1.82	13.54	22.35
UR8G	99	17.77	2.43	12.49	23.87	1.29	0.0001	89	19.06	2.04	15.33	23.68
UR8H	258	20.68 (21.10)		13.28	23.83	0.45	0.0002	271	21.13 (21.35)		15.56	23.67
UL8A	27	8.69	1.50	6.69	12.12	1.18	0.0030	46	9.87	1.63	7.84	13.40
UL8B	43	9.00	1.52	6.60	14.31	1.52	<0.0001	83	10.52	2.02	6.86	17.81
UL8C	88	10.57	1.70	7.81	19.45	1.68	<0.0001	151	12.25	2.21	6.36	18.50
UL8D	134	12.63	1.68	9.31	17.54	1.11	<0.0001	159	13.74	2.13	9.64	20.23
UL8E	116	14.38	1.86	10.36	18.74	1.14	<0.0001	155	15.52	2.06	11.69	22.11
UL8F	78	15.88	1.83	11.70	19.59	1.18	<0.0001	99	17.06	1.84	12.96	22.86
UL8G	96	17.70	2.43	12.49	23.66	1.51	<0.0001	111	19.21	2.01	15.33	23.87
UL8H	285	20.64 (21.05)		10.48	23.64	0.75	0.0001	301	21.39 (21.61)		15.56	23.87
LL8A	46	8.14	1.21	6.60	12.59	1.80	<0.0001	115	9.94	1.81	6.86	14.34
LL8B	56	9.20	1.32	6.96	12.24	1.88	<0.0001	110	11.08	1.85	7.61	16.04
LL8C	116	10.97	1.59	7.25	18.40	1.85	<0.0001	180	12.81	1.92	8.56	18.36
LL8D	96	12.96	1.73	10.08	18.74	1.84	<0.0001	120	14.79	2.05	10.43	20.33
LL8E	120	14.26	1.76	10.69	18.71	1.72	<0.0001	136	15.98	1.97	10.98	22.28
LL8F	102	16.18	1.81	11.95	21.49	1.72	<0.0001	95	17.89	2.13	13.97	23.87
LL8G	100	18.04	2.00	13.36	22.96	1.79	<0.0001	114	19.83	1.85	15.81	23.68
LL8H	245	20.34 (20.70)		13.28	2.94	0.96	0.0004	293	21.30 (21.56)		15.56	23.67
LR8A	47	8.42	1.57	6.34	12.59	1.29	<0.0001	96	9.71	1.61	6.86	13.74
LR8B	59	8.99	1.14	6.96	12.19	2.07	<0.0001	119	11.06	1.87	7.61	17.22
LR8C	124	11.06	1.61	7.25	18.40	1.90	<0.0001	167	12.96	2.13	8.76	20.23
LR8D	104	13.13	1.68	10.08	19.01	1.50	<0.0001	124	14.63	2.01	10.43	20.33
LR8E	92	14.14	1.68	10.36	17.75	1.85	<0.0001	127	16.00	1.85	11.70	20.89
LR8F	102	16.09	1.82	11.95	21.93	1.76	<0.0001	92	17.84	2.14	12.96	22.96
LR8G	110	17.98	2.06	13.40	22.57	1.61	<0.0001	116	19.59	2.02	14.78	23.87
LR8H	200	20.13 (20.52)		13.28	22.54	1.37	<0.0001	267	21.50 (21.85)		15.56	23.87

Note: Summary data for and comparison of TDS data in females. Letters A-H denote Demirjian Stage. For example, UR8A denotes upper right third molar at Demirjian Stage A.
Abbreviations: 8, third molar; LL, lower left; LR, lower right; UL, upper left; UR, upper right.

