

## Dental age assessment in 7–14-year-old Chinese children: Comparison of Demirjian and Willems methods



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### ABSTRACT

Several approaches have proven to be valuable in estimating dental age in children. The Demirjian method, based on crown and root calcification, is the most frequently used tool. The Willems method is a modification of the Demirjian method. There are few studies regarding to compare the application of the two methods in China. This study aims to apply the two methods in a Han population as well as identify if there are some differences between two methods in estimating dental age versus chronological age. Nine hundred forty-one orthopantomograms of 410 boys and 531 girls between seven and 14 years of age were selected from our patient records database with defined standard, and the Demirjian and Willems methods of dental age estimation were applied. The seven left mandibular teeth were scored and calculated in order to obtain the Demirjian and Willems estimated dental ages. It is suggested that the Demirjian method overestimated chronological age by 1.68 years for boys and 1.28 years for girls. The discrepancy between the Demirjian estimate and the chronological age was most frequently observed between 1 and 3.5 years for boys and between 1 and 2 years for girls. While it is indicated that the Willems method overestimated chronological age by 0.35 years for boys and underestimated the age by 0.02 years for girls. The discrepancy between chronological age and Willems estimated age was most frequently observed between –0.5 and 0.5 years for boys and between –1 and 0.5 years for girls. It is demonstrated that the Willems method was more accurate in estimating dental age than the Demirjian method, with a mean absolute error of 0.98 years for boys and 0.93 years for girls. As a result, it is highly recommended that the Willems method should be applied when estimating dental age in Chinese Han population, further modifications to the method are suggested.

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## 1. Introduction

Dental age estimation has a long history, because dental maturation is less variable [1–4] and more free of ethnic differences [5] than other features of human beings. The Demirjian dental age assessment system was first described in 1973 based on a large sample of French-Canadian children [6], evaluating the developmental stage and maturity score of the seven left mandibular permanent teeth on panoramic radiographs. Total

maturity scores are calculated by gender, then converted to dental age according to the Demirjian table [7].

Numerous studies of the Demirjian method in various populations have been undertaken in recent years. However, a significant and consistent overestimation of chronological age has been reported [8–11]. A meta-analysis recently showed that the Demirjian method averaged overestimated the age of girls by 0.65 years (–0.10 years to +2.82 years) and boys by 0.60 years (–0.23 years to +3.04 years) [8]. Willems et al. [12] consequently modified the Demirjian technique in a Belgian population and simplified the calculation steps, resulted in a smaller overestimation of 0.0 years for boys and 0.2 years for girls. Several studies also found that the Willems method was more accurate than the Demirjian method [10,13–15]. However, there are very limited studies been done on the application of the two dental age estimation methods in Chinese children. This study aims to apply the two methods in a

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Han population as well as identify if there are some differences between two methods in estimating dental age versus chronological age.

## 2. Materials and methods

### 2.1. Subjects

Nine hundred forty-one panoramic dental radiographs of children (410 boys and 531 girls, ages ranging from 7 to 14 years) were selected from the patient records database of the Oral and Maxillofacial Radiology Department of a teaching hospital affiliated with Shanghai Jiaotong University School of Medicine from June 2010 to October 2012. The panoramic radiographs were obtained using Kodak 8000-8000C X-ray equipment. Individuals of minority nationality origin, those with congenital or systemic diseases, and those with unclear orthopantomograms and aplasia of permanent mandibular teeth were excluded from the final sample.

Chronological age was determined by subtracting the birthdate from the date of the radiograph and was expressed as years with two decimal places. The sample was divided into eight groups of 1 year each, according to chronological age. Sample size determination for each group was estimated so that the minimum sample size was 19 for boys and eight for girls for each age group. The largest standard deviation (SD) in age difference was 0.96 years for boys and 0.69 years for girls between the Demirjian and Willems methods.

### 2.2. Methods

All orthopantomograms were scored according to the criteria of Demirjian et al. [6,7] and of Willems et al. [12]. The seven left mandibular teeth were scored. First, the stage of every tooth was classified as 'A' to 'H', according to the stage of calcification. Each score was converted into a dental age by gender, as described by Demirjian et al. [6,7] and Willems et al. [12]. All orthopantomograms were scored by two examiners. One hundred images were re-examined after 2 weeks by the same examiners.

Discrepancy between chronological age and estimated dental age were statistically analyzed using the paired *t*-test. The mean absolute error (MAE) was used to determine the accuracy of the two methods. Differences between the two methods were evaluated by subtracting chronological age from estimated dental age to yield minimum (largest underestimate) and maximum (largest overestimate) differences at the individual level. Quartiles were also calculated. The 1st (lowest quartile; 25th percentile) and 3rd (uppermost quartile; 75th percentile) quartiles were determined to concentrate on the data in the middle of the sample. The

**Table 1**

Agreement of developmental stage of permanent teeth of the left and right mandible.

