Research article

A method of estimating age of undocumented children and young adults of different socioeconomic status in Cambodia

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ABSTRACT

A growing number of Cambodian children without legal documentary evidence of date of birth are vulnerable to exploitation. This study aimed to evaluate the applicability of southern Chinese reference dataset for dental age estimation on Cambodian children and young adults of different socioeconomic status. Dental panoramic tomographs (DPT) of 371 Cambodian children and young adults belonging to lower and higher socioeconomic status (SES) groups were analyzed. All the left maxillary and mandibular permanent teeth including the third molars were scored based on Demirjian's classification of tooth development stages. Chronological age (CA) was calculated from the date of birth and date of exposure of radiograph. The mean age of attainment for each stage of development was obtained from the southern Chinese reference dataset. Dental age (DA) was calculated by averaging the mean age scores for all the teeth. Paired t-test and correlation analysis were conducted to measure associations between the chronological age and the dental age for males and females in the lower and higher socio-economic status groups. Underestimation of age was observed in both SES groups using the southern Chinese reference dataset. For the higher SES group, the difference between the chronological and dental age (CA-DA) was 0.26 years for females and 0.11 years for males. The difference was statistically significant only in females ($p < 0.05$). In the low SES group, the results showed a difference of 0.07 years in females and 0.01 years in males; the differences were not statistically significant in both sexes ($p > 0.05$). A strong correlation was observed between the CA and DA in both sex and SES groups ranging from 0.969 to 0.988 ($p < 0.05$). The southern Chinese dental reference dataset can be used to estimate the age of undocumented Cambodian male and female children and young adults of both higher and lower SES.

1. Introduction

1.1. Background

Cambodia has progressed rapidly since the United Nations sponsored elections in 1992. Issuance of identification documentations, for example national ID cards and passports, has improved greatly, however a United Nations report estimated that between 2010 and 2016, only 73% of births were registered in Cambodia [1]. Many Cambodians presently lack formal age documentation and may be unaware of their true age. According to the Thai Government, between July and October 2014, after major migration of Cambodian workers from Thailand, nearly 700 thousand Cambodian migrant workers and 40,000 dependents remained in Thailand without legal documents. These workers registered at One-stop service centers seeking temporary amnesty from deportation [2]. Many of these illegal immigrants were unable to provide evidence of their date of birth, creating problems for the Thai authorities, and many appeared to be minors. For Cambodian nationals, there are other situations when proof of age can be very important. For example, criminal proceedings, place of detention, sentencing, and the defendant's legal rights are all influenced by whether the person is classified as a child or adult [3]. These individuals may be reluctant to give their correct age or, in many cases, may not actually know their age [4].

The Cambodian Labor Law (Article 177) sets 15 years as the minimum age to work and 18 years as the minimum age for hazardous work. Furthermore, the legal age to marry in Cambodia is 18 years. These laws

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are often broken as many Cambodian children are in the workforce, and around 2% of females get married by the age of 15 years and 18% by 18 years [2]. In the courts of law, the ages of children and young adults are often falsified in order to escape prosecution or receive a lesser sentence. In the same way, children working in the sex industry or their pimps may claim that the child is older when confronted by the legal authorities. In most instances, documentation of age may be lacking. The International Labor Organization proposed that all children must be provided with an identity so that they can access public services and reduce their vulnerability within society [2]. Children and adolescents without proper age documentation become vulnerable to anti-social activities including child labor, trafficking, smuggling, prostitution, sexual abuse and pornography. An estimated 18% of Cambodian children are in forced labor and it has been estimated that 1.2 million children are trafficked every year [5]. Cambodia has been identified as a major source for transit and is a destination country for human trafficking. Children in Cambodia are primarily trafficked to Thailand, Vietnam and Malaysia to engage in the sex trade, work as domestic servants or street vendors, or be forced to beg [5]. When the authorities intervene, it is imperative that the age of these children is established so that they can receive appropriate age-related services. The Government of Cambodia has taken several measures to eliminate and prevent child labor and sexual exploitation, but these issues still persist [6].