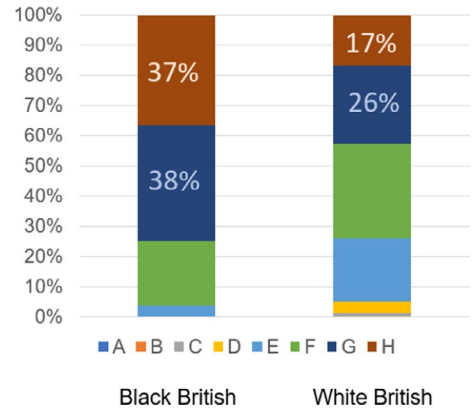

FIGURE 3 Stacked bar graph to show percentages of lower left third molars at TDS A–H in 17-year-old males with two columns, one for each ethnic group

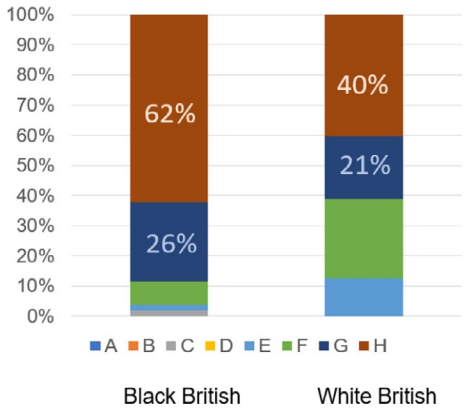

FIGURE 4 Stacked bar graph to show percentages of lower left third molars at TDS A–H in 18-year-old males with two columns, one for each ethnic group

For upper third molars, the average difference was 1.11 years in males and 1.20 years in females. In both males and females, Stages B and C in all third molars show consistently the greatest difference in developmental timing with this difference being 1.9 years for lower third molars in females. For the lower left third molar the mean ages at Demirjian Stages A–H, in both males and females, were highly significantly different ($p < 0.001$).

The differences in the timing of lower left third molar (LL8) development are illustrated in Figure 3, which shows the percentages of each TDS in 17-year-old males. 37% of LL8s in the Black British group and 17% in the White British group were at Stage H. In Black British 17-year-old males, 75% of LL8s were at Stages G or H while this figure was 43% in the White British group. Figure 4 illustrates the results for LL8 TDS for 18-year-old males showing that the majority of LL8s, 62%, have reached developmental completion in this age group of Black British males whilst 40% of LL8 are at Stage H in the White British group.

Even in 6-year-olds, despite the limited number of DPTs available for this age group, the ethnic difference is apparent. The percentages of the LL8 at Stages A, B, and C in males and females of each ethnicity in 6-year-olds are shown in Table 4, indicating earlier initiation of LL8 development in the Black British group. Chi-squared tests showed that these differences were statistically significant for Stage A ($p = 0.003$ for males and 0.023 for females).

Figures 5 and 6 show the distribution of age for each LL8 TDS for males and females, respectively, with every TDS occurring earlier in the Black British group compared to the White British group. These box and whisker plots also illustrate that, for many stages, there is non-normal distribution of TDS data.

TABLE 4 Percentages of LL8 at Stages A, B, and C in six-year-olds

	n	Stage A	Stage B	Stage C
Black British male	13	23% ($n = 3$)	0% (0)	0% (0)
Black British female	17	47% ($n = 8$)	6% ($n = 1$)	0% (0)
White British male	75	3% ($n = 2$)	0% (0)	0% (0)
White British female	80	1% ($n = 1$)	0% (0)	0% (0)

Note: Table showing percentages of TDS A, B, and C in lower left third molars seen in six-year-olds.

