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Comparison of two methods of dental age estimation in 7–15-year-old Malays

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Background. Numerous methods of age estimation have been proposed. The Demirjian method is the most frequently used, which was first applied in a French Canadian population in 1973. The Willems method is a modification of the above and was applied in a Belgian population in 2002.

Objectives. The objectives of this study were to test the applicability of the two methods, namely Demirjian and Willems, for age estimation in a Malay population, and to find the correlation between body mass index and the difference between the dental age and the chronological age.

Materials and Methods. A cross-sectional study involving 214 boys and 214 girls, selected by a simple stratified random sampling method was carried out. The orthopantomograph was used to score the seven left mandibular teeth, and the calculated maturity score was used to obtain the Demirjian dental age. Willems dental age was estimated using the tables proposed in the Willems method.

Results. The Demirjian method overestimated the age by 0.75 and 0.61 years, while the Willems method overestimated the age by 0.55 and 0.41 years among boys and girls, respectively. In boys, the body mass index was significantly correlated to the difference in age using the Willems method.

Conclusion. Further modification of either method is indicated for dental age estimation among the Malay population.

Introduction

The importance of age determination pertains to many fields including treatment planning in orthodontics and paediatric dentistry, as well as in individuals who provide inaccurate details of age as in cases of illegal immigrants and in corpses of unknown identity[1].

The aim of an ideal age estimation technique is to arrive at an age as close to the chronological age as possible. Various age estimation methods have been tested and reported in the literature. In children and adolescents, somatic development, such as skeletal maturity, height, menarche, etc., has been used to assess the age when unknown. Dental age estimation has gained acceptance because it is less variable when compared to other skeletal and sexual maturity indicators[2].

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The two major approaches to dental age estimation are age of tooth eruption and pattern of tooth development[3]. Age of tooth eruption was widely accepted earlier, but now considered imprecise, because eruption is an ongoing process that includes periods in the life of a child when no tooth erupts into the oral cavity[4]. It is also affected by a number of local factors, such as premature extraction of primary teeth or crowding of permanent teeth[5]. Alternatively, the development of teeth using radiographs can be assessed over long periods of time, in a continuous pattern, using different stages of tooth formation as criteria[6].

Among many proposed methods, the Demirjian system of age assessment has been widely accepted[7,8]. The advantages of the Demirjian method include the objective criteria describing stages of tooth development, which have been illustrated with line diagrams and radiographic images in a clear-cut manner.

Numerous studies have been done in recent years using the Demirjian method in various populations[4,9–16]. A considerable number of

studies, however, have reported overestimation and inaccuracy of its use in their respective populations[4,9,10,12,13,17,18]. Willems *et al*.[18] modified the Demirjian technique by creating new tables, from which a maturity score could be directly expressed in years. The cumbersome step of conversion of maturity score to dental age was deleted, making it simpler, yet retaining the advantages of the Demirjian technique. They also found that this method reduced the overestimation of dental age, which was not statistically different from zero in a Belgian population[18]. This method was also adapted by Maber *et al*.[19], who found the estimated dental age to be more accurate than the Demirjian method.

The objectives of this study were to test the applicability of both the Demirjian and Willems methods in a Malay population, and to find the correlation between body mass index (BMI) and the difference between the dental age and the chronological age.

Subjects and methods

Selection criteria of subjects

This cross-sectional study involved 428 Malay children aged 7–15 years (214 boys and 214 girls). The children were selected from nine schools (six primary and three secondary schools) in Kota Bharu, Kelantan, using a simple age-stratified random sampling method from February to November 2006. Initial screening was done to satisfy the selection criteria, namely children (i) of Malay descent and having parents of the same ethnicity; (ii) with no medical history of systemic diseases/disorders; (iii) with no idiopathic short stature; (iv) with no gross malocclusion, which could modify the image on the radiograph; and (v) with no missing left mandibular teeth. Those children who did not satisfy the inclusion criteria were excluded from the study. Following the selection, written informed consent was obtained from the parents. A brief questionnaire was handed out to the parents to be completed and returned, to record the demographic characteristics. The children were brought to the Hospital Universiti Sains Malaysia (USM), where a complete dental charting was done, height and weight were recorded, and orthopantomographs (OPG) were taken.

