Original communication

Dental age assessment (DAA) of Afro-Trinidadian children and adolescents. Development of a Reference Dataset (RDS) and comparison with Caucasians resident in London, UK

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ABSTRACT

The large number of extant Dental Panoramic Tomographs of Afro-Trinidadian subjects were collected and Tooth Development Stages (TDSs) were assessed for each of the 878 radiographs to provide a Reference Dataset (RDS) of Afro-Trinidadian children and adolescents. The values for each of the 256 TDSs present were statistically significantly different from the values for the same TDSs in the UK Caucasian RDS. A validation study of 50 radiographs of Afro-Trinidadian subjects from 24 boys and 26 girls were assessed to enable calculation of the Dental Age (DA). The DA calculated using the UK Caucasian RDS was statistically significantly different from the chronological age. The same radiographs were used to calculate the Age of Attainment of the individual Tooth Development Stages for females and males in both the UK Caucasian subjects, and the Afro-Trinidadians. The majority of these comparisons showed the TDSs in Afro-Trinidadian subjects to develop earlier than the UK Caucasian subjects by approximately 8 months.

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1. Introduction

The use of dental age has long been a problem for employers. In the early part of the 19th century, in the industrial revolution which was centred on England and Wales, children could not be employed in the mines and factories of the North of England unless they were at least 6 years old. The evidence adduced for this was the presence of the first permanent molar in the mouth.[1] In recent years, within the UK and Europe, there is likely to be an increase in the number of requests for age assessment of unaccompanied asylum seeking children[2] resulting in an increase in requests for the provision of foster care and education. A feature of the Dental Age Assessments (DAAs) carried out at King's College London Dental Institute is that many of the asylum seekers appear much older than the claimed age. This has important implications for child protection as social workers are concerned about the placement of mature

young men within the system of child care. A further consideration with young children is the age of criminal responsibility. In the UK this is 10 years of age, and the technique of DAA can now be applied to this age threshold.[3] Other work has looked at the 16-year threshold.[4] Both these investigations involved the creation of a large Reference Dataset (RDS) and then used this to calculate the age of separate study samples of 50 females and 50 males, respectively. This is achieved by averaging the Age of Attainment (AoA) of the Tooth Development Stages present on each of the radiographs of the study sample cases.[5] The system of DAA uses the mathematical techniques of meta-analysis to provide a weighted average. This weighted average is assigned as each individual's dental age.

The issue of ethnic or racial differences has attracted attention as clinical impressions have strongly suggested that West African and Afro-Caribbean children show earlier development of teeth than Caucasian children. A study involving African-Americans indicated that there was little difference between these African American and Caucasian groups.[6] In view of this limited amount of information, the present study was designed to generate a Reference Dataset (RDS) based on Afro-Trinidadian

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children and adolescents. This RDS was then tested for validity by comparing the estimated dental age of 24 Afro-Trinidadian males and 26 Afro-Trinidadian females with dental age estimated using the Afro-Trinidadian RDS and the UK Caucasian Reference Dataset, respectively. These two groups comprised study samples of Afro-Trinidadian subjects that did not form part of the Reference Dataset. This comparison using the Afro-Trinidadian RDS versus UK Caucasian RDS offered an estimation of the error associated with use of an inappropriate Reference Dataset (the UK Caucasian RDS) for age estimation of Afro-Trinidadian subjects. It also emphasises the absolute need to use a Reference Dataset appropriate to the subject (the A-Tr RDS), in terms of ethnicity, for whom age assessment is being attempted.

Fig. 1. Tooth Development Stages: 8 stage system (redrawn after Demirjian et al. 1973[7]).

Table 1
Descriptions of Tooth Development Stages (TDSs), by Demirjian et al. 1973.[7]

Tooth Development Stage (TDS)	Single rooted teeth and multi-rooted teeth [descriptions]
A	In both uniradicular and multiradicular teeth, a beginning of calcification is seen at the superior level of the crypt in the form of an inverted cone or cones. There is no fusion of these calcified points.
B	Fusion of the calcified points forms one or several cusps, which unite to give a regularly outlined occlusal surface.
C	a. Enamel formation is complete at the occlusal surface. Its extension and convergence towards the cervical region is seen.
	b. The beginning of a dentine deposit is seen.
	c. The outline of the pulp shape has a curved shape at the occlusal border.
D	a. Crown formation is complete down to the cemento-enamel junction.
	b. The superior border of the pulp chamber in uniradicular teeth has a definite curved form, being concave towards the cervical region. The projection of the pulp horns, if present, gives an outline like an umbrella top. In molars, the pulp chamber has a trapezoid form.
	c. Beginning of root formation is seen in the form of a radiopaque spicule.
E	Uniradicular teeth
	a. The walls of the pulp chamber now form straight lines, whose continuity is broken by the presence of the pulp horn, which is larger than in the previous stage.
	b. The root development is still less than the crown.
	Multiradicular teeth
	a. Initial formation of the radicular bifurcation is seen in the form of either a calcified point or a semilunar shape.
	b. The root length is still less than the crown height.
F	Uniradicular teeth
	a. The walls of the pulp chamber now form a more or less isosceles triangle. The apex ends in a funnel shape.
	b. Root development is equal to or greater than the crown.
	Multiradicular teeth
	a. The calcified region of the bifurcation has developed further down from its semilunar stage to give the roots a more definite and distinct outline, with funnel shaped endings.
	b. The root length is equal to or greater than the crown height.
G	a. The walls of the root canals are now parallel (distal root of molars).
	b. The apical ends of the root canals are still partially open.
H	a. The apical end of the root canal is completely closed (distal root in molars).
	b. The periodontal membrane has a uniform width around the root and apex.

