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Dental age assessment of southern Chinese using the United Kingdom Caucasian reference dataset

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ABSTRACT

Dental age assessment is one the most accurate methods for estimating the age of an unknown person. Demirjian's dataset on a French-Canadian population has been widely tested for its applicability on various ethnic groups including southern Chinese. Following inaccurate results from these studies, investigators are now confronted with using alternate datasets for comparison. Testing the applicability of other reliable datasets which result in accurate findings might limit the need to develop population specific standards. Recently, a Reference Data Set (RDS) similar to the Demirjian was prepared in the United Kingdom (UK) and has been subsequently validated. The advantages of the UK Caucasian RDS includes versatility from including both the maxillary and mandibular dentitions, involvement of a wide age group of subjects for evaluation and the possibility of precise age estimation with the mathematical technique of meta-analysis. The aim of this study was to evaluate the applicability of the United Kingdom Caucasian RDS on southern Chinese subjects. Dental panoramic tomographs (DPT) of 266 subjects (133 males and 133 females) aged 2–21 years that were previously taken for clinical diagnostic purposes were selected and scored by a single calibrated examiner based on Demirjian's classification of tooth developmental stages (A–H). The ages corresponding to each stage of tooth developmental stage were obtained from the UK dataset. Intra-examiner reproducibility was tested and the Cohen kappa (0.88) showed that the level of agreement was 'almost perfect'. The estimated dental age was then compared with the chronological age using a paired *t*-test, with statistical significance set at $p < 0.01$. The results showed that the UK dataset, underestimated the age of southern Chinese subjects by 0.24 years but the results were not statistically significant. In conclusion, the UK Caucasian RDS may not be suitable for estimating the age of southern Chinese subjects and there is a need for an ethnic specific reference dataset for southern Chinese.

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1. Introduction

1.1. Background

Bone and odontogenic tissues have and can be successfully used to determine age and hence age estimations of children with unknown birth records are performed by evaluating their dental development [1]. Dental age assessments aid in accurately determining the age of subjects with unknown birth records [2]. This is of importance as investigation and penal legislation makes age estimation important so there is also a great need for accuracy. Dental age estimations have usually been carried out by evaluating the applicability of a previously established database as a standard reference dataset of comparison [3,4].

Demirjian and his co-workers derived what is considered to be the most reliable dataset based on a sample of French-Canadian subjects. This dataset has subsequently been tested on various population groups for its universal applicability and comparability and consistent overestimation of the dental age has been reported [5–8]. For example, a study utilizing the Demirjian dataset on 5–7 years old southern Chinese children reported over estimation of dental age. The study further concluded that the dataset was inaccurate and therefore inappropriate for estimating the age of these children [9]. A study validating the Demirjian dataset on a wider age group of 3–16 years old southern Chinese children also demonstrated overestimation of dental age [10].

A UK dataset of Caucasians has been available for a few years and was subsequently tested for accuracy [11]. These investigators were able to accurately estimate the age of the subjects since the dataset they established belonged to the same population group

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[12]. The UK Caucasian reference data set (RDS) has been used as a reference dataset and tested on various populations. This is performed by estimating the age of subjects under investigation using an established dataset, belonging to a different ethnic or population group. The accuracy of the estimated age relies on the close correlation of dental maturity between the populations compared. The applicability of the Demirjian dataset on French-Canadian subjects has already been tested on southern Chinese and this study aimed at testing the applicability of the UK Caucasian RDS. If relatively close, this RDS, rather than the Demirjian data will be compared with the RDS derived from southern Chinese subjects.

1.2. Dental panoramic tomographs

The advantage of dental panoramic tomography (DPT) is that it allows comprehensive imaging of all the teeth and their stage of development, also the simplicity of this imaging technique ensures acceptance by even young children. Furthermore, radiation exposure is relatively low compared to other imaging procedures. Magnification of panoramic imaging has been widely discussed in the literature. Langland and co-workers reported a uniform magnification of 19% for DPTs which is a function of the distance between the focus and the object [14]. Similarly, a 3–10% enlargement on the left side of the mandible has been reported on panoramic radiographs [15]. A justification for using panoramic radiographs is that the distortions and variations in magnification do not affect the assessment because the rating of developing teeth is based on the shape criteria and relative values and not on absolute length measurements [15].