Sample size determination

Sample size was initially estimated as 33 for each age group using single mean estimation with standard deviation (SD) of 14 units[16] in maturity score and precision of 5 units. Because of certain technical difficulties in obtaining OPG, however, the minimum sample size was 18 in two age groups. Hence, a review of sample size was done using the study data by comparing two related means (paired *t*-test) using PS software 2.1.31[20] with the largest SD of 1.45 years in age difference (between chronological age and Willems age; 12 years age group; girls). It was then concluded that there should be at least 19 children in order to detect the difference of 1 year between the chronological age and the dental age. Therefore, only the two age groups (i.e., boys aged 7 and girls aged 8 years) were below the minimum sample size.

Dental age and chronological age

All OPGs were scored by the first author using the criteria set by Demirjian *et al*.[8] The seven mandibular left teeth excluding the third molar were scored; '0' for absence of calcification, and 'A' to 'H', depending on the stage of calcification. The scores for boys and girls were converted to weighted scores and then added together to obtain the maturity score. The dental age was estimated by using the maturity graphs. The graphs were enlarged five times to get accurate values. The value thus obtained was termed *dental age* using the Demirjian method.

The dental age was also estimated by the Willems method, using the tables given by Willems *et al*.[18] The age obtained by this method was termed *dental age* using the Willems method.

The chronological ages of the children were estimated by the difference between date of birth and date at which the radiograph was taken, and converted to years with two decimals.

Table 1. Characterization of the children.

	Boys		Girls	
Variable	**Mean (SD)**	**(Minimum, maximum)**	**Mean (SD)**	**(Minimum, maximum)**
Age (year)	11.3 (02.55)	(006.9, 015.3)	11.2 (02.54)	(006.8, 015.2)
Height (cm)	143.9 (16.33)	(115.0, 175.5)	140.7 (14.87)	(113.7, 166.4)
Weight (kg)	37.2 (16.42)	(016.0, 105.0)	37.2 (17.10)	(007.2, 159.0)

SD, standard deviation.

Correlation with BMI

The BMIs (kg/m^2) of the subjects were compared to the age difference between the dental age (obtained by the Demirjian method or the Willems method) and the chronological age.

Intra- and interexaminer variability

Thirty radiographs were scored by the first author twice in an interval of 1 week. The same 30 X-rays were also scored by another examiner after calibration. The inter- and intraexaminer variations were tested using intraclass correlation coefficient (ICC) for repeated maturity scores, and found to be 0.985 and 0.952, respectively, both of which were considered highly reliable.

Statistical analysis

SPSS 12.0 for Windows (SPSS, Inc., Chicago, IL)[21] was used for all analyses. The differences between the chronological age and the estimated dental age were statistically tested using both paired *t*-test and Wilcoxon signed rank test. As the sample size was less than 30 and having non-normal distribution in some age groups, non-parametric test (Wilcoxon signed rank test) was indicated. To be consistent across the age groups, however, we applied both parametric and non-parametric tests. In all the tests, $P < 0.05$ was considered statistically significant. In addition, the correlation between the chronological and the dental age was obtained by using ICC. Pearson's correlation was used to examine the correlation between BMI and the difference between the dental age and the chronological age.

Ethical issues

The project was approved by the ethics committee of the USM. In addition, written informed consent was taken from all parents of children involved in this study.

Results

The subjects were grouped into nine age groups of 1 year, starting from 7 until 15 years, after converting the chronological age into decimal. Those classified as age 7 included those between ages 6.5 and 7.49, and similarly for other age groups. Table 1 shows the mean and SD of age, height, and weight of the boys and girls. The distribution of the 428 subjects (214 boys and 214 girls) in each age group can be seen in Tables 2 and 3.