2. Materials and methods

2.1. Radiographs for the Reference Dataset

The material for the Reference Dataset in this study comprised a convenience sample of Dental Panoramic Tomographs of children and adolescents attending the Dental Hospital in Trinidad or a private orthodontic practice, also in Trinidad. These were all extant radiographs taken for clinical diagnosis and treatment and re-used for this study.

2.2. Assessment of Tooth Development Stages on the Dental Panoramic Tomographs

All 16 teeth on the left side were categorised using the 8 Tooth Development Stages (TDSs) first described by Demirjian and colleagues in 1973.[7] These Tooth Development Stages (Fig. 1) were accompanied by detailed descriptions of the stages (Table 1). These schematic diagrams and written descriptions were available to the clinician during the assessment process to make stage identification easy.

2.3. Radiographs for the study samples

The Dental Panoramic Tomographs for the study samples were from the same source as the Reference Dataset but were collected after, and separate from, the establishment of the RDS.

2.4. Statistical procedures

All calculations were carried out using STATA.[8] These comprised assessments of intra-rater and inter-rater agreement using Cohen's Kappa, summary data for each of the Tooth Development Stages in the Afro-Trinidadian Reference Dataset, estimation of dental age of the Afro-Trinidadian study female and male samples using the meta-analysis command in STATA and Student's t-test to compare the mean Age of Attainment (AoA) of the Tooth Development Stages in the UK Caucasian Reference Dataset and the Afro-Trinidadian Reference Dataset.

3. Results

3.1. Reference datasets

At the time of the data analysis for this study the RDS comprised 2997 individual radiographs. The data from each of these was held in the DAA Microsoft Access Database. (Table 2.)

Table 2
Number of subjects in the Reference Dataset by gender and ethnicity.

	Caucasian	Afro-Trinidadian	Total
Males	941	415	1356
Females	1178	463	1641
Total	2119	878	2997

Table 3
Summary data for Tooth Development Stages for Afro-Trinidadian and Caucasian subjects.

TDS	Afro-Trinidadian			Caucasian			
	n-tds	Mean age of attainment (years) for tds	se-tds	n-tds	Mean age of attainment (years) for tds	se-tds	Significance
(a) Females							
LL1Af	1	2.29	–	1	3.46	–	
LL1Bf	–	–	–	–	–	–	
LL1Cf	1	2.62		1	3.95		–
LL1Df	11	3.56	0.19	3	4.08	0.48	ns
LL1Ef	26	4.63	0.35	7	5.36	0.25	ns
LL1Ff	28	5.5	0.26	11	5.9	0.24	ns
LL1Gf	37	7.4	0.24	67	8.64	0.19	<0.001
LL2Af	–	–	–	–	–	–	
LL2Bf	–	–	–	–	–	–	
LL2Cf	5	3.1	0.23	1	3.95	–	–
LL2Df	25	4.15	0.17	8	4.96	0.39	<0.05
LL2Ef	29	5.21	0.35	7	5.6	0.25	ns
LL2Ff	33	6.66	0.21	20	6.87	0.25	ns
LL2Gf	51	7.86	0.19	82	8.9	0.14	<0.001
LL3Af	–	–		–	–		–
LL3Bf	–	–		–	–		–
LL3Cf	26	4.01	0.16	4	4.99	0.84	<0.05
LL3Df	36	5.08	0.27	13	5.7	0.33	ns
LL3Ef	54	6.9	0.19	33	7.26	0.29	ns
LL3Ff	71	8.3	0.17	106	9.1	0.10	<0.001
LL3Gf	54	10.17	0.15	68	10.8	0.16	<0.05
LL4Af	–	–		–	–		–
LL4Bf	8	3.4	0.19	2	4.2	0.75	ns
LL4Cf	24	4.31	0.16	10	5.1	0.31	<0.05
LL4Df	48	5.61	0.24	33	7.1	0.23	<0.001
LL4Ef	48	5.61	0.24	33	7.1	0.24	<0.001
LL4Ff	59	9.46	0.14	73	9.83	0.13	<0.05
LL4Gf	46	10.75	0.21	57	10.85	0.19	ns
LL5Af	12	3.41	0.143	4	3.92	1.98	<0.001
LL5Bf	11	4.43	0.27	3	5.54	0.55	ns
LL5Cf	18	5.2	0.47	15	5.82	0.4	ns
LL5Df	67	6.50	0.23	45	7.91	0.18	<0.001
LL5Ef	83	8.36	0.17	71	8.96	0.14	<0.05
LL5Ff	36	9.9	0.14	66	10.8	0.22	<0.05
LL5Gf	58	11.74	0.24	86	11.92	0.17	ns
LL6Af	–	–	–	–	–	–	
LL6Bf	–	–	–	–	–	–	
LL6Cf	–	–	–	–	–	–	
LL6Df	17	3.54	1.9	2	3.9	0.1	ns
LL6Ef	25	4.47	0.16	9	5.23	0.30	<0.05
LL6Ff	22	5.8	0.49	14	6.42	0.24	ns
LL6Gf	106	7.53	0.15	116	8.8	0.13	<0.001
LL7Af	–	–	–	–	–	–	
LL7Bf	16	3.94	0.182	8	4.8	0.28	<0.05
LL7Cf	14	4.71	0.15	14	5.81	0.21	<0.001
LL7Df	98	6.72	0.17	67	8.16	0.16	<0.001
LL7Ef	52	8.83	0.18	78	9.49	0.10	<0.001
LL7Ff	45	10.10	0.13	53	10.4	0.20	ns
LL7Gf	83	12.37	0.20	138	13.49	0.15	<0.001
LL8Af	42	7.37	0.21	26	10.01	0.39	<0.001
LL8Bf	27	9.26	0.24	30	11.69	0.41	<0.001
LL8Cf	41	10.29	0.27	94	12.68	0.27	<0.001
LL8Df	81	12.03	0.22	244	13.9	0.14	<0.001
LL8Ef	57	14.34	0.22	188	15.45	0.11	<0.001
LL8Ff	52	15.28	0.24	168	16.72	0.12	<0.001
LL8Gf	30	16.17	0.26	104	18.09	0.155	<0.001
UL1Af	–	–	–	–	–	–	
UL1Bf	–	–	–	–	–	–	
UL1Cf	–	–	–	–	–	–	
UL1Df	34	4.41	0.28	11	5.07	0.26	ns
UL1Ef	31	5.99	0.34	12	5.98	0.25	ns
UL1Ff	33	6.64	0.24	22	7.57	0.30	<0.05
UL1Gf	41	8.53	0.2	86	9.16	0.13	<0.05