Tooth	Agreement (%)	Kappa value	P value
I1	99.1	0.91	<0.001
I2	99.1	0.91	<0.001
C	99.3	0.94	<0.001
PM1	94.0	0.92	<0.001
PM2	95.1	0.92	<0.001
M1	97.9	0.94	<0.001
M2	93.0	0.90	<0.001

Kappa coefficient of agreement was used to evaluate intra-examiner and inter-examiner variation, and also the developmental stage of permanent teeth of the left and right mandible. All data were statistically analyzed by SPSS 17.0 for Windows (SPSS, Inc., Chicago, IL). *P* values less than 0.05 were considered statistically significant.

The research was approved by Shanghai Jiaotong University Xinhua Hospital Ethics Committee. All patient records and information were anonymous and de-identified prior to analysis.

## 3. Results

The mean chronological age of the children was  $12.15 \pm 1.81$  years (boys,  $11.94 \pm 1.90$  years and girls,  $12.34 \pm 1.69$  years). The distribution of the 941 subjects (410 boys and 531 girls) by age group is shown in Tables 2 and 3. The agreement of developmental stage of permanent teeth of the left and right mandible is showed in Table 1. The agreement of the intra-examiner and inter-examiner variation in dental age assessment for each tooth for all age groups combined was found to be more than 0.88.

### 3.1. Demirjian method

Tables 2 and 3 compare Demirjian dental ages and chronological ages of boys and girls, respectively. The mean age difference was 1.68 years (SD 1.29) for boys ( $P < 0.01$ ), and 1.28 years (SD 1.17) for girls ( $P < 0.01$ ). Obvious overestimation was found in children more than 10 years old, and boys had a higher overestimation than girls. The MEA was approximately 1–2 years in most age groups for both genders, with a mean of 1.83 years for boys and 1.48 years for girls. There was a significant difference in error between the boys and girls ( $t = 5.81$ ,  $P < 0.01$ ).

The discrepancy between dental age and chronological age are shown in Fig. 1. For the Demirjian method, the difference between the dental age and chronological age was most frequently observed between 1 and 3.5 years for boys and between 1 and 2 years for

**Table 2**

Comparison between Demirjian dental age and chronological age in boys (seven teeth, mandibular left side).

Age group	<i>n</i>	Mean (SD)			95% CI of age difference	<i>t</i> statistics (df)	<i>P</i> value <sup>b</sup>	MAE (year)
		Dental age	Chronological age	Age difference <sup>a</sup>				
7	19	8.13 (0.69)	7.64 (0.37)	0.49 (0.73)	0.13, 0.84	2.91 (18)	0.009	0.61
8	19	9.06 (1.46)	8.43 (0.35)	0.63 (1.27)	0.04, 1.23	2.21 (18)	0.039	0.95
9	32	10.02 (1.62)	9.45 (0.32)	0.58 (1.48)	0.04, 1.11	2.20 (31)	0.035	1.28
10	44	12.04 (1.74)	10.54 (0.29)	1.49 (1.71)	0.98, 2.01	5.87 (43)	0.000	1.86
11	62	13.75 (1.37)	11.55 (0.28)	2.21 (1.30)	1.88, 2.54	13.39 (61)	0.000	2.26
12	94	14.72 (1.16)	12.50 (0.28)	2.22 (1.08)	2.00, 2.44	19.95 (93)	0.000	2.24
13	85	15.32 (1.00)	13.45 (0.29)	1.86 (1.02)	1.64, 2.08	16.78 (84)	0.000	1.98
14	55	15.89 (0.35)	14.42 (0.27)	1.47 (0.44)	1.35, 1.58	24.69 (54)	0.000	1.48
Total	410	13.62 (2.59)	11.94 (1.90)	1.68 (1.29)	1.55, 1.80	26.40 (411)	0.000	1.83

CI: confidence interval.

<sup>a</sup> Dental age minus chronological age.

