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Use of Haavikko's method to assess dental age in Chinese children

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Objective To investigate the accuracy and precision of Haavikko's method in estimating dental age (DA) in healthy Chinese children, and evaluate the agreement between DA and dental age in the left mandibular quadrant (DALM) , in order to simplify Haavikko's method by using only the developing teeth in the left half of the mandible. ***Method*** Six hundred and thirteen panoramic photographs of healthy Chinese children were reviewed retrospectively. DA and DALM were calculated using Haavikko's method, but DALM included only the developing teeth in the left mandible. A paired t-test was used to compare the difference between chronological age (CA) and DA, DA and DALM. Correlation coefficients were calculated. Intra-examiner and inter-examiner variation were also evaluated using Cohen's Kappa value. ***Results*** Intra-examiner and inter-examiner Kappa values were 0.90 and 0.84 respectively, indicating a high reliability of Haavikko's method in this study group. The mean difference between DA and CA of the samples was 0.14 years. The correlation coefficient between the two was 0.93. For DA and DALM, the mean difference was 0.05 years, and the correlation coefficient was 0.99. ***Conclusions*** Haavikko's method has a high degree of accuracy and precision when applied in this Chinese population. DALM may be used instead of DA to estimate dental ages.

Key words: dental age, Haavikko method, Chinese population

Introduction

Stature or weight, secondary sex characters, bone age, and dental maturity can be used to estimate chronological age (CA) (Moorrees *et al.*, 1963). Dental maturity, often expressed as dental age (DA), is closely related to somatic development. Dental age is an important indicator in forensic investigations and anthropology, and in evaluating the biological maturity of growing children in pediatric dentistry and orthodontics.

Many methods have been used in estimating dental development, including anatomy, histology, tooth emergence dates and radiology (Nolla, 1960). Among these, the radiological method is most practical and reliable. Several methods for the determination of dental maturity from radiographs have been described (Demirjian *et al*. 1973; Haavikko, 1970; Moorrees *et al*., 1963; Nolla, 1960;). Nolla's method summarizes the development of each individual tooth, but does not give a conversion from developmental stages to dental age. The complexity of Moorrees' method limits its usage. In Demirjian's and Haavikko's methods each developmental stage is given a numerical score according to the system, and the sum of the scores is converted to dental age. Demirjian's method is widely used, but its application to Chinese populations is questionable because the accuracy of this method in young Chinese children is low (Davis and Hagg, 1994).

In the present study, we evaluated the accuracy and precision of Haavikko's method (Haavikko, 1970) in estimating dental age in healthy Chinese children. This method has not previously been used in a Chinese population. At the same time, we calculated the dental age of the left mandibular quadrant (DALM), and evaluated the agreement of DALM and DA, in order to simplify Haavikko's method by using only the developing teeth in the left mandible.

Method

We retrospectively reviewed the panoramic radiographs taken during 2000 to 2009 of Chinese children aged between 3.6-12.5 years in the Department of Radiology, Peking University School and Hospital of Stomatology. Based on their medical records, children with systematic diseases, jaw diseases, congenitally missing teeth and a history of orthodontic treatment were excluded from the sample. Radiographs of poor quality were also excluded. Chronological age was determined from the date of birth, and recorded as years and months.

Dental age was determined on the panoramic radiographs using Haavikko's method (Haavikko, 1970). Haavikko published dental maturity estimation by assessing crown or root stages of all developing teeth. Briefly, tooth formation is divided into 12 stages. Each stage of tooth development is converted into a maturity score by using gender-specific tables (Appendices 1,2). The sum of the scores for all the developing teeth except third molars was divided by the number of developing teeth to get a mean dental age. Teeth with closed apices were not included in the calculation of dental age, because it is impossible to estimate with sufficient precision when the apex closes (Hagg and Taranger, 1985).

DALM was similarly determined, but only the developing teeth of the left mandible were included in that calculation.

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For each gender and age group, the mean difference (DA-CA) and standard deviation (SD), and the correlation coefficient (r) between dental age and chronological age were calculated. The significance of differences between the estimated dental age and chronological age was determined by paired *t*-tests.