1.3. Demirjian's tooth development stages

The number of tooth development stages (TDS) varies between 4 and 24 depending on the system. The classification system developed by Demirjian and his co-workers [5] starts with radiographic appearance of calcification of the crown (Stage A) up to the time of root completion (Stage H), see Fig. 1.

The reliability of scoring a tooth developmental stage was a compromise between a small number of stages that are easy to identify and a large number of stages that are less reliable [11]. Various methods of tooth development stages have been reviewed and Demirjian's method of TDS has achieved the highest values for both observer agreement and for correlation between the stages [16].

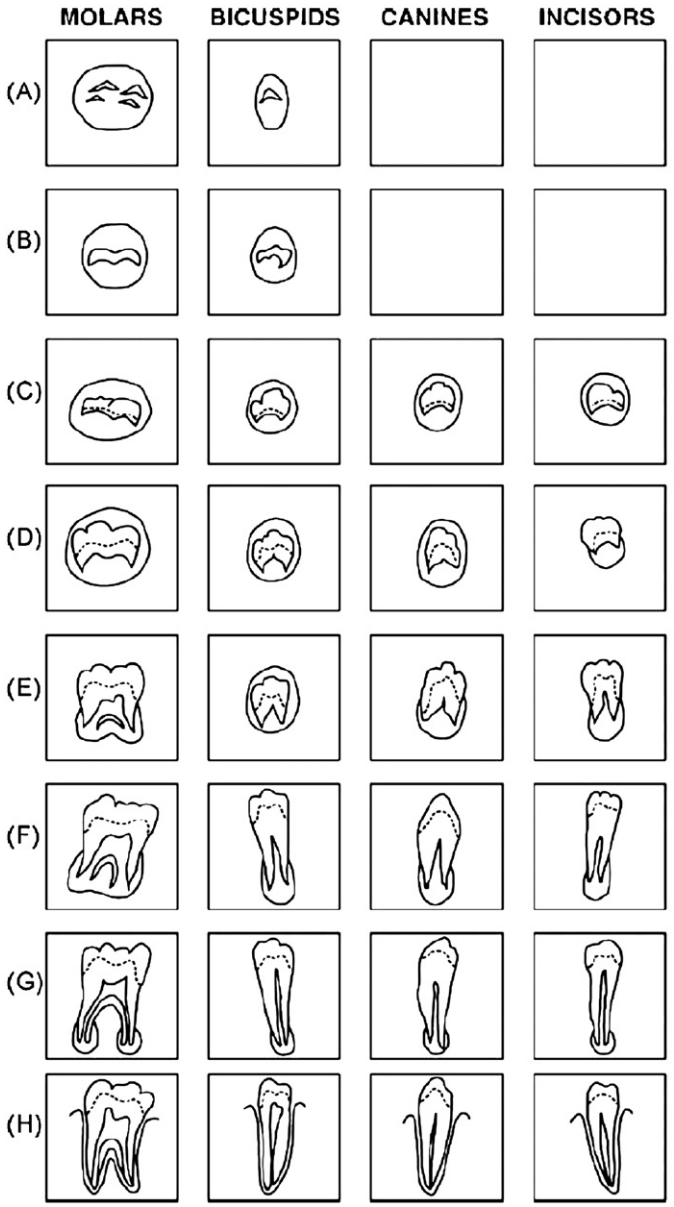

Fig. 1. Line diagrams representing the classification of 8 tooth developmental stages [15].

1.4. The United Kingdom Caucasian reference data set

The United Kingdom Caucasian reference dataset was established by Roberts and his co-workers [11] from a diverse population of 4–24 years old subjects in the United Kingdom. The dental panoramic tomographs (DPT) were scored according to Demirjian's classification of tooth developmental stages (TDS). Maxillary and the mandibular teeth on the left side and also the third molars on the right side were included in the scoring. Boys and girls were scored separately; mean dental ages and corresponding standard errors were obtained for each TDS for all 18 tooth morphology types (TMTs). The final dataset thus comprised of 8 TDS $\times$ 18 TMT $\times$ 2 genders = 288 data sets.