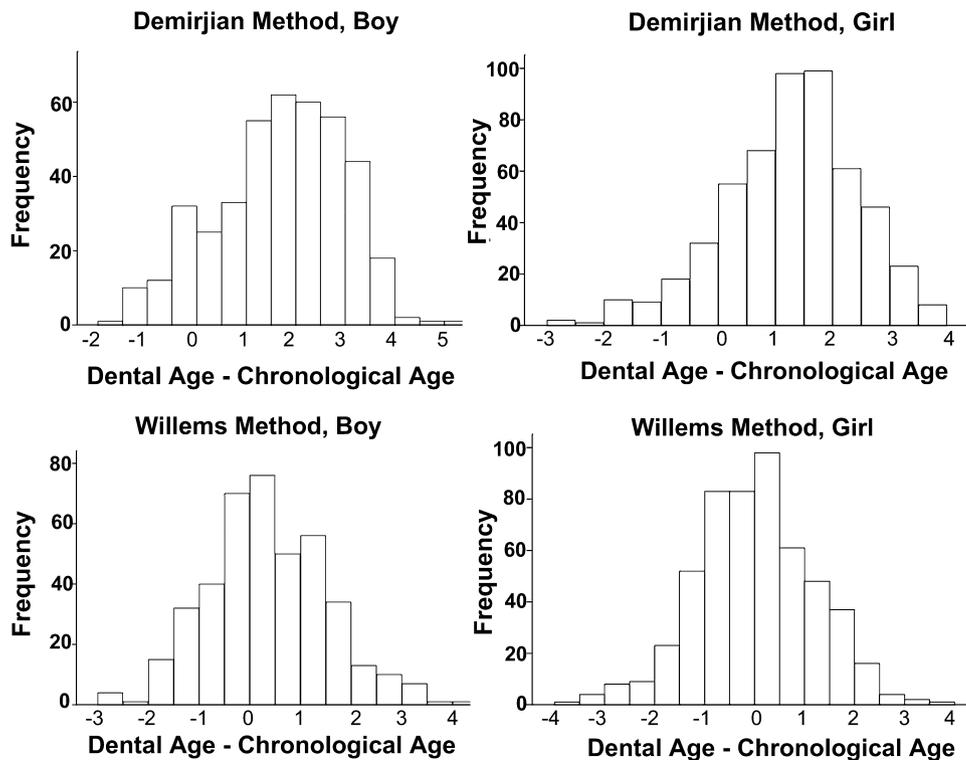
<sup>b</sup> Paired *t*-test.

**Table 3**

Comparison between Demirjian dental age and chronological age in girls (seven teeth, mandibular left side).

Age group	n	Mean (SD)			95% CI of age difference	t statistics (df)	P value <sup>b</sup>	MAE (year)
		Dental age	Chronological age	Age difference <sup>a</sup>				
7	11	7.68 (0.30)	7.50 (0.21)	0.18 (0.26)	0.01, 0.35	2.34 (10)	0.041	0.26
8	18	8.29 (0.92)	8.45 (0.30)	-0.17 (0.96)	-0.64, 0.31	-0.73 (17)	0.474	0.68
9	25	10.03 (1.39)	9.47 (0.37)	0.55 (1.47)	-0.06, 1.16	1.87 (24)	0.074	1.03
10	44	12.16 (1.48)	10.61 (0.26)	1.55 (1.40)	1.13, 1.98	7.34 (43)	0.000	1.76
11	94	13.29 (1.09)	11.64 (0.26)	1.65 (1.06)	1.44, 1.87	15.15 (93)	0.000	1.77
12	146	14.08 (1.17)	12.49 (0.28)	1.58 (1.14)	1.40, 1.77	16.81 (145)	0.000	1.70
13	105	14.80 (1.08)	13.51 (0.30)	1.29 (1.05)	1.08, 1.49	12.53 (104)	0.000	1.47
14	88	15.38 (0.81)	14.49 (0.29)	0.89 (0.83)	0.71, 1.06	9.99 (87)	0.000	1.12
Total	531	13.62 (2.14)	12.34 (1.69)	1.28 (1.17)	1.18, 1.38	25.21 (530)	0.000	1.48

CI: confidence interval.

<sup>a</sup> Dental age minus chronological age.<sup>b</sup> Paired *t*-test.**Fig. 1.** Difference between dental age and chronological age using Demirjian and Willems method.

girls. For boys, the largest age underestimation was 2.0 years and the largest overestimation was 5.5 years (1st quartile = 1.0, mean = 2.0, 3rd quartile = 3.0). For girls, the largest over- and underestimations were 3.0 and 4.0 years, respectively (1st quartile = 1.0, mean = 1.5, 3rd quartile = 2.5).

### 3.2. Willems method

Tables 4 and 5 compare Willems dental ages and chronological ages of boys and girls, respectively. The mean difference for boys was 0.36 years (SD 1.19,  $P < 0.01$ ), and for girls was -0.02 years (SD 1.18,  $P > 0.05$ ). The MAE was approximately one year in most age groups for both genders, with a mean of 0.98 years for boys and 0.93 years for girls. There was no significant difference in error between boys and girls ( $t = 0.89$ ,  $P = 0.37$ ).