Demirjian method

Tables 2 and 3 compare the chronological age and the dental age using the Demirjian method in boys and girls, respectively. The mean age difference was 0.75 (SD = 1.01) in boys and 0.61 (SD = 1.09) in girls. It can be noted that in most of the subgroups, there were statistically significant differences between the chronological age and the dental age. The maximum difference which was an overestimation was seen in the 10, 11, and 12 years age groups in boys, and 9, 10, and 11 years age groups in girls. Underestimation of age was uncommon and seen only in the 15 years age group in boys, and in the 14 and 15 years age groups in girls.

Figures 1 and 2 show the distribution of dental age compared to the chronological age in boys and girls, respectively. A majority of the scores show an overestimation.

Table 2. Comparison between dental age using the Demirjian method and chronological age (in years) among boys.

Age (*n*)	Mean (SD)			95% CI of age difference*	*t* Statistics† (d.f.)	*P* value†	*P* value‡
	Chronological age	Dental age	Age difference*				
7 (18)	7.11 (0.15)	7.91 (0.87)	0.80 (0.76)	(0.43, 1.18)	4.48 (17)	< 0.001	0.001
8 (21)	8.02 (0.14)	8.46 (0.56)	0.44 (0.52)	(0.20, 0.67)	3.89 (20)	0.001	0.001
9 (25)	9.02 (0.13)	9.50 (1.27)	0.48 (1.24)	(–0.03, 0.99)	1.93 (24)	0.065	0.098
10 (25)	9.98 (0.14)	11.38 (1.39)	1.41 (1.30)	(0.88, 1.95)	5.43 (24)	< 0.001	< 0.001
11 (25)	11.07 (0.17)	12.67 (1.03)	1.60 (0.98)	(1.19, 2.00)	8.17 (24)	< 0.001	< 0.001
12 (24)	12.03 (0.15)	13.32 (0.73)	1.29 (0.71)	(1.00, 0.74)	8.90 (23)	< 0.001	< 0.001
13 (25)	13.12 (0.13)	13.75 (0.55)	0.63 (0.51)	(0.42, 0.84)	6.14 (24)	< 0.001	< 0.001
14 (25)	14.07 (0.10)	14.50 (0.58)	0.42 (0.55)	(0.19, 0.64)	3.8 (24)	0.001	0.002
15 (26)	15.10 (0.12)	14.77 (0.42)	–0.33 (0.40)	(–0.49, –0.16)	–4.15 (25)	< 0.001	< 0.001
Total (214)	11.26 (2.55)	12.00 (2.54)	0.75 (1.01)	(0.61, 0.88)	10.78 (213)	< 0.001	< 0.001

*Dental age minus chronological age.
†Paired *t*-test.
‡Wilcoxon signed rank test.
CI, confidence interval; SD, standard deviation.

Table 3. Comparison between dental age using the Demirjian method and chronological age (in years) among girls.

Age (*n*)	Mean (SD)			95% CI of age difference*	*t* Statistics† (d.f.)	*P* value†	*P* value‡
	Chronological age	Dental age	Age difference*				
7 (23)	7.02 (0.13)	7.46 (0.57)	0.44 (0.52)	(0.21, 0.67)	4.04 (22)	0.001	0.001
8 (18)	8.11 (0.14)	8.73 (0.98)	0.62 (0.99)	(0.13, 1.11)	2.65 (17)	0.017	0.025
9 (24)	9.06 (0.14)	10.36 (1.31)	1.30 (1.25)	(0.77, 1.83)	5.09 (23)	< 0.001	< 0.001
10 (25)	10.06 (0.16)	11.61 (1.21)	1.55 (1.17)	(1.07, 2.03)	6.64 (24)	< 0.001	< 0.001
11 (25)	10.89 (0.13)	12.02 (0.98)	1.14 (0.92)	(0.76, 1.52)	6.16 (24)	< 0.001	< 0.001
12 (25)	11.95 (0.12)	12.81 (0.19)	0.86 (0.91)	(0.49, 1.24)	4.74 (24)	< 0.001	0.001
13 (25)	13.04 (0.12)	13.60 (0.34)	0.56 (0.33)	(0.43, 0.70)	8.53 (24)	< 0.001	< 0.001
14 (25)	14.02 (0.13)	13.96 (0.34)	–0.05 (0.31)	(–0.18, 0.08)	–0.76 (24)	0.457	0.443
15 (24)	15.03 (0.10)	14.03 (0.32)	–1.00 (0.35)	(–1.15, –0.86)	–14.16 (23)	< 0.001	< 0.001
Total (214)	11.14 (2.54)	11.75 (2.32)	0.61 (1.09)	(0.46, 0.75)	8.11 (213)	< 0.001	< 0.001

*Dental age minus chronological age.
†Paired *t*-test.
‡Wilcoxon signed rank test.
CI, confidence interval; SD, standard deviation.