Well-tested age estimation methods based on biological profiles have been used for several decades to provide vulnerable children with an accurate estimate of age. However, to date, no age estimation study has been conducted in the Cambodian population. When the documentation to confirm a person's chronological age is lacking, biological indicators can be used as a measure to estimate age [7]. Indicators such as skeletal maturation, height/weight measurement, secondary sexual characteristics, tooth wear patterns, and dental maturation have been used individually and in combination [8]. Dental development correlates more closely with chronological age for children, adolescents and emerging adults than some of the previously mentioned methods, as it is less affected by environmental factors [9]. In particular, Tooth Development Stages (TDSs) have been used for age estimation and extensively studied since the 1960s. One of the most well-known methods was developed by Demirjian and co-workers and it has been proven to be inaccurate and unreliable for any global population [10]. The standards for age estimation have been developed based on preparation of exclusive reference datasets within the population of interest, or by the adaptation of previously established datasets [11, 12]. A reference dataset based on a cohort of 2324 southern Chinese subjects aged between 2 and 24 years has been developed recently since previous databases were based on non-Asian population groups [13].

1.2. Age estimation in Cambodian population

During the Khmer Rouge period from 1975 to 1979 and in the decade following, the whole population of Cambodia was reduced to poverty. Then, with the emergence of peace in the early 1990s until today, there has been a growing middle class and widening gap between the rich and poor, which is particularly evident in the capital city of Phnom Penh [14]. It has been shown that socioeconomic status (SES) has an influence on dental development, and that those of higher SES exhibit more advanced dental development than those of lower SES [15]. Since age estimation is assessed from the maturation pattern of developing dentitions, it can be expected to produce variations in subjects of different SES groups [15]. It has been shown that East Asian populations share 90% of major haplotypes and that phenotypic expressions are closely related [16]. Hence the data derived from dental development of southern Chinese subjects could be expected to be similar to the Cambodian population. This study hence aimed to investigate the applicability of the southern Chinese reference dataset to the Cambodian population, as well

as to investigate the influence of socioeconomic status on dental age estimation.

2. Materials & methods

2.1. Sampling

This cross-sectional study included Cambodian children and young adults aged 5–24 years belonging to lower and higher socioeconomic status groups. Informed consent was obtained from all participants of this study at the time of taking radiographs for the purpose of clinical diagnosis and treatment planning in both university and dental clinic settings. This representative sample of anonymized Dental Panoramic Tomographs (DPT) taken for diagnostic purposes were re-used in this study. DPTs of patients of predominantly low socio-economic status were retrieved from the archives of the dental clinic at the University of Puthisastra. A similar number of DPTs from patients of mainly high socioeconomic status were obtained from a large private dental clinic located in Phnom Penh, Cambodia. DPTs were downloaded at random at each location until the required sample size for DPTs for each age (5–24 years) was met.

The inclusion criteria were clearly defined by the ethnicity. Only children belonging to Khmer ethnic group identified by their name and parental records were included in the study. In addition, the date of birth (DOB) of the children was verified from the government issued authentic birth documents. The exclusion criteria included systemic disease or syndromes that could affect skeletal and dental growth, localized oral pathology, dental anomalies or impacted teeth, severe malocclusion, history of present or past orthodontic treatment, and DPT of poor quality in which one or more targeted teeth could not be scored. Ethical approval was obtained from the Institutional Review Board of International Medical University, Malaysia (JCM-162/2018). Approval for the study was also obtained from the Dental Research Committee at the University of Puthisastra, Cambodia. This study strictly complied with ethical principles and was conducted according to the Declaration of Helsinki for research involving human subjects.

2.2. Data collection

DPTs of subjects and their personal information including chronological age and ethnicity, was obtained from the patient records. Each DPT was given a code and saved as a JPEG image with dimensions of 2610×1529 pixels. The digitized DPT and the participants' information were sent to Kuala Lumpur, Malaysia on an encrypted and password protected Compact Disc for scoring and analysis.