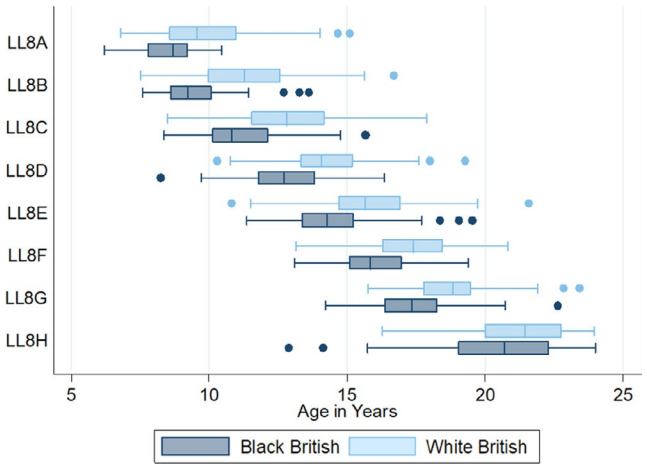

FIGURE 5 Box plot to show the distribution of age around the median for each LL8 TDS to compare data for males in the Black British group with the White British group. The box represents the middle 50% of results, the inter-quartile range, with the median shown by the central bar; and the whiskers can extend to 1.5 times the interquartile range from the nearer quartile. The dots outside the whiskers represent any values that are less or more than 1.5 times the inter-quartile range from the nearer quartile

3.1 | Hypodontia and third molar agenesis

The prevalence of hypodontia in the present sample was found to be greater in the White British group compared to the Black British group and is slightly higher in females of both ethnic groups. In the White British group, 26% of males and 28% of females have hypodontia compared to 10% and 13% of Black British males and females, respectively. Hypodontia is associated with delay in development of the remaining teeth [23].

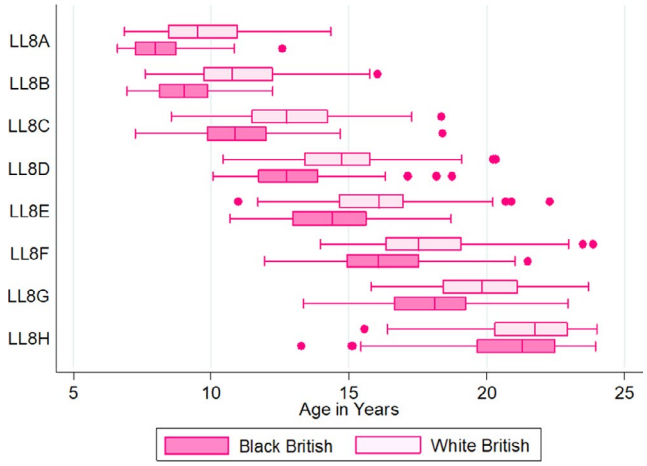

FIGURE 6 Box plot to show the distribution of age around the median for each LL8 TDS to compare data for females in the Black British group with the White British group. The box represents the middle 50% of results, the inter-quartile range, with the median shown by the central bar; and the whiskers can extend to 1.5 times the interquartile range from the nearer quartile. The dots outside the whiskers represent any values that are less or more than 1.5 times the inter-quartile range from the nearer quartile

The frequency of third molar agenesis affecting at least one third molar (TMA) was investigated using a sub-sample of 12.00–19.99 year-olds ($n = 2595$) for whom all third molars were accountable as present or developmentally missing. In Black British males and females, respectively, 8% and 11% showed one or more missing third molar. The White British group showed significantly more TMA with 32% and 34% of males and females, respectively, showing one or more missing third molars.

A much greater prevalence of all developmentally missing teeth, TMA or hypodontia of any severity, was found in the White British group compared to the Black British group.

The prevalence of subjects in the present sample (Table 1) with known complete dentitions, that is, subjects with all permanent teeth present, in Black British males and females is 80% and 76%, respectively, and in White British males and females is 49% and 48%, respectively.

3.2 | Developmentally missing teeth and the timing of third molar development

Tables 5 and 6 show mean ages for third molar TDS in White British and Black British males, respectively, according to dentition status, i.e., complete dentition, hypodontia with or without TMA, and TMA only. The trend is that mean ages for TDS are lower in subjects with complete dentitions compared to those with developmentally missing teeth whether hypodontia with or without TMA, or TMA alone.

Table 7 shows a sub-sample of subjects with complete dentitions, i.e., all permanent teeth present including third molars. Tables 8 and 9 show the results for third molar TDS A–H (censored Stage H) for these subjects, males and females, respectively. The ethnic difference seen in the whole sample with regard to third molar TDS is again shown in this sub-sample with TDS occurring at a younger mean age in Black British compared to White British. The average mean age difference for Stages A–H was, for lower third molars in males, 1.28 years, and in females, 1.62 years. For upper third molars, the average difference was 0.88 years in males and 1.18 years in females.