Table 3 (*continued*)

TDS	Afro-Trinidadian			Caucasian			
	n-tds	Mean age of attainment (years) for tds	se-tds	n-tds	Mean age of attainment (years) for tds	se-tds	Significance
UL2Af	–	–	–	–	–	–	
UL2Bf	1	2.29	–	3	2.57	0.60	–
UL2Cf	23	3.85	0.17	2	4.81	0.85	ns
UL2Df	31	5.09	0.33	13	5.6	0.22	ns
UL2Ef	41	6.47	0.19	18	6.93	0.35	ns
UL2Ff	24	7.36	0.22	32	7.87	0.21	ns
UL2Gf	40	8.94	0.21	80	9.55	0.11	<0.05
UL3Af	–	–	–	–	–	–	
UL3Bf	–	–	–	–	–	–	
UL3Cf	18	3.8	0.2	5	4.6	0.29	ns
UL3Df	47	5.2	0.24	16	6.4	0.33	<0.05
UL3Ef	59	7.24	0.15	54	7.96	0.2	<0.05
UL3Ff	68	8.91	0.17	105	9.29	0.1	<0.05
UL3Gf	43	10.36	0.19	71	11.4	0.19	<0.001
UL4Af	1	2.29	–	–	–	–	
UL4Bf	–	–	–	–	–	–	
UL4Cf	29	4.27	0.13	15	5.6	0.45	<0.05
UL4Df	68	6.2	0.19	44	7.5	0.2	<0.001
UL4Ef	53	8.40	0.16	96	9.3	0.11	<0.001
UL4Ff	47	9.73	0.16	50	9.87	0.16	ns
UL4Gf	18	10.39	0.32	32	11.69	0.30	<0.05
UL5Af	5	3.66	0.11	3	3.80	0.21	ns
UL5Bf	18	4.36	0.142	2	5.3	0.85	ns
UL5Cf	20	5.7	0.4	17	6.9	0.49	ns
UL5Df	75	6.83	0.16	42	7.7	0.19	<0.001
UL5Ef	51	8.93	0.21	96	9.3	0.13	ns
UL5Ff	35	9.9	0.18	47	10.33	0.19	ns
UL5Gf	24	10.88	0.35	54	12.18	0.22	<0.05
UL6Af	–	–	–	–	–	–	
UL6Bf	–	–	–	–	–	–	
UL6Cf	–	–	–	–	–	–	
UL6Df	29	3.84	0.16	4	4.67	0.71	ns
UL6Ef	28	5.12	0.17	18	7.28	0.55	<0.001
UL6Ff	21	6.6	0.56	22	7.57	0.32	ns
UL6Gf	58	7.74	0.20	102	8.78	0.14	<0.001
UL7Af	–	–	–	–	–	–	
UL7Bf	15	3.98	0.16	6	4.4	0.22	ns
UL7Cf	15	4.98	0.18	12	6.1	0.35	<0.05
UL7Df	115	7.15	0.16	116	8.65	0.12	<0.001
UL7Ef	38	9.31	0.19	46	9.48	0.17	ns
UL7Ff	29	10.34	0.26	33	10.25	0.23	ns
UL7Gf	40	12.25	0.36	85	13.06	0.20	<0.05
UL8Af	19	7.99	0.27	23	9.41	0.26	<0.001
UL8Bf	29	8.93	0.22	33	10.23	0.36	<0.05
UL8Cf	37	10.33	0.33	58	11.77	0.34	<0.05
UL8Df	98	12.26	0.23	217	14.02	0.14	<0.001
UL8Ef	53	14.48	0.28	201	1500	0.10	<0.05
UL8Ff	36	15.44	0.16	196	16.22	0.1	<0.05
UL8Gf	21	16.02	0.50	124	17.66	0.11	<0.001
(b) Males							
LL1Am	–	–	–	–	–	–	
LL1Bm	–	–	–	–	–	–	
LL1Cm	–	–		–	–		–
LL1Dm	12	3.48	0.22	9	4.52	0.27	<0.05
LL1Em	26	4.91	0.22	10	5.22	0.20	ns
LL1Fm	21	5.88	0.15	16	6.01	0.30	ns
LL1Gm	46	7.66	0.21	102	9.38	0.15	<0.001
LL2Am	–	–	–	–	–	–	
LL2Bm							
LL2Cm							
LL2Dm	28	4.56	0.24	15	4.76	0.23	ns
LL2Em	26	5.69	0.18	17	5.68	0.28	ns
LL2Fm	34	6.94	0.17	27	7.55	0.23	<0.05
LL2Gm	47	8.05	0.18	124	9.62	0.15	<0.001