2.3. Data processing

The details (location, record number, date of birth, date of radiograph, sex and ethnicity) were entered in the Microsoft Excel®. Chronological age (CA) was calculated from the date of birth (DOB) and date of exposure of radiograph (DOR) using a formula: DOR-DOB/365.25. This formula counted each day in a year including the leap year and provided the chronological age in decimal years for each subject. All DPT were scored by two trained and calibrated examiners who were blinded to the chronological age (CA) of the participant. All the left maxillary and mandibular permanent teeth (16 teeth per subject) were given scores based on Demirjian's classification of tooth developmental stages (Figure 1). The classification system comprised eight stages beginning from the initial calcification (Stage A) up to root completion (Stage H). The contralateral tooth was assessed when a tooth on the left side was missing or difficult to interpret. For each subject, a mean age estimate was obtained based on the stage of development for each specific tooth from the southern Chinese reference datasets for males and females. For
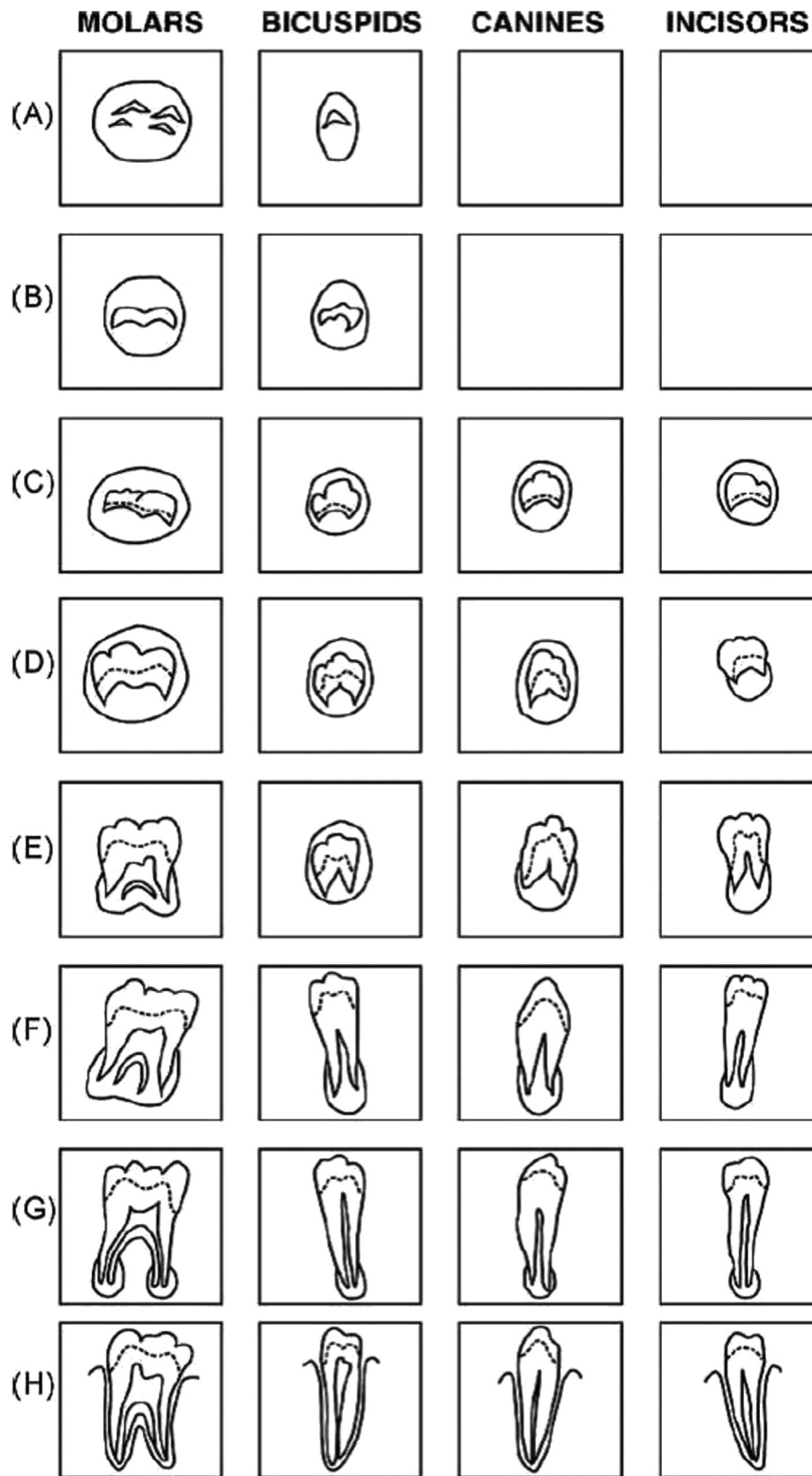
Figure 1. The tooth development stages described by Demirjian et al. 1973.

example, for a male subject with LL3 at stage C, the corresponding mean age was obtained from database values for LL3Cm. Obtaining such data for stage H was omitted. The mean ages were then averaged to estimate the dental age (DA). Using SPSS software (SPSS 16.0, IBM Inc, Chicago, IL), paired t-test and correlation analysis were conducted between the chronological age and the estimated dental age for each subject. The obtained difference (CA-DA) indicated the accuracy of the estimated age to the gold standard (chronological age) for each subject under study.