TABLE 5 Mean age at third molar TDS A–H in White British males with three different dentition statuses

	White British males					
	Complete dentitions		Hypodontia (with or without TMA)		TMA only	
TDS	*n*	Mean	*n*	Mean	*n*	Mean
UR8A	14	9.08	16	9.65	15	9.27
UR8B	69	10.34	37	11.70	16	11.42
UR8C	112	11.86	41	13.17	15	13.09
UR8D	94	13.39	32	14.30	10	14.30
UR8E	68	14.87	31	15.74	3	16.42
UR8F	56	16.60	24	16.99	2	18.35
UR8G	56	17.90	18	18.10	2	18.67
UR8H	140	20.68	22	20.20	3	20.78
UL8A	22	9.43	17	10.71	7	9.53
UL8B	54	10.36	31	11.09	20	10.93
UL8C	114	11.87	44	13.20	12	13.36
UL8D	91	13.33	37	15.04	12	14.99
UL8E	71	14.62	28	15.41	4	14.77
UL8F	62	16.60	28	17.09	5	18.65
UL8G	53	17.83	22	18.17	3	19.46
UL8H	142	20.79	27	20.02	8	19.76
LL8A	40	9.71	58	10.10	44	9.68
LL8B	79	11.13	36	11.98	18	11.81
LL8C	142	12.51	39	14.00	10	13.46
LL8D	43	14.05	20	14.65	6	14.71
LL8E	89	15.59	36	16.29	3	17.09
LL8F	55	17.18	16	17.56	3	18.69
LL8G	45	18.65	12	18.23	2	18.08
LL8H	132	20.80	17	19.94	4	20.71
LR8A	46	9.95	52	9.99	40	9.74
LR8B	73	10.93	39	12.09	18	12.02
LR8C	146	12.55	37	13.83	12	13.44
LR8D	44	14.08	28	15.01	6	15.80
LR8E	71	15.58	28	16.86	2	18.27
LR8F	64	16.98	21	17.40	6	18.24
LR8G	44	18.41	10	18.63	0	
LR8H	138	20.73	15	19.83	2	20.13

Note: Table showing mean ages of White British males at third molar TDS in subjects with complete dentitions, hypodontia with or without TMA, and TMA only.

TABLE 6 Mean age at third molar TDS A-H in Black British males with three different dentition statuses

	Black British Males					
	Complete dentitions		Hypodontia (with or without TMA)		TMA only	
TDS	*n*	Mean	*n*	Mean	*n*	Mean
UR8A	9	8.78	5	9.80	4	9.69
UR8B	44	9.13	5	10.03	3	9.88
UR8C	80	10.61	8	11.42	1	11.47
UR8D	101	12.47	17	13.33	2	14.79
UR8E	70	13.91	6	13.68	3	12.75
UR8F	57	15.63	10	17.09	0	
UR8G	56	16.84	3	18.64	1	19.05
UR8H	124	20.14	6	19.91	0	
UL8A	11	8.86	2	10.44	0	
UL8B	42	9.18	6	9.65	3	9.38
UL8C	77	10.47	12	12.04	5	12.99
UL8D	100	12.57	19	12.99	3	11.22
UL8E	77	14.01	6	16.34	2	14.09
UL8F	54	15.56	9	16.86	2	17.12
UL8G	52	16.89	3	16.95	1	19.05
UL8H	127	19.87	8	20.08	0	
LL8A	20	8.79	11	8.02	11	8.02
LL8B	51	9.52	13	9.29	8	9.16
LL8C	102	11.13	18	11.61	5	11.19
LL8D	70	12.86	11	12.52	3	12.07
LL8E	77	14.18	12	15.41	3	15.89
LL8F	57	15.85	8	16.83	1	19.39
LL8G	51	17.08	7	18.23	1	17.99
LL8H	129	20.06	8	20.25	0	
LR8A	18	8.84	13	8.18	12	7.97
LR8B	57	9.42	14	9.32	8	9.38
LR8C	98	11.26	13	11.93	4	11.50
LR8D	70	12.92	13	12.73	3	12.07
LR8E	75	14.26	7	14.11	1	13.15
LR8F	56	15.81	8	17.15	2	18.69
LR8G	53	16.77	6	18.06	0	
LR8H	121	20.20	8	20.40	0	