To investigate the correlation between DA and DALM, the mean difference and standard deviation (SD), and the correlation coefficient (r) between these two estimated dental ages were calculated, and a paired *t*-test was used to test their statistical significance.

Fifty radiographs were selected at random and re-evaluated by the same examiner one month after the first reading. Twenty radiographs were selected at random and examined by a radiologist. The intra-examiner and inter-examiner variation regarding whether DA equals to CA were calculated using Cohen's Kappa value. DA fell within CA ±0.5 was defined as DA equals to CA (Uslenghi *et al*., 2006).

Results

During sample collection, 3 cases of systemic disease, 6 of poor radiograph quality, and 28 of congenital missing teeth were excluded. Finally, 613 children were included, including 285 males and 328 females. The samples were arranged in one-year intervals ranging from 3.6-4.5 to 11.6-12.5 years (Table 1).

Table 1. Distribution of samples

Age Group years	*Males Number*	*Females Number*	*Total Number*
3.6~4.5	4	11	15
4.6~5.5	6	17	23
5.6~6.5	3	9	12
6.6~7.5	30	28	58
7.6~8.5	38	49	87
8.6~9.5	61	47	108
9.6~10.5	50	57	107
10.6~11.5	51	62	113
11.6~12.5	42	48	90
Total	285	328	613

Table 2. Differences between dental age and chronological age

	Range (DA-CA), years	*Mean difference (SD) years*	*p*	*r*
Male	-2.3 to 2.2	0.07 (0.86)	0.15	0.916*
Female	-2.5 to 2.1	-0.19* (0.77)	<0.001	0.946*
Total	-2.5 to 2.2	-0.14* (0.82)	<0.001	0.934*

*statistical significance

Table 3. Differences between dental age and chronological age for each age group

Age group years	*Males*			*Females*		
	Range (DA-CA) years	*Mean difference (SD) years*	*p*	*Range (DA-CA) years*	*Mean difference (SD) years*	*p*
3.6~4.5	-0.1 to 0.3	0.10 (0.18)	0.35	-0.4 to 0.7	0.15 (0.34)	0.16
4.6~5.5	-0.8 to 0.3	-0.17 (0.50)	0.45	-1.1 to 0.6	-0.19 (0.44)	0.09
5.6~6.5	-0.8 to 0	-0.37 (0.40)	0.26	-1.4 to 0.5	-0.42 (0.52)	0.95
6.6~7.5	-1.4 to 0.9	0.03 (0.59)	0.81	-1.6 to 1.7	-0.30* (0.75)	0.046
7.6~8.5	-1.2 to 1.5	-0.29* (0.63)	0.01	-1.5 to 0.8	-0.59* (0.62)	<0.001
8.6~9.5	-2.3 to 2.3	-0.33* (1.07)	0.03	-2.1 to 1.7	-0.54* (0.89)	<0.001
9.6~10.5	-2.3 to 2.2	-0.29* (1.00)	0.03	-2.5 to 2.1	0.22 (0.92)	0.08
10.6~11.5	-1.5 to 1.6	0.41* (0.85)	0.01	-2.0 to 1.3	0.10 (0.67)	0.22
11.6~12.5	-1.2 to 1.2	0.10 (0.49)	0.20	-1.2 to 0.9	-0.29* (0.45)	<0.001
Total	-2.3 to 2.2	0.07 (0.86)	0.15	-2.5 to 2.1	-0.19* (0.77)	<0.001

*statistical significance

Reliability in the present study was assessed by the comparison of dental age findings using Haavikko method by the author and a radiologist working independently. The percentages of intra-examiner and inter-examiner agreement on stages of dental development were 85.6% and 71.2% respectively. Intra-examiner and inter-examiner Cohen's Kappa values regarding whether DA equals to CA were 0.90 and 0.84 respectively, which is in the range regarded as demonstrating a good and acceptable agreement (Landis and Koch, 1977).

By using Kolmogorov-Smirnov test, the data of the differences between DA and CA fit normal distribution (p=0.08). The ranges, means and standard deviations of the differences between DA and CA were summarized in Table 2 and listed in detail by age group in Table 3. The mean difference between DA and CA for the samples was -0.14 years (51 days), suggesting a high correlation between DA and CA. The correlation coefficient between DA and CA was 0.93 ($p<0.001$), indicating a statistically significant linear correlation between them.