3. Results

3.1. Sample population

A total of 371 Dental Panoramic Tomographs (DPT) were included in this study. This comprised of 171 DPTs of 86 females and 85 males in the lower socioeconomic status group, and 200 DPT's comprising 101 males and 99 females in the higher economic status group. The ages of the subjects ranged from 5 to 24 years. The chronological ages of males and females in the higher and lower SES groups did not vary significantly (p > 0.05).

3.2. Examiner reliability

For evaluating examiner reliability, around 10% of the DPT were randomly chosen from the high and low SES samples. Intra-examiner reliability for the first examiner (KM) who evaluated the DPTs of subjects in the lower SES group was 0.944 and for the second examiner (AR) who evaluated the higher SES group was 0.828. Inter-examiner reliability between the examiner 1 (KM) and 2 (AR) was 0.866 based on the evaluation of DPTs in both low and high SES. The intra- and inter-examiner reliability scores between the examiners were "almost perfect" (p < 0.05) [17].

3.3. Differences between the chronological age and dental age in low and high SES groups

The descriptive statistics for chronological age (CA) and dental age (DA) and the difference between CA and DA (CA-DA) was summarized in Table 2. The mean CA for females in the lower SES group was 13.96 (SD 0.85). Males of higher socioeconomic status had a mean CA of 12.17 (SD 1.02). The lower and upper boundaries of the 95% confidence limits of agreement for the age groups were mostly within 2 years. The difference between the chronological age (CA) and the dental age was 0.07 years in females (p > 0.05) and 0.01 years in males (p > 0.05). No statistically significant difference was found between the CA and DA in children and young adults in the higher SES group. The mean CA for the males in the higher socioeconomic group was 12.17 years (SD 4.51), whilst the mean DA was 12.06 years (SD 4.52). The mean CA for females in the higher SES group was 12.55 years (SD 4.55), whilst the mean DA was 12.29 years (SD 4.61). The data showed that the mean difference between CA and DA (CA-DA) was 0.11 years for males and 0.26 years for females. The difference between the CA and DA among Cambodian males in the higher SES group was not statistically significant (p > 0.05) whereas in females it was significant (p < 0.05) (Table 1). Overall, the southern Chinese reference dataset slightly underestimated the age of Cambodian subjects in both lower and higher SES groups.

3.4. Correlation analysis

Pearson correlation coefficient analysis was conducted between the two variables chronological and dental age in males and females, in lower and higher socioeconomic status groups respectively. Strong positive correlations were observed between both sexes in the higher and

lower SES groups, with the correlation coefficient (r) ranging from 0.969 to 0.988 (see Table 2).

3.5. Bland & Altman plots

Using the data pooled across age groups, a Bland-Altman plot showed that the differences between CA and DA were randomly distributed around a mean difference of 0.01 (SD 0.85) years in females (Figure 2) and 0.07 (SD 1.03) years in males of lower SES (Figure 3). A trend was noted that points to Cambodian participants beyond 20 years in both sexes having their ages overestimated when using the southern Chinese reference data set. In the higher SES group, the Bland-Altman plot showed that differences between CA and DA were scattered in a random fashion around the mean difference of 0.11 (SD 1.02) years in males (Figure 4) and 0.26 (SD 0.73) years in females (Figure 5).

4. Discussion

In most circumstances dental age estimation is conducted for subjects who lack legal documentation to establish age. It is a reliable, non-invasive, inexpensive and relatively simple procedure [18]. However, the development of ethnic-specific reference datasets is essential for accurate age estimation, since different ethnic groups may have different dental development characteristics [12]. It has been shown that the accuracy of dental age estimation depends on the number of developing teeth included in the assessment. Greater accuracy in assessment of age has been reported in younger children compared to adolescents followed by young adults. Estimation of age of subjects more than 24 years of age becomes difficult as all the teeth have achieved complete root development [13]. Although many dental reference datasets exist from many countries, this is the first ever dental age study conducted in Cambodia, and the first to categorize the subjects based on socioeconomic status to test its effect on the variations in the estimated age.