Note: Table showing mean ages of Black British males at third molar TDS in subjects with complete dentitions, hypodontia with or without TMA, and TMA only.

TABLE 7 Sub-sample of subjects with complete dentitions

	Males	Females	Total
White British	653	640	1293
Black British	562	569	1131
Total	1215	1209	2424

Note: Table showing sample size of male and female subjects with complete dentitions grouped by ethnicity.

Despite smaller numbers of subjects, mean ages at Demirjian Stages A–H for all third molars in females were highly significantly different ($p < 0.04$). In males, the difference was highly significant for all TDS B–G ($p < 0.008$) with less consistency at Stage A, where sample sizes were particularly small, and Stage H where the censored result did not reflect the non-censored result for every third molar.

4 | DISCUSSION

This is a large carefully conducted study with a sample size exceeding that of similar published dental development studies with as uniformly structured age distribution as possible within the limitations of the GSTT Romexis database. The half-yearly sampling intervals provide a robust estimate of the summary statistics and the SD are relatively low. The results show a highly significant ethnic difference in the timing of third molar development with TDS in the Black British group occurring earlier than in the White British group. This applies to all stages of third molar development in both males and females. Figures 3 and 4 illustrate the striking ethnic difference in the timing of LL8 development with Black British males ahead of White British males around the 18-year-old threshold at 17 and 18 years of age as well as the notable range of TDS at these ages in both groups. It is interesting that in 6-year-olds, despite the limited number of DPTs available for this age group, third molars in Black British males and females appear to be developing significantly earlier than in their White British counterparts. This finding lends support to the suggestion that once initiated, tooth formation proceeds at a chronologically regular rate [15,24] as the results suggest that this early advancement appears to persist and be reflected by earlier achievement of Stage H.

Wide age ranges for each TDS mean that any age estimation must be tempered by a wide possible margin of error. It was thought that the wide age ranges seen in samples containing several ethnicities could perhaps be narrowed by separating data by ethnicity. In fact, this study shows that wide age ranges are present in both Black British and White British groups confirming the wide ranges seen in published studies and underlining the difficulty of accurate age estimation for one individual. The non-normal distribution of TDS data contradicts conventional assumptions and questions the validity of DAE calculations based on summary data. Nevertheless, the difference demonstrated between ethnic groups is of significance regarding DAE, indicating the substantial risk that children and young adults of African ancestry may have their age overestimated if third molar development is compared with Caucasian reference data.

As all the subjects in this study have attended GSTT as a result of geographical convenience and along the same referral pathways, differences in the timing of dental development due to geographical, dietary, lifestyle, or socio-economic differences, while not specifically addressed, are minimised. The study was thus deliberately confined to subjects in the UK, and it is conceded that the compiled Black British group may not necessarily be representative of Black ethnic groups in Africa. Inevitably, clerical errors in hospital records are likely to have led to several erroneous results, but the large

TABLE 8 Results for third molars stages A–H (including censored Stage H) for males with complete dentitions, i.e., all permanent teeth present including third molars