1.5. Advantages of the United Kingdom Caucasian reference data set

The United Kingdom Caucasian reference dataset includes both maxillary and mandibular teeth for analysis. Since the mandible is often frequently lost in mass victim disasters, age assessment can still be performed using the maxillary dentition. Dental development follows a systematic growth pattern so that at approximately 16 years of age, almost all of the teeth, except the third molars achieve root closure. Hence, third molars serve as the only source of information for dental age estimation after 16 years of age. For this reason, the third molars were also included in the UK Caucasian dataset.

The mathematical technique of meta-analysis of dental age (DA) provides a precise estimate of the expected DA in a subject by calculating a weighted mean of the mean ages of each stage of tooth development in that subject [11].

The scores of the UK Caucasian RDS which were directly expressed as mean dental ages were calculated by averaging the weighted mean estimates of various tooth developmental stages. This makes the dental age calculation more accurate and simple unlike Demirjian's system for which the estimated dental age is only an approximate calculation and a conversion has to be performed in order to relate the weighted maturity scores to the dental age.

2. Materials and methods

2.1. Study population

A total of 266 (133 males and 133 females) dental panoramic tomographs (DPTs) belonging to southern Chinese subjects aged 2–21 years were obtained from the archives of Prince Philip Dental Hospital, Hong Kong. The DPTs had been exposed previously for clinical diagnostic purposes. The mean ages of the subjects included in the study were 11.49 ± 5.45 years for males and 11.52 ± 5.47 years for females. The sample was split into 19 separate age groups, at an interval of one year each; 14 DPTs were allotted to each age group. Patients with bilaterally missing maxillary and mandibular teeth and growth anomalies were excluded from the study.

2.2. Digitization, viewing and scoring methods

The DPTs were scanned at a resolution of 300 dpi in grey scale format (Canon, Canon Inc, Japan) and viewed on a widescreen monitor (Philips 201E, Philips Electronics, Taiwan) at a standard magnification of 160% (Microsoft Picture Manager, Microsoft Corp, US). When doubt existed, the original DPTs were re-evaluated without magnification on a viewing table (Cabin Light, Cabin Industries, Japan). An example of a scanned panoramic image is shown in Fig. 2. All the images were scored by a single calibrated examiner using Demirjian's classification of tooth developmental stages (A–H).

All the maxillary and mandibular tooth morphology types (TMT) on the left side and the third molars on the right side were included in the scoring process. When a tooth on the left side was missing, the corresponding tooth on the right side was substituted. For each TDS, the mean dental age and the corresponding standard error were obtained from the UK Caucasian RDS. The values corresponding to Stage H were omitted from the scoring process (Table 1).

The data was then transferred to a spreadsheet (Microsoft Excel, Microsoft Corp, US) which contained details of the subject's chronological age (CA) obtained from the patient notes, and the scores for each TDS for calculation of dental age using meta-analysis.

Fig. 2. Panoramic radiograph showing the teeth at various stages of development. Chronological age of this subject was calculated as 10.65 years. Scoring for TDS of this subject was illustrated in the Table 1.

Table 1
Summary data of the values obtained from the United Kingdom database for corresponding TDS. Scoring for teeth with stage H is omitted. The lowest mean age is 8.94 years for UL1 and the highest mean age is 12.10 years for LL5.

Tooth	Stage	Mean	Standard error
UL1	UL1G	8.94	0.33
UL2	UL2H	–	-
UL3	UL3F	9.23	0.32
UL4	UL4F	10.51	0.39
UL5	UL5F	11.10	0.39
UL6	UL6H	–	-
UL7	UL7E	9.45	0.37
UL8	UL8B	10.20	0.18
UR8	UR8B	9.92	0.18
LL1	LL1H	–	-
LL2	LL2H	–	-
LL3	LL3F	9.22	0.26
LL4	LL4F	10.50	0.59
LL5	LL5F	12.10	0.49
LL6	LL6H	–	–
LL7	LL7E	8.97	0.45
LL8	LL8B	11.78	0.48
LR8	LR8B	11.74	0.41

2.3. Statistical analysis

2.3.1. Calculation of dental age (DA) by meta-analysis

Statistical software was used to calculate the dental age by meta-analysis (STATA, Stata Corp, Version 9.0, 2005). For each patient, the mean and standard errors for all the TDS were utilized for the meta-analysis calculation. A random and fixed pool estimate was created at the 99% confidence interval. The mean dental age derived by random pool estimate was considered as the dental age (DA) for that patient.