The reference dataset for the southern Chinese was developed in response to the UK and French-Canadian reference datasets for dental age estimation not being applicable to southern Chinese children [19, 20]. A sample of 1,123 females and 1,183 males aged from 2 to 25 years were used to establish this reference dataset. An additional study with 484 participants (229 males and 255 females) aged from 2 to 25 years of age was later used to validate the southern Chinese reference dataset [13]. It has been established that southern China is the origin of many ethnic groups throughout East Asia and the Pacific [21]. Recent genetic studies based on mitochondrial DNA and Y-chromosome allelic markers strongly suggest that even remote populations in northern China originated from southern China [22, 23]. These migrations commenced during the pre-historic period and it is accepted that southern Chinese are the root of the many population groups in south east, north east and far east Asia [24, 25]. The phenotype of this population group can be identified by their physical appearance including the characteristic epicanthic fold and shovel-shaped incisors. East Asian population groups share 90% of major haplotypes and hence exhibit common phenotypic expressions [25]. The present study presented an opportunity to test the applicability of southern Chinese reference data to the Cambodian population, by comparing the dental development of southern Han Chinese with ethnic Khmer in Cambodia.

Table 1. Difference between chronological age and dental age in subjects in low and high socioeconomic status groups.

| SES	Sex	CA	DA	CA-DA	SD	SEM	Lower CI	Upper CI	p-value†
Low	Males	12.72	12.65	0.07	1.03	0.136	-2.080	0.338	0.635
	Females	13.96	13.95	0.01	0.85	0.100	-0.188	0.211	0.908
High	Males	12.17	12.06	0.11	1.02	0.118	-0.125	0.348	0.351
	Females	12.55	12.28	0.27	0.73	0.082	0.1	0.427	0.002*

SES-Socioeconomic status, CA-Chronological age, DA-Dental age, SD-Standard deviation, SEM-Standard error of mean, CI-Confidence interval, †paired t-test, *statistically significant value p < 0.05.

Table 2. Correlation between the chronological age and dental age in subjects in low and high socioeconomic status groups.

SES	Sex	CA-DA	r	p-value
Low	Males	0.07	0.969	0.001*
	Females	0.01	0.981	0.001*
High	Males	0.11	0.976	0.001*
	Females	0.27	0.988	0.001*

SES-Socioeconomic status, CA-Chronological age, DA-Dental age, r-Pearson correlation coefficient, *statistically significant value $p < 0.05$.