	Comparison of third molars Stages A–H in males with complete dentitions											
	Black British					Difference between means/ medians	*p* Value *T* tests M-W tests	White British				
TDS	*n*	Mean Median	SD	Min	Max			*n*	Mean Median	SD	Min	Max
UR8A	9	8.78	1.04	6.97	10.46	0.30	0.2427	14	9.08	0.98	7.87	11.35
UR8B	44	9.13	0.92	7.39	11.51	1.21	<0.0001	69	10.34	1.39	8.17	13.43
UR8C	80	10.61	1.49	7.69	14.09	1.26	<0.0001	112	11.86	1.67	8.48	16.90
UR8D	101	12.47	1.50	8.25	16.36	0.93	<0.0001	94	13.39	1.46	9.59	17.98
UR8E	70	13.91	1.33	11.24	17.41	0.96	0.0002	68	14.87	1.72	10.77	19.66
UR8F	57	15.63	1.22	13.09	19.09	0.97	0.0002	56	16.60	1.63	13.15	21.57
UR8G	56	16.84	1.62	12.89	21.27	1.05	0.0001	56	17.90	1.35	14.88	20.49
UR8H	124	20.14	2.11	15.75	23.90	0.53	0.0161	140	20.68	1.92	14.46	23.95
UR8H	81	18.72		15.75	21.22	0.20	0.7920	67	18.93		14.46	20.45
UL8A	11	8.86	0.81	7.73	10.46	0.57	0.0792	22	9.43	1.17	7.87	11.98
UL8B	42	9.18	0.96	7.39	11.51	1.18	<0.0001	54	10.36	1.42	8.17	13.54
UL8C	77	10.47	1.25	8.39	13.97	1.39	<0.0001	114	11.87	1.71	8.48	17.07
UL8D	100	12.57	1.50	8.25	16.36	0.76	0.0003	91	13.33	1.49	9.59	17.98
UL8E	77	14.01	1.36	11.24	17.41	0.61	0.0083	71	14.62	1.70	10.77	18.92
UL8F	54	15.56	1.17	13.09	18.21	1.04	0.0001	62	16.60	1.62	13.15	21.57
UL8G	52	16.89	1.50	14.13	20.47	0.94	0.0007	53	17.83	1.43	14.46	20.49
UL8H	127	19.87	2.25	12.89	23.89	0.91	0.0002	142	20.79	1.85	16.28	23.95
UL8H	72	18.28		12.89	20.44	0.69	0.0110	57	18.97		16.28	20.45
LL8A	20	8.79	0.92	6.97	10.46	0.92	0.0034	40	9.71	1.31	7.87	12.59
LL8B	51	9.52	1.31	7.69	13.62	1.62	<0.0001	79	11.13	1.67	8.45	16.70
LL8C	102	11.13	1.52	8.36	15.69	1.38	<0.0001	142	12.51	1.69	8.48	16.51
LL8D	70	12.86	1.44	8.25	16.36	1.19	0.0001	43	14.05	1.68	10.29	17.99
LL8E	77	14.18	1.31	11.37	17.69	1.41	<0.0001	89	15.59	1.95	10.81	21.57
LL8F	57	15.85	1.16	13.09	18.48	1.33	<0.0001	55	17.18	1.55	13.15	20.49
LL8G	51	17.08	1.45	14.21	20.71	1.57	<0.0001	45	18.65	1.10	15.76	20.69
LL8H	129	20.06	2.25	12.89	23.90	0.74	0.0023	132	20.80	1.95	16.28	23.95
LL8H	76	18.55		12.89	20.69	0.41	0.2557	57	18.97		16.28	20.59
LR8A	18	8.84	1.01	6.97	10.73	1.11	0.0030	46	9.95	1.52	7.87	13.69
LR8B	57	9.42	1.27	7.69	13.62	1.52	<0.0001	73	10.93	1.62	8.51	16.70
LR8C	98	11.26	1.40	8.70	15.69	1.29	<0.0001	146	12.55	1.62	8.48	17.68
LR8D	70	12.92	1.64	8.25	16.73	1.15	0.0001	44	14.08	1.51	10.77	17.99
LR8E	75	14.26	1.33	11.37	17.69	1.32	<0.0001	71	15.58	1.97	10.81	21.57
LR8F	56	15.81	1.20	13.09	18.48	1.17	<0.0001	64	16.98	1.62	13.15	20.49
LR8G	53	16.77	1.55	12.89	20.47	1.64	<0.0001	44	18.41	1.13	15.76	21.94
LR8H	121	20.20	2.01	15.75	23.90	0.53	0.0148	138	20.73	1.91	16.28	23.95
LR8H	64	18.53		15.75	20.44	1.50	<0.0001	97	20.03		16.28	21.92