Discrepancy between dental age and chronological age are shown in Fig. 1. For the Willems method, the difference between

chronological and dental ages was most frequently observed between -0.5 and 0.5 years for boys and between -1.0 and 0.5 years for girls. For boys, the largest under- and overestimation of age were 3.0 and 4.5 years, respectively (1st quartile = -0.5; mean = 0.5; 3rd quartile = 1.5). For girls, the largest under- and overestimation was 4.0 years (1st quartile = -1.0; mean = 0.5; 3rd quartile = 1.0).

### 3.3. Comparison between Demirjian method and Willems method

The difference between the Demirjian dental age and the Willems dental age was 1.31 years (SD 0.99) for boys and 1.27 years (SD 0.61) for girls ( $P < 0.01$ ). Fig. 2 shows that the Demirjian method yielded obvious overestimation compared with chronological age in several age groups, especially for children older than 10 of both genders. In contrast, the Willems method resulted in less obvious overestimation. We also compared the MAE for the two

**Table 4**

Comparison between Willems dental age and chronological age in boys (seven teeth, mandibular left side).

Age group	n	Mean (SD)			95% CI of age difference	t statistics (df)	P value <sup>b</sup>	MAE (year)
		Dental age	Chronological age	Age difference <sup>a</sup>				
7	19	7.83 (0.77)	7.64 (0.37)	0.18 (0.80)	−0.20, 0.57	1.00 (18)	0.330	0.61
8	19	8.65 (1.25)	8.43 (0.35)	0.22 (1.03)	−0.28, 0.72	0.92 (18)	0.371	0.84
9	32	9.55 (1.22)	9.45 (0.32)	0.10 (1.09)	−0.29, 0.49	0.52 (31)	0.610	0.94
10	44	10.90 (1.03)	10.54 (0.29)	0.36 (1.01)	0.05, 0.66	2.35 (43)	0.024	0.85
11	62	11.94 (0.93)	11.54 (0.28)	0.40 (0.90)	0.17, 0.63	3.52 (61)	0.001	0.72
12	94	12.73 (1.22)	12.50 (0.28)	0.23 (1.13)	0.00, 0.46	1.99 (93)	0.049	0.81
13	85	13.77 (1.57)	13.45 (0.29)	0.32 (1.56)	−0.02, 0.66	1.90 (84)	0.061	1.30
14	55	15.26 (1.19)	14.42 (0.27)	0.84 (1.22)	0.52, 1.17	5.14 (54)	0.000	1.34
Total	410	12.31 (2.35)	11.94 (1.90)	0.36 (1.19)	0.24, 0.47	6.08 (409)	0.000	0.98

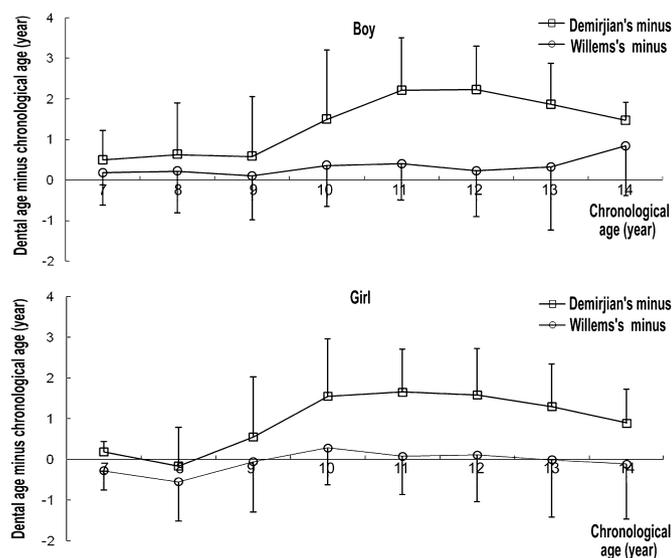
CI: confidence interval.

<sup>a</sup> Dental age minus chronological age.<sup>b</sup> Paired t-test.**Table 5**

Comparison between Willems dental age and chronological age in girls (seven teeth, mandibular left side).