Willems method

Tables 4 and 5 show the comparison between the chronological age and the dental age using the Willems method. It can be seen that there is no statistical significance between the dental age and the chronological age in 9, 13, and 15 years subgroups among boys, and in 7, 8, 11, 12, and 15 years subgroups among girls. The mean age difference is statistically significant, resulting from an overestimation, which was less than that seen using the Demirjian method.

Figures 3 and 4 show the distribution of dental age compared to the chronological age in boys and girls, respectively. The overestimation is almost comparable between all age groups.

Comparison between Demirjians method and Willems method

Table 6 shows the agreement between chronological age and dental age using the Demirjian and Willems methods. The Willems method estimated age more accurately than the Demirjian method.

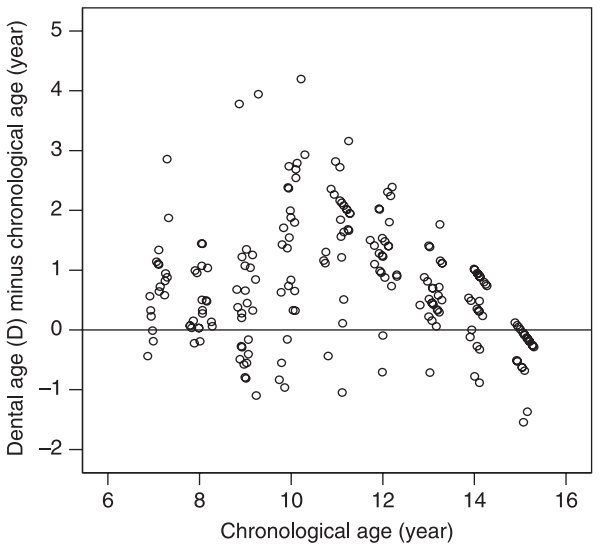

Fig. 1. Accuracy of dental age (Demirjian method) among boys.

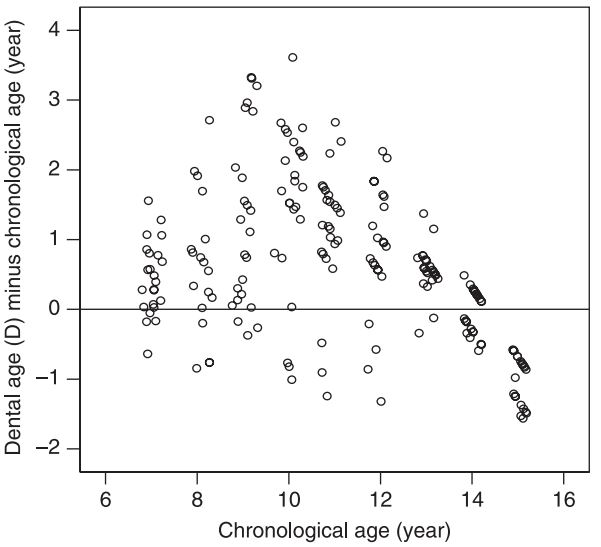

Fig. 2. Accuracy of dental age (Demirjian method) among girls.