Notes: Summary data for and comparison of TDS data in males with complete dentitions. N.B. Blue highlighted rows show censored results for third molars at Demirjian Stage H with the average age as the median and results of Mann Witney (M-W) test.

sample size compensates for these influences. There is no reason to believe that there are intentional inaccuracies with reported dates of birth. Although it is possible that some individuals were not born in the UK, it is far more likely that they were.

The challenges posed in DAE are underlined by the findings regarding hypodontia and TMA. Developmentally missing teeth of all tooth types were found to be significantly more prevalent in the White British group, but the results also suggest that

TABLE 9 Results for third molars stages A–H (including censored Stage H) for females with complete dentitions, i.e., all permanent teeth present including third molars

	Comparison of third molars Stages A–H in females with complete dentitions											
	Black British							White British				
TDS	*n*	Mean Median	SD	Min	Max	Difference between means	*p* Value *T* tests M-W tests	*n*	Mean Median	SD	Min	Max
UR8A	13	8.55	1.27	6.97	10.70	0.90	0.0394	31	9.45	1.60	6.86	13.18
UR8B	38	8.86	1.36	6.60	12.22	1.53	<0.0001	46	10.38	1.84	7.23	14.73
UR8C	66	10.26	1.37	7.81	14.94	1.29	<0.0001	99	11.55	1.74	8.18	17.22
UR8D	109	12.46	1.44	9.31	16.29	0.92	<0.0001	104	13.38	1.70	9.85	20.23
UR8E	85	14.06	1.80	10.08	18.31	1.07	0.0001	107	15.13	1.97	11.66	20.69
UR8F	56	15.63	1.75	11.70	19.59	0.90	0.0019	66	16.54	1.62	13.54	22.28
UR8G	64	17.12	2.18	12.49	21.91	1.55	0.0001	46	18.67	1.87	15.88	22.96
UR8H	109	20.27	2.15	15.10	23.91	0.71	0.0095	84	20.99	1.98	16.40	23.85
UR8H	81	19.69			21.77	0.93	0.0011	67	20.62			22.75
UL8A	15	8.57	1.30	6.97	10.70	1.09	0.0109	30	9.65	1.51	7.84	13.18
UL8B	35	8.64	1.09	6.60	12.19	1.50	<0.0001	50	10.14	1.78	6.86	16.04
UL8C	64	10.15	1.26	7.81	13.40	1.64	<0.0001	94	11.79	1.90	8.18	18.36
UL8D	109	12.38	1.46	9.31	16.80	0.94	<0.0001	104	13.33	1.82	9.85	20.23
UL8E	89	14.15	1.70	10.36	18.17	0.98	0.0001	114	15.13	1.79	11.69	20.69
UL8F	63	15.76	1.89	11.70	19.59	0.72	0.0131	63	16.48	1.71	12.96	21.32
UL8G	55	17.14	2.43	12.49	21.91	1.52	0.0002	53	18.66	1.78	15.88	22.96
UL8H	111	20.19	2.20	15.10	23.91	0.95	0.0013	80	21.14	2.00	16.40	23.85
UL8H	82	19.40		15.10	21.77	1.32	0.0001	62	20.72		16.40	22.75
LL8A	17	7.99	0.95	6.60	10.47	1.84	0.0001	54	9.84	1.89	6.86	14.34
LL8B	38	8.93	1.06	6.96	12.19	2.11	<0.0001	72	11.04	1.98	7.61	16.04
LL8C	92	10.80	1.45	7.25	14.67	1.72	<0.0001	124	12.51	1.78	8.84	18.36
LL8D	75	12.66	1.42	10.08	16.33	1.69	<0.0001	73	14.36	1.91	10.43	19.09
LL8E	89	14.08	1.77	10.69	18.71	1.64	<0.0001	103	15.72	1.96	10.98	22.28
LL8F	78	16.02	1.78	12.63	21.49	1.40	<0.0001	56	17.42	1.83	14.38	22.96
LL8G	61	17.56	1.86	14.20	21.91	1.24	0.0002	43	18.80	1.53	15.81	22.89
LL8H	108	20.42	2.13	15.10	23.91	0.83	0.0038	81	21.25	2.03	16.40	23.85
LL8H	78	19.78		15.10	21.77	1.08	0.0002	62	20.85		16.40	22.84
LR8A	13	7.88	1.00	6.60	10.47	1.68	0.0003	50	9.56	1.57	6.86	13.74
LR8B	44	8.88	1.02	6.96	12.19	2.12	<0.0001	79	11.01	1.78	7.61	15.76