Table 3 (continued)

TDS	Afro-Trinidadian			Caucasian			
	n-tds	Mean age of attainment (years) for tds	se-tds	n-tds	Mean age of attainment (years) for tds	se-tds	Significance
LL3Am	–	–	–	–	–	–	–
LL3Bm	1	3.72	-	3	5.31	0.142	–
LL3Cm	21	4.13	0.25	6	4.28	0.33	ns
LL3Dm	38	5.84	0.26	27	6.79	0.41	<0.05
LL3Em	72	7.4	0.13	70	8.02	0.24	<0.05
LL3Fm	62	9.35	0.19	152	9.74	0.09	<0.05
LL3Gm	57	11.08	0.19	59	11.87	0.16	<0.001
LL4Am	–	–	–	–	–	–	–
LL4Bm	7	3.1	0.21	5	3.88	0.19	<0.05
LL4Cm	20	4.4	0.20	18	4.82	0.16	ns
LL4Dm	53	6.1	0.14	45	7.8	0.32	<0.001
LL4Em	53	6.1	0.14	45	7.80	0.32	<0.001
LL4Fm	48	9.85	0.23	80	10.33	0.14	ns
LL4Gm	56	11.41	0.19	56	11.68	0.18	ns
LL5Am	6	3.36	0.19	8	5.94	1.53	ns
LL5Bm	14	4.48	0.35	4	4.63	0.38	ns
LL5Cm	12	5.42	0.31	20	5.23	0.19	ns
LL5Dm	70	6.5	0.15	61	8.35	0.25	<0.001
LL5Em	71	8.54	0.16	102	9.49	0.11	<0.001
LL5Fm	37	10.46	0.26	83	10.98	0.19	ns
LL5Gm	72	11.7	0.19	63	12.47	0.19	<0.001
LL6Am	–	–	–	–	–	–	
LL6Bm	–	–	–	–	–	–	
LL6Cm	–	–	–	–	–	–	
LL6Dm	15	3.7	0.18	7	4.7	0.38	<0.001
LL6Em	22	4.85	0.22	22	5.12	0.19	ns
LL6Fm	29	5.97	0.13	16	6.68	0.4	<0.05
LL6Gm	103	8.03	0.15	163	9.32	0.12	<0.001
LL7Am	7	3.14	0.17	2	4.67	0.21	<0.001
LL7Bm	8	4.05	0.18	18	5.19	0.35	ns
LL7Cm	15	5.07	0.31	19	6.25	0.30	<0.05
LL7Dm	102	7.13	0.16	86	8.67	0.19	<0.001
LL7Em	61	9.03	0.17	103	9.68	0.11	<0.001
LL7Fm	35	10.65	0.25	70	10.91	0.17	ns
LL7Gm	84	12	0.17	106	13.67	0.14	<0.001
LL8Am	42	8.49	0.31	67	9.86	0.16	<0.001
LL8Bm	26	9.58	0.36	30	9.58	0.37	<0.001
LL8Cm	28	9.96	0.37	63	12.95	0.28	<0.001
LL8Dm	88	11.66	0.2	147	13.61	0.17	<0.001
LL8Em	50	14	0.25	137	15.27	0.1	<0.001
LL8Fm	34	15.45	0.22	133	16.5	0.1	<0.001
LL8Gm	23	16.1	0.46	74	17.77	0.17	<0.001
UL1Am							
UL1Bm	–	–	–	–	–	–	
UL1Cm	1	2.71	-	4	4.68	0.58	–
UL1Dm	31	4.41	0.22	14	5.01	0.25	ns
UL1Em	27	5.84	0.15	20	6.08	0.26	ns
UL1Fm	37	7.26	0.16	54	8.72	0.19	<0.001
UL1Gm	42	8.58	0.19	119	9.85	0.14	<0.001
UL2Am	–	–	–	–	–	–	
UL2Bm	–	–	–	–	–	–	
UL2Cm	16	3.53	0.19	13	5.42	0.47	<0.001
UL2Dm	28	5.19	0.19	15	5.56	0.38	ns
UL2Em	40	6.81	0.18	17	6.40	0.28	ns
UL2Fm	33	7.91	0.16	70	9.05	0.24	<0.05
UL2Gm	39	9.07	0.25	107	9.92	0.11	<0.001
UL3Am	–	–	–	–	–	–	
UL3Bm	–	–	–	–	–	–	
UL3Cm	23	3.99	0.21	12	4.89	0.29	<0.05
UL3Dm	43	5.88	0.19	31	6.88	0.36	<0.05
UL3Em	70	7.53	0.13	91	8.44	0.18	<0.001
UL3Fm	60	9.68	0.16	123	9.97	0.10	ns
UL3Gm	38	11.16	0.2	60	11.92	0.17	<0.001
UL4Am	–	–	–	–	–	–	
UL4Bm	9	3.04	0.17	4	3.87	0.24	<0.05
UL4Cm	22	4.82	0.25	22	5.54	0.41	ns