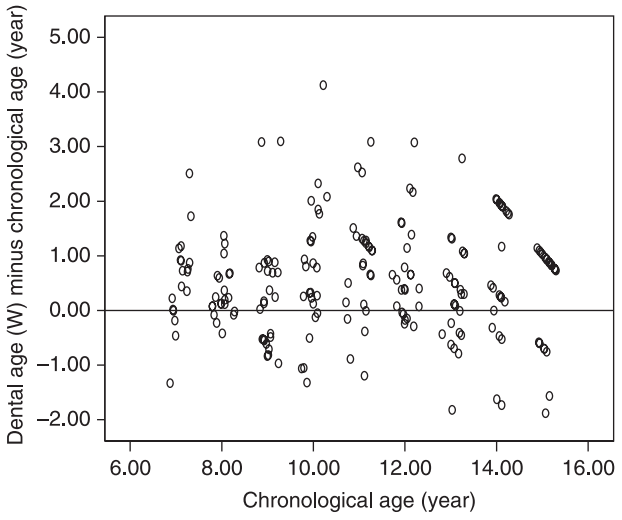

Fig. 3. Accuracy of dental age (Willems method) among boys.

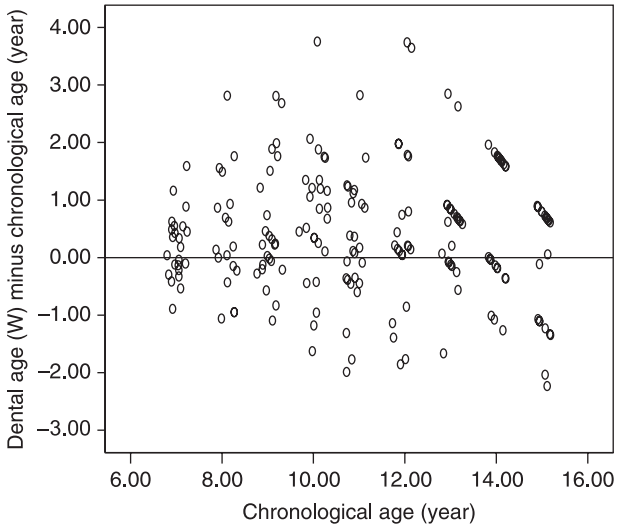

Fig. 4. Accuracy of dental age (Willems method) among girls.

BMI and age difference

Among boys, the BMI was statistically correlated to the difference between the dental age and the chronological age using the Willems method ($r = 0.15$; $P = 0.025$). There was no such correlation, however, using the Demirjian method among boys, and by both methods among girls.

Discussion

Peninsular Malaysia has a population of mixed ethnicity, the majority consisting of Malays (54.1%), Chinese (25.4%), and Indians (7.5%), and the remaining constituting minor ethnic groups and foreigners[22]. The study sample, however, involved only Malays, who also form the majority in the state of

Table 4. Comparison between dental age using the Willems method and chronological age (in years) among boys.

Age (*n*)	Mean (SD)			95% CI of age difference*	*t* Statistics† (d.f.)	*P* value†	*P* value‡
	Chronological age	Dental age	Age difference*				
7 (18)	7.11 (0.15)	7.69 (0.96)	0.58 (0.85)	(0.16, 1.01)	2.91 (17)	0.010	0.011
8 (21)	8.02 (0.14)	8.35 (0.51)	0.33 (0.47)	(0.12, 0.54)	3.22 (20)	0.004	0.005
9 (25)	9.02 (0.13)	9.30 (1.08)	0.28 (1.06)	(–0.15, 0.72)	1.34 (24)	0.192	0.288
10 (25)	9.98 (0.14)	10.73 (1.31)	0.75 (1.22)	(0.25, 1.26)	3.09 (24)	0.005	0.006
11 (25)	11.07 (0.17)	11.94 (1.07)	0.87 (1.01)	(0.46, 1.29)	4.33 (24)	< 0.001	0.001
12 (24)	12.03 (0.15)	12.75 (0.93)	0.72 (0.89)	(0.34, 1.09)	3.97 (23)	0.001	0.001
13 (25)	13.12 (0.13)	13.39 (0.95)	0.27 (0.91)	(–0.11, 0.64)	1.46 (24)	0.153	0.158
14 (25)	14.07 (0.10)	14.86 (1.21)	0.78 (1.17)	(0.29, 1.27)	3.32 (24)	0.003	0.004
15 (26)	15.10 (0.12)	15.44 (0.94)	0.34 (0.91)	(–0.03, –0.71)	1.92 (25)	0.067	0.010
Total (214)	11.26 (2.55)	11.81 (2.76)	0.55 (0.99)	(0.42, 0.68)	8.15 (213)	< 0.001	< 0.001

*Dental age minus chronological age.
†Paired *t*-test.
‡Wilcoxon signed rank test.
CI, confidence interval; SD, standard deviation.

