Comparative Assessment of The Willems DentalAge Estimation Methods: A Chinese Population-Based Radiographic Study

Jian Wang
Shanghai Jiao Tong University

Linfeng Fan
Shanghai Jiao Tong University

Meizhi Sui
Shanghai Jiao Tong University

Shihui Shen
Shanghai Jiaotong University: Shanghai Jiao Tong University

Jiaxin Zhou
Shanghai Jiao Tong University

Xiaoyan Yuan
Shanghai Jiao Tong University

Yiwen Wu
Shanghai Jiao Tong University

Pingping Zhong
Shanghai Jiao Tong University

Fang Ji
Shanghai Jiao Tong University

Jiang Tao (✉️ doctor_taojiang@126.com)
Shanghai Jiao Tong University School of Medicine

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Abstract

Objectives

The objective of the work was to assess the accuracy of the two Willems dental age estimation methods (gender-specific (Willems I) and non-gender-specific (Willems II)) in a Chinese population.

Materials and Methods

A total of 1211 oral panoramic radiographs (582 boys and 629 girls) of the Chinese Han population aged 11-to-16-year-old were collected. Dental ages (DAs) were calculated using the Willems method. Statistical significance was set at a p-value < 0.05. Age differences between chronological age (CA) and dental age were analyzed by paired t-tests and mean absolute error (MAE).

Results

The differences between CA and DA determined by the Willems I method were + 0.44 and + 0.09 years for boys and girls, respectively. When using the Willems II method, these differences were + 0.57 and − 0.09. The MAEs of the Willems I method between DA and CA were 0.95 and 1.00 years in boys and girls, respectively. For Willems II, MAEs were 1.02 and 1.00 years in boys and girls.

Conclusions

This study showed that the Willems I method was more accurate than the Willems method in the boys’ group for predicting age. While the Willems is more competitive in the girls’ group. Neither method may be satisfactory for 11-to-16-year-old teenagers in Eastern China.

Introduction

The development characteristics of teeth have been applied in legal, forensic, and clinical fields as an effective weapon to decipher age information[1–3]. In the realm of legal, and forensic science, the decoded age information has cast light on many social affairs, such as welfare distribution, athlete selection, child enrollment, cadaver identification, and refugee checks[4, 5]. More importantly, age estimation helps juveniles delineate to a large extent for doubted age-related problems[6]. In the community of the clinic, applications have been extended to support routine therapeutic diagnosis and strategy decisions in orthodontics and pediatric dentistry[7].

To date, several radiographic dental age assessment methods for children have been proposed and validated, such as Demirjian[8], Nolla[9], Willems[10], and the London atlas[11], which adopt developing features of teeth reflected on radiographs. Taking Willems method for instance[10], to acquire the wanted
dental age, you have to classify and stage the left 7 mandibular teeth from an oral panoramic radiograph in the first step according to the reference dataset; second, sum up all the 7 teeth's scores and the result then turns into the ideal dental age value. The Willems method was put forth in 2001 based on a sample of the Belgian Caucasian population, several reports have validated its accuracy among different regions and populations ever since. Over- and underestimation of age have been announced in different parts of the world[1, 5, 9, 12–25].

In the initial version, Willems et al. established a gender-specific method (Willems I, W1). This model came out in 2001 and has gained popularity ever since. A few years later, Willems et al. simplified the former model into a non-gender-specific model (Willems II)[26]. In other words, there is no need to distinguish the inner differences between boys and girls and integrate the former two conversion tables into one. With respect to Chinese populations, dental age estimations concerning the Willems method have been reported over recent years[1, 4, 5, 16, 21, 27]. To date, no Willems non-gender-specific method has been tested in China. This work was designed to compare the applicability and accuracy of the two Willems dental age methods (Willems I vs Willems II) among children aged 11–16 years old in an eastern Chinese population.

### Methods And Materials

**Methods:**

Respective Retrospective cross-sectional research was conducted in a hospital in Shanghai, eastern China. The Independent Ethics Committee of the Shanghai Ninth People's Hospital, affiliated with Shanghai Jiao Tong University School of Medicine (2017-282-T212) approved and authorized the project.

All the included OPGs were randomly selected from the database of the hospital and followed by strict inclusion standards, which have been elucidated in previous work[7].

The patients underwent an OPG check before any oral treatments. All 1211 samples were from a Chinese Han population aged 11 to 16 years old.

**Stata analysis**

A total of 1211 OPGs were qualified for the current work. The information of each age group at an interval of one year is displayed in Table 1.