2.3.2. Intra-examiner reproducibility

For evaluating intra-examiner reproducibility, 20 radiographs were randomly selected from the set of radiographs used in this study and re-scored after a period of at least 2 weeks. Tooth developmental stages of the initial and re-scored DPTs were compared and the Cohen kappa values were calculated [17].

2.3.3. Calculation of differences in the age estimation

Statistical significance was set at $p < 0.01$ and paired t-test was utilized to derive differences between the estimated dental age and the chronological age.

3. Results

The Cohen's kappa value score was calculated to be 0.88. This showed that the intra-examiner reproducibility was 'almost perfect'.

For a subject with a chronological age of 10.65 years, the estimated dental age from the United Kingdom database ranged between 9.58 years and 10.88 years. The estimated mean dental age for that subject was calculated as 10.23 years (Table 2). A forest plot was further generated from the mean dental age and the corresponding standard error for each TDS, derived from the United Kingdom database (Fig. 3).

The mean differences of the estimated dental age with corresponding standard deviation for males and females are displayed in Fig. 4. The standard deviations of the mean dental ages were lower in the subjects who were younger than 7 years and the mean difference in dental age (DA–CA) decreased with increasing age. Moreover, consistent underestimation of dental age was

Table 2
An example of the estimated dental age (DA), with upper and lower age limits. The DA for this subject was 10.23 years.

Method	Estimated DA	Upper 99% CI	Lower 99% CI	z Value	p Value
Random	10.233	9.581	10.884	40.471	0.000

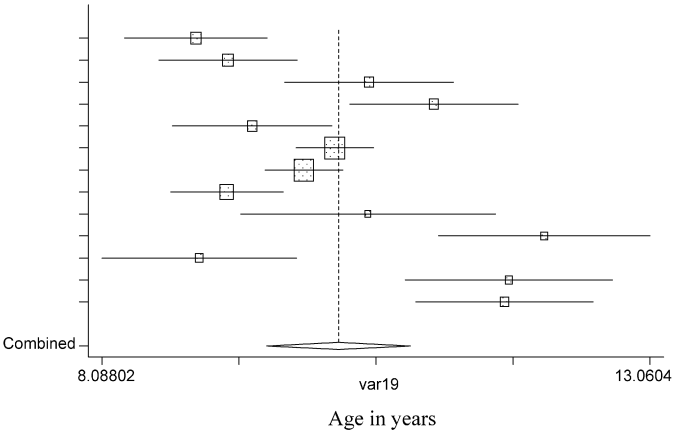

Fig. 3. Forest plot showing dental ages with corresponding standard error estimated from the weighted mean estimates of the United Kingdom database.

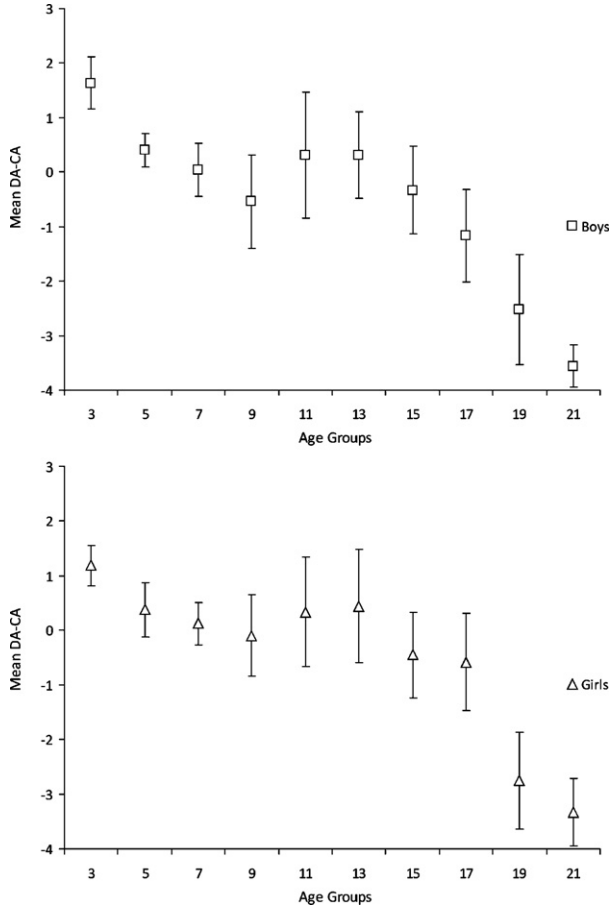

Fig. 4. Mean difference between the estimated dental age (DA) and chronological age (CA) among southern Chinese boys and girls.

observed after 15 years of age and the underestimation was more pronounced after 18 years (Fig. 4).