In girls, the mean difference between DA and CA varied from -0.59 to 0.22 years in different age groups. The greatest difference was seen in 7.6-8.5 and 8.6-9.5 year-old group, which were -0.59 and -0.54 years respectively. In boys, the mean difference of DA and CA in different age-groups varied from -0.37 to 0.41 years. The highest difference of 0.41 years was found in 10.6-11.5 year-old group (Table 3).

To test whether or not dental age from the left mandibular quadrant (DALM) alone could be used in the Haavikko method, the percentage of cases where DALM fell within DA ±0.5 years was calculated for each age group (Figure 1). Overall, DALM of 94% subjects fell within the range of DA ±0.5 years. The coefficient between DA and DALM was 0.993, demonstrating that DA and DALM were highly correlated.

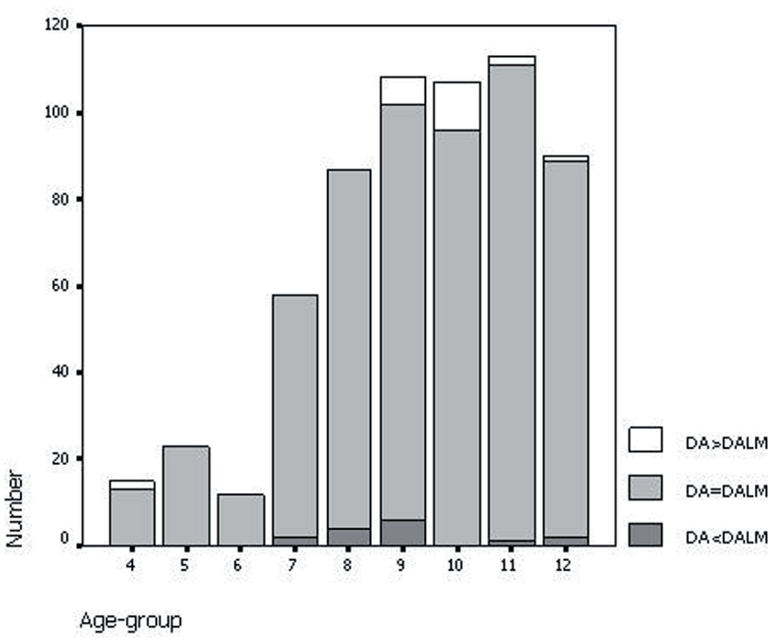
Discussion

The method of Haavikko, based on the tooth development of Finnish children, has been used in a number of different populations (Butti *et al*., 2009; Haavikko, 1970; Uslenghi *et al*., 2006). Staaf *et al*. (1991) found Haavikko's method to be more accurate in their Scandinavian samples compared to Demirjian's method, while Maber *et al*. (2006) considered Demirjian's to be more suitable for their British sample.

In the present study, reliability of Haavikko's method in Chinese children was demonstrated by a high degree of agreement in inter-examiner and intra-examiner evaluation . The difference between DA and CA was minimal, amounting to 0.14 years on average. It is generally accepted that a difference within ±0.5 year is regarded as nearly equal (McKenna, *et al.* 2002). A significant positive linear relationship between DA and CA indicated a high accuracy of Haavikko's method in this study group.

In trying to simplify Haavikko's method, this study evaluated the agreement of DALM and DA. DALM used only the developing teeth in the left mandible to evaluate dental age instead of all the permanent teeth in the four quadrants. The high agreement between DALM and DA in the present study demonstrated the feasibility of replacing DA with DALM.

We expected the greatest variation would occur in males, as the dates of eruption are generally more variable in males (Koshy and Tandon, 1998). However, the accuracy of Haavikko's method in 7.6-9.5 year-old group of females was relatively low in this study group. Ethnic



Note: DA>DALM: DA-DALM > 0.5 years
DA=DALM: -0.5 years ≤ DA-DALM≤0.5 years
DA<DALM: DA-DALM <- 0.5 years.