The present study explored whether SES was associated with dental age. One of the two groups was from a dental school where most patients attending were lower income whereas the other group was from a large private clinic where most patients were from the higher income backgrounds. Cambodia's "rural poor" were not included in the study and so the results cannot be generalized to the wider Cambodian population. The relatively low number of subjects in the study may have limited its power to detect significant differences between the sub-groups [26]. Our results demonstrated that the difference between CA and DA in Cambodian females and males in the low SES group was small, being only 0.01 years and 0.07 years respectively. This is in agreement with the study by Wong et al. reported that the dental age estimations of the northern Chinese based on southern Chinese reference datasets were
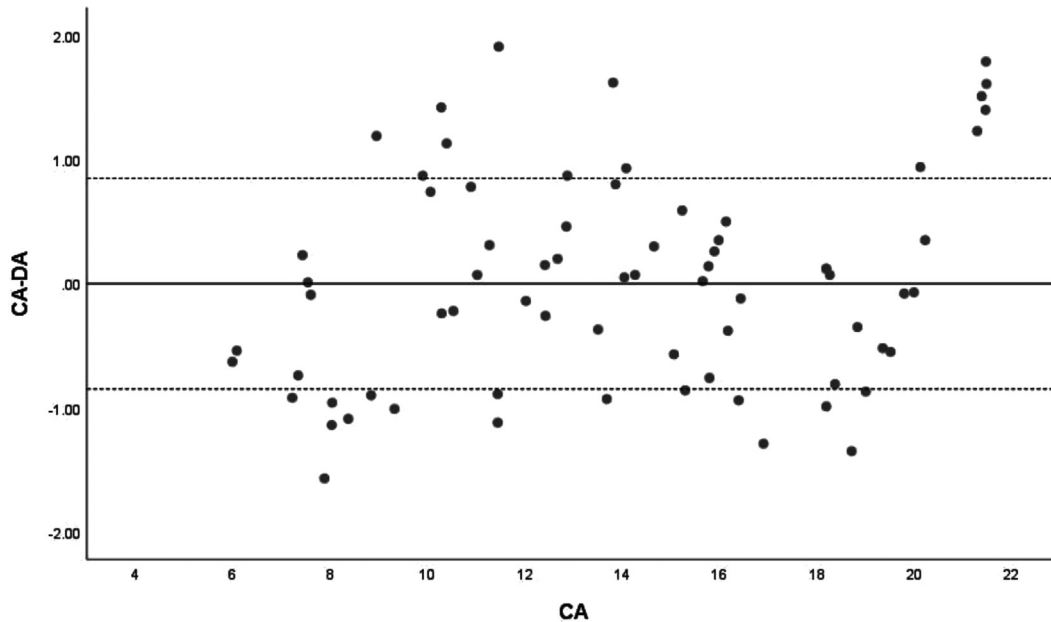
Figure 2. Bland-Altman plot for Chronological Age (CA) and Dental Age (DA) estimated from the southern Chinese reference dataset in females of low socioeconomic status.
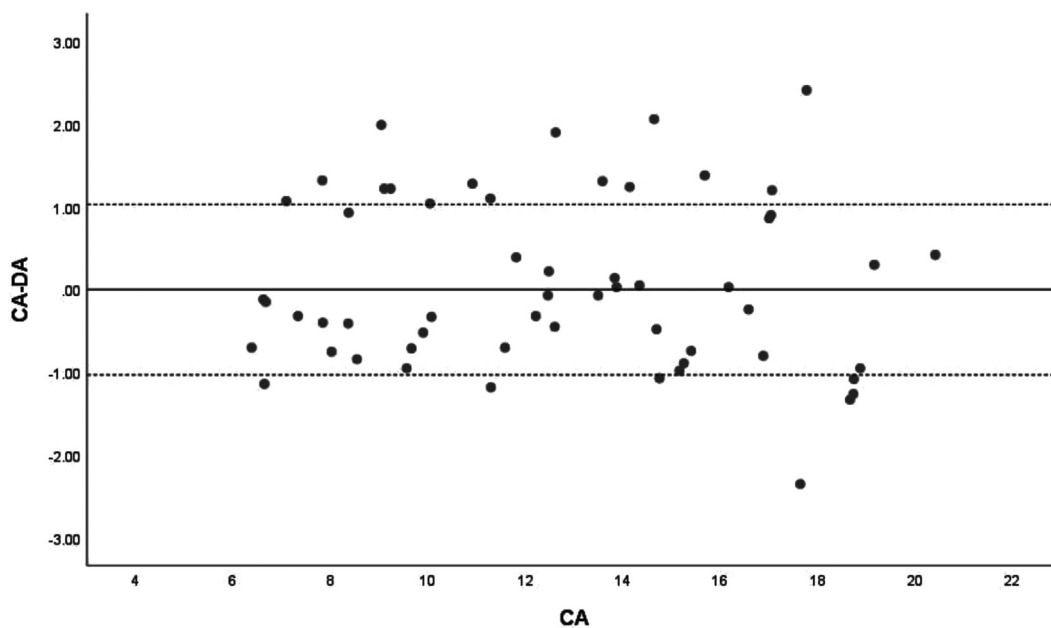
Figure 3. Bland-Altman plot for Chronological Age (CA) and Dental Age (DA) estimated from the southern Chinese reference dataset in males of low socioeconomic status.
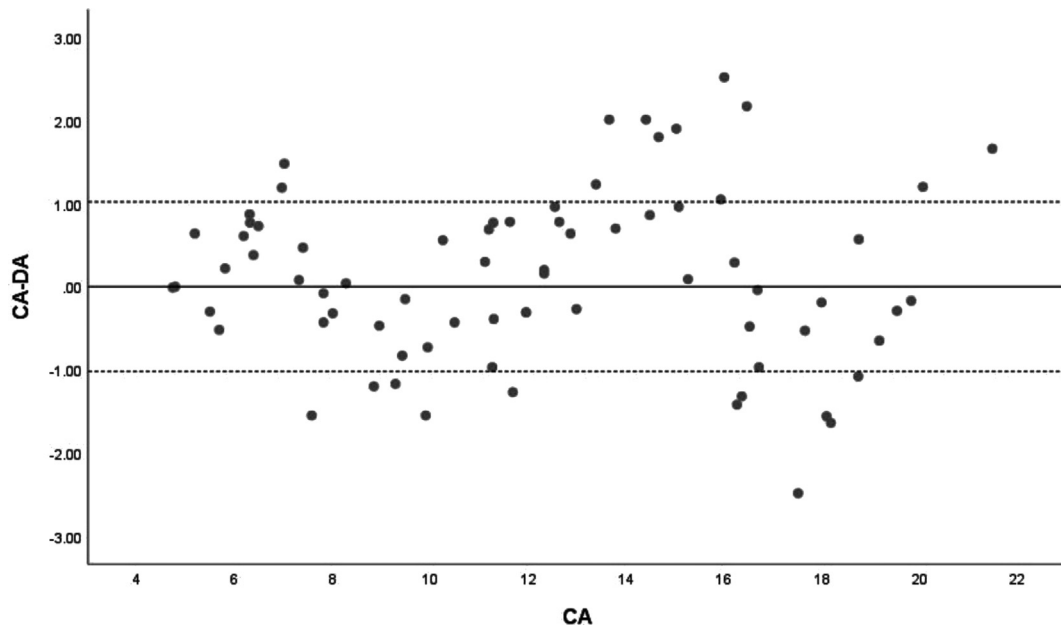
Figure 4. Bland-Altman plot for Chronological Age (CA) and Dental Age (DA) estimated from the southern Chinese reference dataset in males of high socio-economic status.
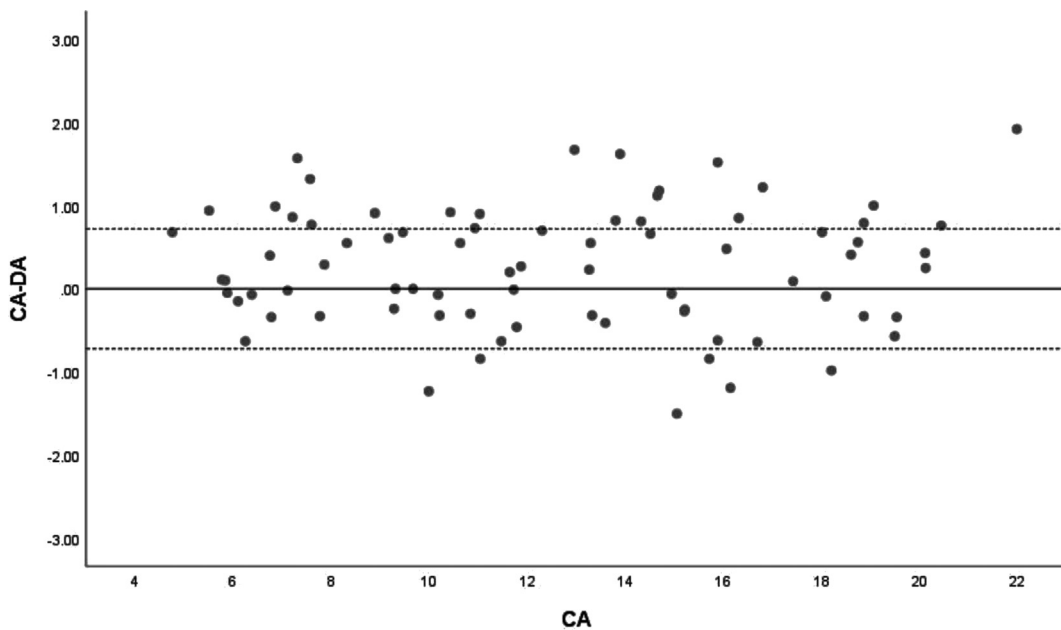