TABLE 9 (Continued)

	Comparison of third molars Stages A–H in females with complete dentitions											
	Black British								White British			
TDS	*n*	Mean Median	SD	Min	Max	Difference between means	*p* Value *T* tests M-W tests	*n*	Mean Median	SD	Min	Max
LR8C	96	10.90	1.49	7.25	15.04	1.72	<0.0001	112	12.62	1.89	8.76	20.23
LR8D	82	12.93	1.66	10.08	19.01	1.43	<0.0001	84	14.35	1.85	10.43	19.29
LR8E	72	13.86	1.60	10.36	17.75	1.88	<0.0001	96	15.75	1.69	11.90	20.69
LR8F	79	15.95	1.70	12.49	19.59	1.51	<0.0001	53	17.46	2.02	12.96	22.96
LR8G	66	17.62	2.04	13.40	21.91	1.30	0.0002	53	18.91	1.84	14.78	23.34
LR8H	103	20.27	2.18	15.10	23.91	0.94	0.0021	72	21.21	2.04	16.40	23.85
LR8H	76	19.72		15.10	21.77	1.48	<0.0001	62	21.20		16.40	23.33

Notes: Summary data for and comparison of TDS data in males with complete dentitions. N.B. Blue highlighted rows show censored results for third molars at Demirjian Stage H with the average age as the median and results of Mann-Witney (M-W) test.

developmental delay of third molars is associated with hypodontia with or without TMA, and with TMA alone. The possibility that the ethnic difference seen in the whole sample is due to increased prevalence of developmentally missing teeth in the White British group is negated when a comparison is made of third molar TDS in subjects with complete permanent dentitions. The ethnic difference prevails in these subjects and again demonstrates that third molar TDS generally occurs at least one year earlier in the Black British group compared to the White British group. Differences in the timing of dental development between subjects of, for example, Black Caribbean and Sub-Saharan African descent were not investigated using the present sample due to the limited numbers in those sub groups. Although differences between such groups have been suggested [11], any potential differences found in the present sample, for the reasons expressed above, would not be expected to improve DAE accuracy for individual subjects. In considering ancestry composition of the Black subjects, there was a trend of earlier third molar development in those of Sub-Saharan African although this was not formally analysed.

5 | CONCLUSION

Highly significant differences in the timing of third molar development between Black British and White British ethnic groups have been demonstrated. For both males and females, the timing of third molar development occurred earlier in the Black British group. This is shown for all third molars and at all Demirjian stages. Mean ages for females were generally at least 1.5 years ahead, and males at least 1 year ahead, for every Demirjian stage A–H of all third molars. In the largest study, to our knowledge, of its kind, and the first to compare African and Caucasian groups in the United Kingdom, 5590 subjects allowed these differences to be clearly identified. In any age estimation context, archaeological, forensic identification scenarios, or forensic applications in the living, the importance of ethnicity and the use of appropriate ethnic reference data is affirmed and the particular risk of overestimating the age of an individual of African ancestry using Caucasian reference data recognised.

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ORCID

Sally E. Andrews https://orcid.org/0000-0003-3362-287X

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