Age group	n	Mean (SD)			95% CI of age difference	t statistics (df)	P value <sup>b</sup>	MAE (year)
		Dental age	Chronological age	Age difference <sup>a</sup>				
7	11	7.22 (0.53)	7.50 (0.21)	−0.28 (0.48)	−0.61, 0.04	−1.95 (10)	0.080	0.45
8	18	7.90 (1.01)	8.45 (0.31)	−0.55 (0.97)	−1.04, −0.07	−2.40 (17)	0.028	0.91
9	25	9.42 (1.18)	9.47 (0.37)	−0.06 (1.23)	−0.57, 0.44	−0.25 (24)	0.802	0.81
10	44	10.89 (0.98)	10.61 (0.26)	0.28 (0.91)	0.00, 0.55	2.01 (43)	0.051	0.77
11	94	11.71 (0.98)	11.64 (0.26)	0.08 (0.94)	−0.12, 0.27	0.80 (93)	0.429	0.71
12	146	12.60 (1.18)	12.49 (0.28)	0.11 (1.15)	−0.08, 0.30	1.12 (145)	0.263	0.91
13	105	13.50 (1.45)	13.51 (0.30)	−0.01 (1.41)	−0.28, 0.26	−0.08 (104)	0.935	1.10
14	88	14.37 (1.35)	14.49 (0.29)	−0.12 (1.35)	−0.41, 0.16	−0.87 (87)	0.389	1.17
Total	531	12.35 (2.07)	12.34 (1.69)	−0.02 (1.18)	−0.08, 0.12	−0.30 (530)	0.762	0.93

CI: confidence interval.

<sup>a</sup> Dental age minus chronological age.<sup>b</sup> Paired t-test.**Fig. 2.** Comparison of dental age between Demirjian method and Willems method by gender.

methods. As seen in Tables 2–5, the Willems method was more accurate than the Demirjian method for both genders, with a lower MAE.

#### 4. Discussion

Demirjian method has been established for more than four decades and has become the most widely accepted method on

estimating dental age. However, limited studies are discussed its application in mainland Han Chinese children. The Demirjian's scoring system is based on the developmental stages of the left mandibular permanent teeth, because evidences show that it is symmetric development of the two sides [6,7]. But it is still uncertain in the Chinese Han population. We identified the Demirjian's developmental stage of every permanent tooth of the two sides of mandible and found the agreement is almost perfect. It

demonstrates that the left permanent mandibular teeth are shown to be representative of all the permanent teeth of the mandible in Han population.

Consistently overestimation of chronological age is found in Demirjian dental age in Han population, which has been frequently reported in other populations [9,11,16–20]. In our study, an average overestimation is 1.68 years for boys and 1.28 years for girls, results that are similar to those of previous studies in Hong Kong [21] and others [7,8]. Most individuals have a mean estimate dental age and mean absolute error at least one year older than the given age category. The significant age overestimation seen in this study also demonstrated that the Demirjian method may not be suitable for Chinese children. We also find that there is a tendency of overestimation of age for older individuals (>10 years), and the overestimation was larger for boys than for girls. Previous studies have shown that tooth development is different by gender for older children [22,23]. Gender differences in tooth calcification generally arise at about 10 years of age in Chinese children [24]. The onset of puberty may contribute to tooth development.

The Willems method reduces the average overestimation, with 0.36 years for boys and –0.02 years for girls. Errors in age estimation are smaller in every age group with the Willems method, a result consistent with the findings of previous related studies [10,13,25–28]. Most individuals have an absolute deviation of less than one year, resulted in a smaller mean absolute error of 0.98 years for boys and 0.93 years for girls. It is indicted that the Willems method was more accurate in estimating dental age than the Demirjian method in Han population.

However, the Willems method still had a mean absolute error of approximately one year, a less accurate result than the findings of a related report [29]. This result did not meet our expectations. The Willems method is based on age-related morphological changes of tooth development. Research has shown that age-related morphological changes in teeth can also be measured and that the resulting measurement ratios correlate with age [28,30,31]. However, the model based on related measurement variables has proven unstable in some Asian populations [32,33]. Moreover, previous studies have failed to consider the tooth as a whole. We supposed that integrating the Willems method with the related measurement variables could increase the predictive power of the method, with the aid of a multiple regression model.

The limitations of this study must be acknowledged. This was a retrospective study of orthopantomograms sampled from the patient record database of a teaching hospital. We selected all children with hospital records over the previous 2 years who met the study criteria. However, other factors that may have influenced enrollment were not available. Secondly, the enrolled children had a narrow age range from 7–14 years. Therefore, the results must be interpreted with caution and not considered representative of southeastern Chinese children in general.

## 5. Conclusions

As a result, it is highly recommended that the Willems method should be applied when estimating dental age in Chinese Han population. However, the method should be used with considerable caution, and we recommend consideration of the tooth as a whole as a further modification in dental age estimation.

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