Table 3 (continued)

TDS	Afro-Trinidadian			Caucasian			
	n-tds	Mean age of attainment (years) for tds	se-tds	n-tds	Mean age of attainment (years) for tds	se-tds	Significance
UL4Dm	73	6.5	0.14	78	8.30	0.20	<0.001
UL4Em	51	8.58	0.17	115	9.51	0.11	<0.001
UL4Fm	40	9.71	0.21	50	10.41	0.17	<0.05
UL4Gm	29	11.14	0.21	35	12.03	0.17	<0.05
UL5Am	10	3.45	0.23	3	3.65	0.18	ns
UL5Bm	12	4.69	0.38	5	4.72	0.33	ns
UL5Cm	21	5.43	0.18	22	6.44	0.71	ns
UL5Dm	81	7.18	0.12	85	8.31	0.13	<0.001
UL5Em	48	9.01	0.17	117	9.75	1.0	<0.001
UL5Fm	29	10.63	0.21	49	10.68	0.2	ns
UL5Gm	32	11.10	0.34	41	12.27	0.20	<0.001
UL6Am	–	–	–	–	–	–	
UL6Bm	–	–	–	–	–	–	
UL6Cm	–	–	–	–	–	–	
UL6Dm	22	3.89	0.26	11	4.16	0.18	ns
UL6Em	27	5.73	0.34	41	7.96	0.35	<0.001
UL6Fm	35	7.40	0.32	54	9.19	0.25	<0.001
UL6Gm	56	8.03	0.17	112	9.11	0.17	<0.001
UL7Am	3	3.60	0.27	2	4.36	5.9	ns
UL7Bm	10	3.85	0.19	15	4.90	0.2	<0.001
UL7Cm	15	5.44	0.28	19	6.22	0.31	ns
UL7Dm	18	7.52	0.17	170	9.18	0.12	<0.001
UL7Em	47	9.50	0.18	46	9.93	0.17	ns
UL7Fm	28	11.01	0.23	38	11.13	0.18	ns
UL7Gm	32	12.83	0.34	69	13.26	0.22	ns
UL8Am	21	8.91	0.33	36	9.53	0.12	ns
UL8Bm	23	8.83	0.24	31	10.62	0.30	<0.001
UL8Cm	29	10.14	0.31	55	11.74	0.33	<0.001
UL8Dm	94	12.04	0.19	157	13.9	0.15	<0.001
UL8Em	42	14.74	0.28	136	15.04	0.10	<0.001
UL8Fm	24	15.45	0.23	135	16.02	0.10	<0.05
UL8Gm	13	16.30	0.71	93	17.35	0.13	ns

[n-tds – number for each tooth development stage; mean or average age of attainment of each tooth development stage by gender (f – female; m – male); se – Standard Error]; significance of differences is 0.05 or 0.001.
Code for TDSs: L = Lower, U = Upper, second L = Left, 1, 2, etc = tooth identifier, A, B, = Demirjian Stage; f = female, and m = male.
The usual summary statistics reported are 'n', 'mean', and 'sd'. In this table the se is reported instead of sd as it is this value, along with the mean, that is used for the weighted average calculation in the meta-analysis software – see worked example. The 'sd' can be calculated from the values for 'se' and 'n'.