CA was calculated by the date of the OPG taken preoperatively minus the date of birth, which was expressed by two decimal points,

All X-ray images were evaluated by the Willems method (Willems I and Willems II). To acquire the actual DA, we have to evaluate all the 7 left mandibular teeth (with third molars excluded)’s developmental stages (from A to H) judging from the status of the initial crown's formation to the terminal apex’s
closure. Then, we marked all the 7 teeth's scores and summed them up to obtain the ideal DA value with the provided dataset tables.

Cohen's kappa tests were employed to make the inner- and inter-agreements' tests [28]. Intra- and inter-agreements were calculated to give better quantitative values of agreements during the studies with the repeated data. The analysis included descriptive and inferential statistics. Descriptive statistics such as the mean differences and standard deviation (S.D.) were calculated. Differences between DA and CA were generated by subtracting DA from CA, i.e., (DA-CA). Then, differences were stratified based on age and sex and analyzed using the paired t-test. The mean absolute error (MAE) was used to assess the precision of the two Willems methods. All analyses were conducted in SPSS 17.0 for Windows (SPSS, Inc., Chicago, IL). A P value less than 0.05 was considered to be statistically significant.

| Age groups | boys | girls | Total |
|------------|------|-------|-------|
| 11         | 73   | 105   | 178   |
| 12         | 112  | 97    | 209   |
| 13         | 109  | 99    | 208   |
| 14         | 106  | 105   | 211   |
| 15         | 96   | 110   | 206   |
| 16         | 86   | 113   | 199   |
| Total      | 582  | 629   | 1211  |
Table 2
Accuracy comparison of Willems I method of dental age estimation.

| Gender | Age group | CA (years) Mean ± SD | DA (years) Mean ± SD | CA-DA (years) Mean ± SD | P     | MAE  |
|--------|-----------|----------------------|----------------------|-------------------------|-------|------|
| boys   | 11        | 11.47 ± 0.28         | 11.52 ± 0.91         | (-)0.05 ± 0.98          | 0.665 | 0.78 |
|        | 12        | 12.50 ± 0.28         | 12.05 ± 0.83         | 0.45 ± 0.84             | 0     | 0.75 |
|        | 13        | 13.46 ± 0.28         | 13.05 ± 1.18         | 0.40 ± 1.20             | 0.001 | 1.03 |
|        | 14        | 14.42 ± 0.31         | 14.19 ± 1.60         | 0.23 ± 1.59             | 0.147 | 1.12 |
|        | 15        | 15.48 ± 0.28         | 14.85 ± 1.15         | 0.63 ± 1.14             | 0     | 1.05 |
|        | 16        | 16.48 ± 0.24         | 15.53 ± 0.73         | 0.95 ± 0.77             | 0     | 0.95 |
| Total  |           | 13.98 ± 1.63         | 13.54 ± 1.79         | 0.44 ± 1.17             | 0     | 0.95 |
| girls  | 11        | 11.45 ± 1.16         | 12.11 ± 1.64         | (-)0.66 ± 1.34          | 0     | 1.03 |
|        | 12        | 12.46 ± 0.29         | 13.03 ± 1.04         | (-)0.58 ± 1.05          | 0     | 0.86 |
|        | 13        | 13.49 ± 0.26         | 13.62 ± 1.26         | (-)0.13 ± 1.24          | 0.289 | 1.02 |
|        | 14        | 14.47 ± 0.32         | 14.09 ± 1.75         | 0.39 ± 1.72             | 0.025 | 1.25 |
|        | 15        | 15.43 ± 0.27         | 15.12 ± 1.04         | 0.31 ± 1.04             | 0     | 0.76 |
|        | 16        | 16.46 ± 0.29         | 15.38 ± 0.82         | 1.08 ± 0.80             | 0     | 1.08 |
| Total  |           | 14.03 ± 1.81         | 13.93 ± 1.73         | 0.09 ± 1.37             | 0.091 | 1    |
Table 3
Accuracy comparison of Willems II method of dental age estimation.