Table 5. Comparison between dental age using the Willems method and chronological age (in years) among girls.

Age (*n*)	Mean (SD)			95% CI of age difference*	*t* Statistics† (d.f.)	*P* value†	*P* value‡
	Chronological age	Dental age	Age difference*				
7 (23)	7.02 (0.13)	7.22 (0.62)	0.20 (0.57)	(–0.05, 0.45)	1.67 (22)	0.110	0.114
8 (18)	8.11 (0.14)	8.52 (1.02)	0.41 (1.04)	(–0.11, 0.96)	1.66 (17)	0.114	0.214
9 (24)	9.06 (0.14)	9.60 (1.12)	0.55 (1.06)	(0.10, 0.99)	2.51 (23)	0.019	0.034
10 (25)	10.06 (0.16)	10.79 (1.19)	0.73 (1.14)	(0.26, 1.21)	3.19 (24)	0.004	0.005
11 (25)	10.89 (0.13)	11.10 (1.15)	0.26 (1.09)	(–0.23, 0.66)	0.99 (24)	0.331	0.397
12 (25)	11.95 (0.12)	12.47 (1.50)	0.52 (1.45)	(–0.08, 1.12)	1.80 (24)	0.084	0.032
13 (25)	13.04 (0.12)	13.54 (0.93)	0.50 (0.90)	(0.13, 0.87)	2.76 (24)	0.011	0.006
14 (25)	14.02 (0.13)	14.66 (1.15)	0.64 (1.11)	(0.18, 1.09)	2.88 (24)	0.008	0.051
15 (24)	15.03 (0.10)	14.92 (1.06)	–0.11 (1.07)	(–0.57, 0.34)	–0.53 (23)	0.605	0.361
Total (214)	11.14 (2.54)	11.55 (2.74)	0.41 (1.08)	(0.26, 0.55)	5.51 (213)	< 0.001	< 0.001

*Dental age minus chronological age.
†Paired *t*-test.
‡Wilcoxon signed rank test.
CI, confidence interval; SD, standard deviation.

Table 6. Agreement between chronological age and the two age-estimation methods among boys and girls.

Sex	ICC^d (95% CI)	ICC^w (95% CI)
Boys	0.88 (0.66, 0.95)	0.91 (0.82, 0.95)
Girls	0.87 (0.75, 0.92)	0.91 (0.86, 0.94)

CI, confidence interval; ICC, intraclass correlation coefficient; ICC^d, agreement between chronological age and dental age using the Demirjian method; ICC^w, agreement between chronological age and dental age using the Willems method.

Kelantan, which was the location of the study. This was done to ensure ethnic uniformity of the study sample, considering that the development of teeth varies among populations[3,16], and that it is genetically determined[23]. In addition, a simple age-stratified random sampling method was used to ensure a good representation of the population.

OPG is considered the best tool for age estimation in children[24], because intraoral radiography is difficult to obtain in children without image distortion. Wood[25] argued that OPG being a tomograph can result in teeth, especially those tilted in a buccolingual direction, falling out of the focal trough, resulting in misestimation of age. To overcome this disadvantage, all cases were screened for severe malocclusion and tilting of teeth. Most retrospective studies, however, do not allow for this kind of case selection.

One study evaluating the different age estimation methods has observed that the Demirjian method was the most reliable, because of high accuracy and precision especially in the younger age group[26]. However, considering the mean age difference between the chronological age and the estimated dental age, other studies have revealed statistically significant differences of 0.73 and 0.51 years[12], 0.68 and 0.62 years[10], 0.4 and 0.6 years[4], and 0.25 and 0.23 years[19] in boys and girls, respectively. The authors have also pointed out that the Demirjian standards are inapplicable in their respective population. In our study, a difference of 0.75 years in boys, and 0.61 years in girls was similar to previous studies. Having expected these results, it seemed redundant to test only the Demirjian method in our population.