Figure 1. *Histograms of the number of cases where dental age (DA) was greater than, equal to or less than dental age of left mandibular quadrant (DALM).*

differences could be a possible explanation (Koshy and Tandon, 1998). Besides, socio-economic status has great influence on the somatic development of children (Zhao *et al*. 1990), and should be taken into consideration in estimating dental age. China is a country with vast territory and unbalanced economic development. Further studies involving larger numbers of children should be undertaken to confirm the reliability of Haavikko's method in the assessment of Chinese children, especially for girls between 7.6-9.5 years old.

Conclusion

This is the first report to use Haavikko's method in an analysis of a Chinese population. The findings indicate that Haavikko's method is applicable to evaluate dental ages in Chinese children.

DALM, using only the developing teeth in left mandible to evaluate dental ages, produced results which correlated well with DA estimated from assessing all the permanent teeth in the four quadrants. This suggests that DALM could be used instead of DA to evaluate dental ages, which would make the application of Haavikko's method more simple and convenient.

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Appendix 1. Maturity score table for boys

		I^1	I^2	C	P^1	P^2	M^1	M^2
maxillary	0							
	Ci							3.7
	Cco					4.6		4.1
	C1/2				4.5	5.8		5.3
	C3/4		3.3	3.3	6.0	6.7		6.4
	Cc	3.3	4.6	4.6	6.8	7.1	3.6	7.3
	R1/4	5.7	6.8	7.0	8.4	8.6	5.8	10.2
	R1/2	6.8	7.3	8.4	9.5	9.9	6.2	11.6
	R3/4	7.3	8.6	9.8	10.7	11.3	7.2	12.3
	Rc	8.7	9.6	12.3	11.5	12.0	8.1	13.6
	Ac	9.8	10.8	13.6	13.3	14.0	9.8	16.2
mandibular	0							
	Ci							3.9
	Cco					4.4		4.5
	C1/2				3.7	5.2		5.4
	C3/4			3.3	5.5	6.1		6.7
	Cc		3.3	4.3	5.9	7.0	3.5	7.4
	R1/4	4.3	5.4	6.9	8.0	8.5	5.1	9.7
	R1/2	5.6	6.2	8.2	9.6	9.7	6.0	11.2
	R3/4	6.3	7.3	9.6	10.4	11.1	6.6	12.1
	Rc	7.2	8.1	11.6	11.8	12.1	7.3	13.4
	Ac	8.0	9.6	13.2	12.8	13.8	9.8	15.7

Provided by Dr Helen M. Liversidge from Department of Paediatric Dentistry, St Bartholomew's and the Royal London School of Medicine and Dentistry, Queen Mary and Westfield College, University of London, UK.

Appendix 2. Maturity score table for girls

		I^1	I^2	C	P^1	P^2	M^1	M^2
maxillary	0							
	Ci							3.8
	Cco					4.3		4.1
	C1/2				4.1	5.6		5.1
	C3/4		3.3	3.3	5.6	6.1		5.8
	Cc	3.3	4.4	4.5	6.3	6.6	3.5	6.9
	R1/4	5.4	5.8	6.3	8.0	8.5	5.1	9.4
	R1/2	6.4	7.4	7.7	9.4	9.7	6.0	10.9
	R3/4	7.0	8.0	9.0	10.4	10.5	6.8	11.5
	Rc	8.2	8.5	11.2	10.9	11.3	7.5	12.5
	Ac	9.3	9.6	12.7	12.6	13.4	9.2	15.1
mandibular	0							
	Ci							3.9
	Cco					4.2		4.1
	C1/2				3.9	5.0		5.0
	C3/4				4.7	6.0		6.0
	Cc			4.1	5.4	6.4	3.5	7.0
	R1/4	3.6	5.1	6.3	8.1	8.5	5.1	9.0
	R1/2	5.8	6.3	7.0	9.3	9.6	6.0	10.4
	R3/4	6.3	6.5	8.7	10.4	10.7	6.4	11.3
	Rc	6.8	7.1	10.3	11.1	11.5	6.9	12.5
	Ac	8.0	9.0	11.5	12.1	12.8	9.2	14.7

Provided by Dr Helen M. Liversidge from Department of Paediatric Dentistry, St Bartholomew's and the Royal London School of Medicine and Dentistry, Queen Mary and Westfield College, University of London, UK.