| Gender | Age group | CA (years) Mean ± SD | DA (years) Mean ± SD | CA-DA (years) Mean ± SD | P | MAE |
|--------|-----------|----------------------|----------------------|-------------------------|---|-----|
| boys   | 11        | 11.47 ± 0.28         | 11.4 ± 0.91          | 0.07 ± 0.98             | 0.556 | 0.8 |
|        | 12        | 12.50 ± 0.28         | 11.99 ± 0.84         | 0.5 ± 0.86              | 0   | 0.78 |
|        | 13        | 13.46 ± 0.28         | 12.94 ± 1.20         | 0.52 ± 1.21             | 0.012 | 1.07 |
|        | 14        | 14.42 ± 0.31         | 14.01 ± 1.66         | 0.41 ± 1.64             |     | 1.24 |
|        | 15        | 15.48 ± 0.28         | 14.64 ± 1.24         | 0.84 ± 1.21             | 0   | 1.14 |
|        | 16        | 16.48 ± 0.24         | 15.41 ± 0.77         | 1.06 ± 0.81             | 0   | 1.06 |
|        | Total     | 13.98 ± 1.63         | 13.41 ± 1.78         | 0.57 ± 1.20             | 0   | 1.02 |
| girls  | 11        | 11.45 ± 1.16         | 12.35 ± 1.58         | (-)0.91 ± 1.30          | 0   | 1.01 |
|        | 12        | 12.46 ± 0.29         | 13.25 ± 0.99         | (-)0.79 ± 1.00          | 0   | 0.94 |
|        | 13        | 13.49 ± 0.26         | 13.81 ± 1.21         | (-)0.32 ± 1.19          | 0.008 | 0.75 |
|        | 14        | 14.47 ± 0.32         | 14.26 ± 1.68         | 0.21 ± 1.65             | 0.205 | 1.17 |
|        | 15        | 15.43 ± 0.27         | 15.25 ± 0.99         | 0.18 ± 1.00             | 0.061 | 0.75 |
|        | 16        | 16.46 ± 0.29         | 15.50 ± 0.79         | 0.95 ± 0.77             | 0   | 0.95 |
|        | Total     | 14.03 ± 1.81         | 14.11 ± 1.66         | (-)0.09 ± 1.34          | 0.106 | 1   |

Results

A total of 1211 OPTs of sub-adults aged from 11 to 16 years were eligible for the present study, including 582 boys and 629 girls. The samples were classified into 6 subgroups at an interval of one year. Details concerning samples were listed in Figure 1.

Inter and intra-agreements

The Cohen's kappa values reached 0.78 and 0.79 for boys and girls, respectively, which displayed good inter-and intra-agreement in the experiments.

Willems I method

Using the Willems I dataset, the mean dental age for boys and girls was 13.54 and 13.93 years, respectively. The general mean difference (CA-DA) for boys and girls was 0.44 ± 1.17 (P < 0.05) and 0.09 ± 1.37 (P > 0.05), respectively. An underestimation (CA-DA) of age was observed in all the subgroups.
except for boys in the 11-12-year group and girls in the 11–12, 12–13, and 13-14-year groups. The mean absolute error was 0.95 and 1.00 years for boys and girls, respectively.

**Willems II method**

Adopting the Willems II method, the mean dental age for boys and girls was 13.41 and 14.11 years, respectively. The overall mean difference (CA-DA) for boys and girls was $0.57 \pm 1.20$ (P < 0.05) and $(-)0.09 + 1.34$ (P > 0.05), respectively. An underestimation (CA-DA) of age was observed in all the subgroups except for the girls in the 11-12-, 12-13- and 13-14-year groups. The mean absolute error was 1.02 and 1.00 years for boys and girls, respectively.

| Gender | N    | Willems I |           | Willems II |           | Willems I vs II |
|--------|------|-----------|-----------|------------|-----------|-----------------|
|        |      | Mean CA-DA (Mean ± SD) | MAE | Mean CA-DA (Mean ± SD) | MAE | HI (Mean ± SD) | P-value |
| Boys   | 582  | (-)0.44 ± 1.17 | 0.95 | (-)0.57 ± 1.20 | 1.02 | (-)0.13 ± 0.23 | 0       |
| Girls  | 629  | (-)0.99 ± 1.37 | 1.08 | 0.09 ± 1.34  | 1     | 0.18 ± 0.08    | 0       |
| Total  | 1211 | 0.26 ± 1.28   | 0.98 | 0.23 ± 1.32  | 1.01 | 0.03 ± 0.23    | 0       |

**Discussion**

Dental age estimation is of vital importance in the communities of forensic science and clinical dentistry[9, 20, 29–32]. Does a practical and accurate method exist to elucidate the inner relationships between the teeth and chronological age? Many works have been put forward and aroused drastic discussions. From decades of age to the last ten years, there have been huge explorations in the community of dental age estimation. In retrospect, Demirjian, along with his colleagues, performed clinical research between tooth development and chronological age in 1973[8]. They have proven a correlation between tooth development and actual age. Since then, several methods have been upgraded or constructed based on oral radiographs and tested in different populations and regions. Of them, some should be voiced here for their non-invasion and convenience, such as the Willems method[10], Cameriere method[33], and London atlas method[11].