Figure 5. Bland-Altman plot for Chronological Age (CA) and Dental Age (DA) estimated from the southern Chinese reference dataset in females of high socio-economic status.

closely correlated. The difference was only -0.06 years for females and -0.10 years for males [27]. Jayaraman et al. reported that the Demirjian dataset overestimated the age of Chinese females by 0.65 years (-0.10 years–2.82 years) and males by 0.60 years (-0.23 years–3.04 years) [19].

In the present study, the southern Chinese reference dataset under-estimated the dental ages of Cambodian females and males in low and high SES whereas the studies of Wong et al. and Jayaraman et al. showed an overestimation [19, 27]. A systematic review and meta-analysis done on the French-Canadian data set of Demirjian reported that out of 34 studies on dental age estimation, two studies showed underestimation in male populations while one study showed underestimation in female populations [20]. The possible explanation for this may be related to socioeconomic status which has not been taken into account in previous

studies, but which was an important variable in the present study. However, the degrees of discrepancy between CA and DA for all subjects age in the Cambodian study were within an acceptable range as shown by the small magnitude of absolute difference between CA and DA.

Being the first study on age estimation in the Cambodian population, our findings suggest that the southern Chinese dental reference dataset was able to fairly accurately estimate the age of Cambodian males and females. This imparts further support to the relative reliability of using southern Chinese reference dataset to estimate the age of Cambodian children and young people of lower and higher SES. Analysis of the Bland-Altman plots revealed that especially in the males of high SES, points representing participants of younger ages appeared less distributed around the line of mean difference than points representing older participants. Tomas et al. showed

that Demirjian was unable to predict age in adults and its prediction decreased with age [28]. Similarly, Birchler et al. reported that dental age was estimated with less precision for older participants and Urzel and Bruzek cautioned against age estimation for individuals aged over 14 years [29, 30]. The most plausible reason might be that because there are fewer developing teeth in older individuals available for scoring, there is less data to use for estimating their age. In addition, larger differences between their chronological age and estimated age are seen in older individuals due to the higher degree of variability in tooth development compared with children [31]. With this in mind, the present study included both maxillary and mandibular left permanent teeth as well as third molars for age estimation to improve accuracy of age estimation for older individuals. The difference between CA-DA in Cambodian males and females in the high SES group was 0.11 years and 0.26 years respectively. This finding is similar to a study that compared the southern Chinese dataset on northern Chinese males and females and found the CA-DA differences to be 0.10 years and 0.06 years respectively [27]. In southern Chinese, the UK Caucasian dataset estimated the age difference (CA-DA) to be 0.25 years for males and 0.23 years for females [19]. At a practical level, the southern Chinese dataset can be used to estimate the age of Cambodian children and young people without authentic birth documentation, particularly for those involved in anti-social or illegal activities.

This study has a few limitations. Firstly, the sampling frame included only patients attending the hospitals. This study involved a retrospective analysis of radiographs obtained from children and adolescents attending two large clinics in the capital city of Cambodia. The first was a dental school clinic whose client base is mainly low-income families including many children from non-governmental organizations who were provided with free treatment. The other clinic was a large private dental hospital frequented by wealthy Cambodians where the cost of treatment is more than double the price at the university clinic. Hence we believe it is reasonable to categorize the two groups as being "lower socioeconomic status" and "higher socioeconomic status. However, possible selection bias cannot be completely ruled out. In addition, the very poor were probably not represented in the sample, since generally they do not attend the dentist, and do not have panoramic radiographs taken. Secondly, this study used a relatively small sample size for the age by sex categories. Despite the small magnitude of absolute difference between CA and DA, this resulted in relatively large boundary values for the 95% limits of agreement and SEM. However, a sub-group analysis based on age cohorts for males and females of low and high SES could be useful to evaluate the application of the reference dataset to specific age ranges. We could not conduct this due to limited sample size. Further studies with a larger sample size to look into the stability of using this reference data set in both sexes and each age range may be warranted. Thirdly, only the southern Chinese reference dataset was used in the present study due to ethnic similarity. Other methods such as the Willems method, Nolla's method, and the Cameriere's method could be tested for accuracy [32, 33, 34] to assess the need for construction of population specific reference standards for Cambodian population.

5. Conclusions

This study found that for Cambodian children and young adults, the difference between the chronological age and dental age estimated from the southern Chinese reference dataset was small. Therefore, it can be concluded that the southern Chinese reference dataset can be used to estimate the age of undocumented Cambodian children and young adults from both lower and higher socioeconomic status.

Declarations

Author contribution statement

L. Kar May and A. Mei Shian: Performed the experiments; Wrote the paper.

C. Durward: Analyzed and interpreted the data; Wrote the paper.

J. Jayaraman: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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