The overall mean difference between the estimated dental age and chronological age was −0.25 (±1.43) years for males and −0.23 (±1.37) years for females. This indicates that the UK Caucasian RDS underestimated the age of southern Chinese males by 0.25 years ($p = 0.04$) and females by 0.23 years ($p = 0.05$). However, the results were not statistically significant at $p < 0.01$ level.

4. Discussion

The applicability of the UK Caucasian reference data set was tested on 2–21 years old southern Chinese children and emerging adults for whom an overall underestimation of 0.24 years was observed. This result was consistent with a previous study which evaluated the applicability of the UK Caucasian dataset for Australian Caucasians aged 4–24 years. A delay in dental development by 0.82 years was observed for the Australian subjects who were age matched with the UK Caucasians [18]. Moreover, they were able to accurately estimate the age for the UK Caucasians since the subjects and the RDS subjects belonged to the same population group.

Variation among younger and older age groups was observed when Demirjian's dataset was utilized for age estimations of southern Chinese children aged 5–7 years [19]. The results of the current study showed similar variations. Hence, to analyze the differences in age estimation between the younger and the older age groups, the sample was separated into two groups, 2–11 years and 12–21 years; males and females were considered separately. The UK Caucasian RDS overestimated the age of young males by 0.37 years and females by 0.39 years. By contrast, when applied to the older age group, it underestimated the age of males by 1.05 years and females by 0.98 years. Thus, it would appear prudent not only to use ethically appropriate databases, but also to group subjects by age and gender. This variation with increasing age could be because the accuracy of the estimated dental age is influenced by the number of teeth and their stages of development at the time of analysis. In this regards, the number of developing teeth available for assessment gradually decreases from younger to older children and this could be a probable cause for differences in the age estimation [19].

An important advantage of the UK Caucasian RDS is that it involves the scoring of the maxillary and mandibular teeth. Demirjian and his co-workers [5] included only seven teeth on the left side of the mandible for their assessment, also they omitted to score the maxillary dentition as they had difficulty in scoring teeth in the maxillary region. By contrast, the inclusion of maxillary teeth in the age estimation study increased the number of teeth for assessment which substantially improved the accuracy of the estimated age. Scoring the maxillary dentition was found to be relatively challenging due to anatomical superimpositions and the skeletal morphology of the maxillary region. Mesiodistal tooth angulations in panoramic films have been evaluated and it has been found that exaggerated root divergence between the maxillary canine and the first premolar occurs [20]. The 8 stage scoring of TDS is based on relative values and not the absolute measurements, superimpositions and distortions do not significantly affect the assessment [15].

During the course of the study, it was observed that most panoramic images showed slight distortion on the left side. It has been reported that the normal duration taken for capturing a panoramic radiograph is 3–4 min [21], and the axis of rotation of the panoramic machine tube (Orthoralix SD ceph, Gendex, Monza, Italy) used in the study was from left to right so that the image on the right-side was captured first, followed by the left-side. The possible reason for distortion may be that the children become restless towards the end of the image taking procedure resulting in minor head movements and hence distortion of the image on the left side. However, a defect in the axis of rotation of the tube itself can also contribute to distorted images but no fault was found with the machine used throughout the present study.

The number of teeth and the staging of development included in the analysis have been suggested to cause overestimation of age [19]. Genetic influence, socio-economic status and other environmental conditions that influence dental and skeletal maturity have also been reported [7,22]. These observations were supported by our finding that the UK database could not accurately estimate the age of southern Chinese subjects. Inconsistent results were also observed for Australian and Trinidadian subjects and this may be attributable to varying degrees of dental maturity between the different ethnic and population groups [13,18].

5. Conclusion

The dental ages of southern Chinese calculated from the UK Caucasian reference dataset are not statistically significantly different, but the differences are of sufficient magnitude to indicate that for age estimation of the southern Chinese subjects, of unknown age, it would be prudent to develop an ethnic specific reference dataset based on radiographs of southern Chinese subjects.

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