The Willems method was first proposed by Willems et al. based on a population of Belgian-Caucasian teenagers in 2001[10]. The Willems method, in other words, a modified Demirjian dental age assessment method, simplified the former method by leaving out a step of data processing and improved the accuracy of dental age assessment. The initial Willems method remained a sex-specific trait, similar to
the Demirjian method mentioned. Later, Willems et al. rethought the old method and constructed a reduced non-gender specific method (Willems II) to better serve the community of dental age estimation[26]. Willems II method provides a common standard for both genders. The Willems II method will display good performance in bioarchaeological studies, while the sex of skeletal remains is unknown. Although some studies on the Willems method have been conducted in other regions on the planet, to the best of our knowledge, the practical effect of the Willems II method has only been reported in only 3 studies and has not been fully investigated thus far [15, 34, 35]. Hence, the better choice of the two Willems methods applied in a population of eastern China is meaningful to explore.

The Willems method has gained popularity to a great extent as an easy-to-check approach to estimating the actual age. The Willems I method’s over/underestimation of age has been reported worldwide. Overestimation of chronological age was validated in a variety of counties or regions such as India[36], Turkey[37], Thailand[38], Spain[39], Kenya[40] and Poland [41]. elsewhere, there were also reports of underestimation in north China[21], Tunisia[35], and Sri Lanka[42]. In allusion to the differences of the Willems method among several regions, a systemic review, and meta-analysis we conducted previously concerning the Willems I method revealed the Willems method overestimated CA by 0.18 years and 0.06 years for boys and girls, respectively[4]. It also revealed that ethnicity specificity was necessary when adopting the Willems I method. This conclusion was consistent with other similar meta-analyses[22, 23, 43]. In the current work, the underestimation of age was $+0.44 \pm 1.17$ (p $< 0.05$) and $+0.09 \pm 1.37$ (p = 0.091) for the boy and girl groups, respectively. From the whole perspective, compared with the boys’ group, the girls’ group showed a more accurate effect of age assessment as a whole. This phenomenon was also viewed in our previous works and other printed studies[5, 44].

For the Willems II method, only a few works have been reported over the last decades(Table 4). Urzel et al. observed a mean difference between CA and DA of 0.03 years for both genders [15]. As is depicted in the Fig. 3, we did not display the exact positions of DA by the Willems II method for both genders because the original paper only showed a mean difference value of 0.00 years from a whole scale. They concluded that both methods were appropriate when applied to a French population, although the Willems I method was more accurate according to their data. Another similar study from an Indian population revealed that the mean values were $0.06 \pm 0.80$, $-0.11 \pm 0.79$, and $-0.01 \pm 0.80$ years for boys, girls, and the total sample, respectively [34]. Among Tunisian sub-adults [35], the Willems II method tended to underestimate age by 0.91, and 0.64 years for boys and girls, respectively. Whereas the Willems I method indicated an underestimation of chronological age by 0.40 years for boys, and by 0.69 years for girls. In their investigation, Willems I was more accurate when compared with Willems II in the Tunisian population. In the current study, the mean values of CA-DA were $0.57 \pm 1.20$ (p $< 0.05$) and $-0.09 + 1.34$ (p = 0.106) years for boys and girls, respectively. A more accurate estimation was observed in the girls’ group in the two methods. These results revealed that Willems I was more accurate and reliable for boys, while Willems II was a better option for girls. Our results are in accordance with the aforementioned studies.

Despite the accuracy assessment of Willems I and Willems II, the study still has limitations that must be elucidated. The samples we collected ranged from 11 to 16 years old. We did not retrieve lower age
groups younger than 11 years old. Larger sample size will help better understand the suitability of the methods.

In conclusion, the present study investigated the applicability of the Willems I and Willems II methods with a sample of eastern Chinese teenagers aged 11 to 16 years old. These outcomes suggest that Willems I is more accurate for boys, while the Willems II method prefers girls; both methods may not be a perfect match for the eastern Chinese Han population. An ethnicity-specific model based on the Willems method or further modifications is encouraged to prosper the science of dental age estimation.

**Declarations**

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**Authors’ contributions**

JW: Conceptualization, Methodology, Writing – Original Draft. XYY: Software, Investigation. MZS, JXZ: Validation – Investigation. PPZ: Validation, Data Curation YWW: Formal Analysis. LFF: Resources. FJ: Investigation, Project Administration. JT: Writing – Review & Editing, Supervision

**Availability of data and materials**

Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

**Conflict of interest**

Neither the author nor any of the co-authors have any potential conflicts of interests related to the submission and publication of this manuscript.

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Figures
Figure 1
Willems I vs Willems II in boys group

Figure 2
Willems I vs Willems II in girls group
Figure 3

Comparison of the age differences (DA-CA)(years) of the four studies with Willems I and II methods