3.2. Between rater agreement

The intra-rater agreement of the principal investigator (KM) was 90.00%, giving a kappa value of 0.8815. A similarly good correspondence was found between the two investigators (KM and GR) which was 87.63%. These assessments are considered 'Almost Perfect'.[9]

3.3. Age of attainment of Tooth Development Stages summary data

The summary data abstracted from the full data set for each Tooth Development Stage is shown for both Afro-Trinidadian and Caucasian subjects (Table 3a and 3b). The number of TDSs, the mean, and the standard error are shown for both males and females. [Statistical note – it is usual to report the standard deviation of the data to indicate the variation inherent in the sample. In this submission the standard error has been used as the meta-analysis calculations require this statistic as it weights the output by for n-tds and sd-tds. The sd-tds can be calculated from the se-tds and n-tds].

It is clear that on the majority of occasions the Age of Attainment of the Tooth Development Stages in the Afro-Trinidadian subjects is

Table 4
Demographic details of AN entered into Excel spreadsheet.

Afro-Trinidadian	Date of birth	Date of radiograph	Chronological age	Dental age
Male	18-06-95	05-10-04	9.30	9.28

earlier than the Caucasian subjects (Table 3a and 3b). This lower mean age of attainment occurs in 97.16% (171 of 176) of the Tooth Development Stages with only 2.84% (5 of 176) of occasions with the Caucasian mean ages younger than the Afro-Trinidadians. These differences, with the Afro-Trinidadian attaining the Tooth Development Stages earlier were statistically significant at the 0.05 or less level of probability on 60.23% (106 of 176) of occasions.

3.4. A worked example using the Afro-Trinidadian Reference Dataset and the mathematical techniques of meta-analysis

Step 1 A Microsoft Excel workbook is opened and the information relating to the Dental Age Assessment is entered onto a single worksheet

Step 2 Recording of demographic details: ethnicity, gender, date of birth, date of radiograph. (Table 4)

Step 3 The Dental Panoramic Tomograph is imported into the Excel Spreadsheet (Fig. 2).

Step 4 All the teeth on the left side are viewed and the Tooth Development Stages identified with the aid of the schematic diagram (Fig. 1) and the descriptions of each of the stages (Table 1). These stage assignments are then added to the table shown below. The Reference Dataset (Table 3a or 3b) is then used to provide the mean age in years and the standard error. Teeth at stage H are not used. The data 'extracted' from the Reference Data Set(s) are displayed in Table 5.

Step 5 This excel spread sheet (Table 5) was pasted into STATA version 11 which was then used to calculate the weighted mean age for the subject AN using the random effects statistical model (Fig. 3).[8]

Step 6 This process is repeated on separate worksheets for each subject. This includes the Dental Panoramic Tomograph, date of birth, date of radiograph, gender, ethnicity, calculated chronological age, spreadsheet of data for each of the Tooth Development Stages present on the Dental Panoramic Tomograph, the calculated dental age, and the forest plot illustrating the spread of values for the TDSs for the subject of immediate concern. Following this the CA and estimated DA for each subject is then pasted into a separate worksheet so that the full numerical data is available on a single spreadsheet within the Excel workbook.

Fig. 2. Dental Panoramic Tomograph of AN.

Table 5
Tooth development stages with mean age (years) and standard error for subject AN.

Tooth	Stage	Mean age (yrs)	Standard error
UL1	UL1H	–	–
UL2	UL2H	–	–
UL3	UL3F	9.68	0.16
UL4	UL4F	9.71	0.21
UL5	UL5E	9.01	0.17
UL6	UL6H	-	-
UL7	UL7E	9.50	0.18
UL8	UL8C	10.14	0.31
LL1	LL1H	–	–
LL2	LL2H	–	–
LL3	LL3F	9.35	0.19
LL4	LL4F	9.85	0.23
LL5	LL5E	8.54	0.16
LL6	LL6G	8.03	0.15
LL7	LL7E	9.03	0.17
LL8	LL8B	9.58	0.36

3.5. Validation of the Afro-Trinidadian Reference Dataset

To test the applicability of the Afro-Trinidadian RDS a separate study sample of 50 Dental Panoramic Tomographs of Afro-Trinidadian subjects was selected from the same sources as the reference set. These were a convenience sample and comprised the first 26 diagnostic quality Dental Panoramic Tomographs of females obtained from new patient clinics. The data (dental age) from these radiographs did not form part of the Reference Dataset. (Table 6). A further 24 dental panoramic radiographs from male subjects provided dental age data in the same way. (Table 7).

The comparison of chronological age and dental age of the Afro-Trinidadian study sample using the Caucasian Reference Dataset shows there to be a highly statistically significant difference between the groups for both females and males. The females are overestimated by 10.5 months on average and the males are overestimated by 8.25 months on average. These differences are highly statistically significantly different.