An important factor that influences reproducibility is the choice of tooth stage assessment[19]. The Demirjian method is found to have good reproducibility, and the Willems method, a modification of the former, is found to be more accurate than the Demirjian method[18,19]. Hence, our choice for a second method of age assessment was the Willems method. Using this method, our study found an overestimation of 0.55 and 0.41 years among boys and girls, respectively, which was statistically significant. In the original study in a Belgian population, Willems *et al.*[18] found this method to overestimate age, but it was not statistically significant. The results of this study were in contrast to those of Maber *et al.*[19], who found an overall underestimation of age using the Willems method in their population.

It is clear that the age was overestimated for the majority of the children with the maximum in the 10–12 years age groups in boys, and in the 9–11 years age groups in girls. Similar findings have also been noted by others[24,27], whereas Leurs *et al.*[4] found a significant difference in the 5–10 years age groups. Eid *et al.*, however, found the overestimation to be greater in the older children[10], and Koshy and Tandon also found a greater overestimation in the 12–15 years age groups[13]. Thus, some studies, including this study, show an increased overestimation of age almost preceding the onset of pubertal changes, which probably reflects a sudden spurt in growth of dental tissues also, along with the overall growth. It is also a well-established fact that puberty sets in earlier among girls which may explain the overestimation of age in girls marginally earlier than in boys. Furthermore, varying degrees of underestimation of age noticed among both boys and girls of higher age groups by both methods also indicate that dental growth is not a steady and uniform process, but associated with para-pubertal speed fluctuations.

Farah *et al.*[24] claimed that the probability of predicting accurate age using the Demirjian method is 51.7% in girls and 56.4% in boys, and considered this to be good. In our study, the reliability of predicting the accurate chronological age in boys and in girls was 88% and 87%, respectively. Eid *et al.*[10] also found similar values in their study.

The fact that there was a significant difference when dental age was estimated using the Demirjian method may imply that either there has been a positive secular trend in growth over the 30 years since the standards have been published in a French Canadian population or that the standards cannot be applied to other populations. A positive secular trend has been supported by other studies[12,28,29]. Such a reason, however, implies that recently created standards, like the Willems method, should be applicable in other populations. Our study clearly shows that there is a statistical difference when using the Willems method of age estimation. Hence, based on our findings, it is unlikely that the overestimation is because of a positive secular trend. Conversely, it may be more appropriate to assume that the Demirjian method may not be applicable to all populations. Liversidge *et al.*[12] refuted that the Demirjian standards vary between populations, when they noted that both Caucasians and Bangladeshi children had similar standards of tooth development. This hypothesis can be appropriately studied further in a multiracial population like Malaysia, where all races have inhabited a similar environment for generations. In our study, we noted that neither method of age estimation was appropriate for a Malay population, an indication that population standards specific for Malays are needed.

The significance of a positive correlation between the BMI and the overestimation of

age using the Willems method in boys points to the possibility of an accelerated dental growth with overweight. This is not a convincing observation, however, as the girls did not show a similar correlation by either method. A Brazilian study[10] showed no correlation, while Hilgers *et al*.[30] stated that accelerated dental development is seen in overweight children. Hence, any role of BMI in this respect remains rather speculative.

The limitations of this study include the cross-sectional nature and the limited number of subjects selected from one area. Additionally, this approach to determine dental age may be questioned because of the marked variation in dental age reported in children with the same chronological age[31]. The inconsistency of the examiner's assessment can be contributory to varied results[15]. Hence, the authors would recommend that newer standards be established for a Malay population, using larger samples to establish better accuracy in age determination.

What this paper adds

- A study on the development of permanent teeth in Malay children has not been published so far.
- The Willems method of age determination is easier to calculate and more accurate compared to the Demirjian method. It should be tested in additional populations to verify its applicability.

Why this paper is important to paediatric dentists

- Standards of tooth development vary among populations, and this should be kept in mind when treating children.

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