In contrast, the dental age of the same Afro-Trinidadian study groups when estimated using the Afro-Trinidadian Reference Dataset showed the differences to be small and *not* statistically significant. For females this was of the order of 2 weeks and for males of the order of 3 months on average. Neither of these differences was statistically significantly different.

4. Discussion

The data presented here are the first Reference Dataset for an Afro-Trinidadian population resident on the twin island Republic of
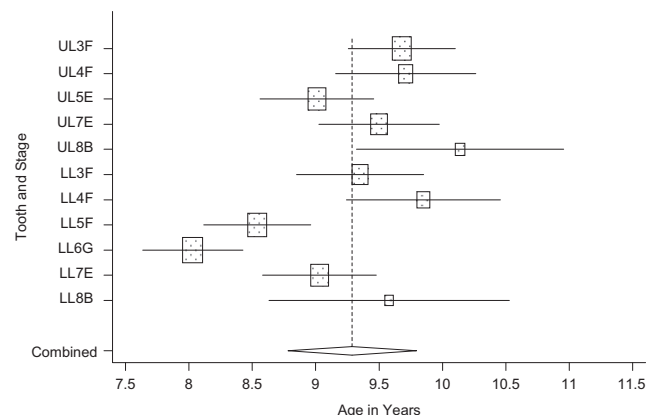

Fig. 3. Forest plot of Tooth Development Stages for subject NA.

Table 6
Chronological age (CA) of 26 Afro-Trinidadian females compared with dental age (DA) calculated using the Afro-Trinidadian Reference Dataset and the UK Caucasian Reference Dataset.

Afro-Trinidadian dental age using Afro-Trinidadian Reference Dataset (a)	Difference (CA minus Afro-Trinidadian-DA) (b)	Chronological age (CA) (c)	Difference (CA minus Caucasian-DA) (d)	Caucasian dental age using Caucasian Reference Dataset (e)
8.96	−0.08	8.88	−0.76	9.64
9.02	−0.12	8.90	−0.69	9.59
3.42	−0.27	3.15	−1.15	4.30
8.87	−0.11	8.76	−0.93	9.69
10.12	−1.75	8.37	−2.62	10.99
12.99	+0.06	13.05	−1.27	14.32
13.30	−0.12	13.18	−1.56	14.74
8.41	+1.12	9.53	+0.15	9.38
9.43	−0.84	8.59	−1.59	10.18
14.9	+0.94	15.84	0.00	15.84
9.80	+0.14	9.94	−0.82	10.76
12.11	+0.50	12.61	−0.72	13.33
8.50	+0.25	8.75	−0.68	9.43
7.75	+0.32	8.07	−0.81	8.88
4.70	+0.28	4.98	−1.12	6.10
9.85	−0.10	9.75	−1.04	10.79
9.00	−0.60	8.40	−1.20	9.60
10.7	+0.13	10.83	−0.80	11.63
10.07	−0.50	9.57	−1.48	11.05
9.00	+0.46	9.46	−0.24	9.70
8.80	+0.03	8.83	−0.57	9.40
8.20	+0.77	8.97	−0.03	9.00
8.04	−0.01	8.03	−0.57	8.6
6.01	−0.10	5.91	−1.19	7.10
10.40	+0.92	10.96	−0.04	11.00
9.95	+0.04	9.91	−0.96	10.95

Afro-Trinidadian Reference Dataset dental age (a) vs. chronological age (c): mean difference = 0.05yrs [99% Confidence Interval: −0.37 to 0.27]; $p < 0.6564$ (not statistically significantly different).
Caucasian reference dataset dental age (e) vs. chronological age (c): mean difference = 0.87yrs [99% Confidence Interval: 0.54–1.19]; $p < 0.00001$ (highly statistically significantly different).

Table 7
Chronological age (CA) of 24 Afro-Trinidadian males compared with dental age (DA) calculated using the Afro-Trinidadian reference dataset and the UK Caucasian reference dataset.

Afro-Trinidadian dental age using Afro-Trinidadian Reference Dataset (a)	Difference (Afro-Trinidadian-CA minus DA) (b)	Chronological age (CA) (c)	Difference (Caucasian-CA minus DA) (d)	Caucasian dental age using Caucasian Reference Dataset (e)
8.16	+0.03	8.13	−1.12	9.25
11.20	−0.8	10.40	−1.62	12.02
10.76	−0.22	10.54	−1.17	11.71
15.45	−0.52	14.93	−1.43	16.36
11.62	+0.55	12.17	−1.25	13.42
14.36	+0.04	14.76	−0.35	15.11
9.34	−0.78	8.56	−1.43	9.99
7.20	−0.44	7.66	−0.81	8.47
9.54	+1.57	11.11	+0.9	10.21
9.30	+1.56	10.86	+0.51	10.35
8.30	+0.15	8.45	−0.85	9.30
3.49	−0.4	3.09	−1.68	4.77
15.45	+1.07	16.51	+0.25	16.26
9.92	+1.79	11.71	+1.15	10.56
8.58	−0.01	8.57	−1.01	9.58
9.60	+0.31	9.91	−0.71	10.62
11.14	+0.06	11.20	−0.67	11.87
14.35	−2.02	12.33	−2.82	15.15
7.62	+0.69	8.31	−0.49	8.80
9.30	0	9.30	−0.02	9.10
9.02	+0.51	9.53	−0.33	9.86
10.30	−0.12	10.18	−0.77	11.07
11.12	+0.74	11.86	−0.5	12.36
13.10	+1.26	14.36	+0.24	14.12

Afro-Trinidadian Reference Dataset dental age (a) vs. chronological age (c): mean difference = −0.24 yrs [99% Confidence Interval: −0.69 to 0.21]; $p < 0.1489$ (not statistically significantly different).
Caucasian Reference Dataset dental age (e) vs. chronological age (c): mean difference = 0.68 yrs [99% Confidence Interval: 0.20–1.15]; $p < 0.0005$ (highly statistically significantly different).

Trinidad and Tobago in the Caribbean. The data confirm a clinical impression held by many colleagues that the dental development of children and adolescents of Afro-Caribbean origin occurs earlier than in Caucasian children. The data presented show that this occurs at the level of the individual Tooth Development Stages for both females and males. The earlier development of all the teeth is carried through to the Dental Age Assessments using the weighted average produced using the Meta-Analysis software.[8] Investigators need to understand that it is the mathematical techniques of Meta-Analysis that are used. In conventional Meta-Analysis the data that is combined to give weighted averages are from independent clinical studies. In the calculation of dental age, the numerical data from teeth are correlated as all of the teeth used in the calculation are within the same individual. This needs to be borne in mind when interpreting the results. Notwithstanding this concern, the results obtained using Meta-Analysis software appears to be reliable.

It is of considerable interest that almost all the Tooth Development Stages in the Afro-Trinidadians are attained earlier than in Caucasians, the proportion being over 97%. This emphatically demonstrates the earlier development in Afro-Trinidadian children compared to UK Caucasian children.

The translation of this earlier development through to Dental Age Assessments in both females and males is to be expected and as shown, this earlier maturation is greater for Afro-Trinidadian girls than it is for boys. The overall trend is similar to that described in a recent study on 3rd molars, using a scheme of 15 tooth Development Stages, and comparing South African Black children with UK Caucasian children.[10] A similar finding was reported in a comparison between German Caucasians and South African Black subjects,[11] although the South African subjects were up to 2 years ahead of the German Caucasians for mean age of attainment of individual Tooth Development Stages. This is an intriguing finding as the differences in the rate of development between Caucasians, Afro-Trinidadians, and South African black subjects appears to follow a gradient with the South African subjects attaining maturity earliest with the German Caucasians achieving maturity latest, and the Afro-Trinidadians in between. This appears logically consistent as the Afro-Trinidadian genetic make up is mixed native African and Caucasian. There is a need for more detailed work on this issue of racial and ethnic variation in tooth development. An important matter is the need to use an identical system of assessment so that the results are comparable. The use of the Demirjian Tooth Development Stages is reliable in terms of the assessment of stages even when several different investigators have carried out assessment of the same material.[12] This method of age assessment uses the first part of the Demirjian method; that is to say the use of 8 stages, A–H, which are clearly defined (Fig. 1 and Table 1). This constrained use of the Demirjian stages has been used previously with success.[10,11] The second part of the Demirjian system, which integrates the data from the Tooth Development Stages provides 'averaged percentile curves' from which the dental age can be read. The results using the complete Demirjian method are less accurate when used on populations other than the French Canadian children and adolescents studied by Demirjian.[7] Studies on a UK[13] and Northern Turkish populations[15] using the Demirjian method resulted in children being assessed as 'older' when using the original French Canadian Reference material.[7] A further problem with the scoring system of the Demirjian system is that it is impossible to identify the precise point at which differences in dental maturation occur, although the system was able to successfully differentiate on an age basis alone between Pacific Islander and New Zealand Maori children.[14] Although the complete Demirjian system of estimating age appears to be falling in to disfavour because of the equivocal results when applied to populations other than French-Canadians, the 8 stage system of Tooth Development Stages does, however, provide a widely applicable system of estimating the Age of Attainment that enables easy comparison between different ethnic groups. As is illustrated in this report, these differences are discernible at the Tooth Development Stage Level, the basic units of analysis in Dental Age Assessment. These differences between UK Caucasian and Afro-Trinidadian Tooth Development Stages carry through to differences in the outcome variable of dental age for an individual subject.

This report is the first to provide a full Reference Dataset for an Afro-Caribbean population, namely, the Afro-Trinidadian population of Trinidad and Tobago. This is also the first to provide a Reference Dataset suitable for Dental Age Assessment of an identifiable human group of mixed genetic origin. Further work is planned to finesse the Afro-Trinidadian Reference Dataset by increasing the numbers for n-tds in the younger age groups. The full dataset on which this report is published is available to collaborative investigators by contacting the principal investigator at kmoze@yahoo.com or the corresponding author at graham.j.roberts@kcl.ac.uk

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