### Häävikko's method to assess dental age in Italian children

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SUMMARY The aim of this study was to determine if Häävikko's maturation standards are applicable to Italian children. The sample included 500 healthy Caucasian children 3.9–15.4 years of age: 267 girls [mean age 9.6 years, standard deviation (SD) 2.1] and 233 boys (mean age 9.9 years, SD 2.1), living in Italy. All dental ages were assessed from panoramic films by one examiner using Häävikko's method. A second examiner independently scored 48 panoramic films to evaluate the reproducibility of the dental age measurements.

A good correlation (0.95) was found, as shown by Cohen's kappa. To evaluate the relationship between dental age estimated by Häävikko's standards and the chronological age of the Italian sample, Bland and Altman's graphical method was employed. Moreover, centiles of dental age were constructed both for girls and boys using the LMS (L = skewness, M = median, S = coefficient of variation) method of Cole and Green.

It was found that Häävikko's standards tended to underestimate chronological age in this Italian sample. Dental maturation standards as described by Häävikko do not appear suitable for Italian children; instead, centile curves constructed for girls and boys using the LMS method could be used for the estimation of dental age in the Italian population.

#### Introduction

The overall somatic maturity of a subject defines their physiological age. This age can be evaluated through the degree of maturation of one or more functional systems such as skeletal, dental, or tegumental. Among the indicators of physiological age, dental age seems to correlate well with chronological age (Lewis and Garn, 1960; Demirjian et al., 1985) but not necessarily with skeletal age (Lewis, 1991). Agreement between dental, skeletal, and chronological age could be relevant both for orthodontists and paediatricians. Orthodontists could use such knowledge, for example, to decide on the timing of a particular treatment while paediatricians might be interested in knowing if the dental maturity of a child with a certain disease is delayed (Gaethofs et al., 1999; Hauk et al., 2001) or advanced (Lehtinen et al., 2000). Correlation between dental and chronological age is also useful in forensic dentistry to estimate the age of a child with an uncertain birthdate (Foti et al., 2003; Cameriere and Ferrante, 2008).

Several methods for evaluating dental age have been proposed, the simplest of which is to assess dental age by eruption time (Clements *et al.*, 1957; Nanda, 1960; Carr, 1962). This method cannot be used in subjects with a complete primary dentition who have not yet undergone formation of the mixed dentition. Radiographic estimation seems more reliable and is not affected by this drawback (Sapoka and Demirjian, 1971). Dental pantomograms (DPTs) offer a global view of the maturation of the whole dentition (Larheim *et al.*, 1984). Over the years, several radiographic methods have been proposed (Nolla, 1960; Liliequist and Lundberg, 1971; Demirjian et al., 1973; Cameriere et al., 2006).

In the present study, the method of Häävikko (1974) was employed. It would appear that this method has not previously been tested in the Italian population. The aim was therefore to verify if Häävikko's maturation standards are suitable for healthy Italian children.

#### Subjects and methods

A group of 3000 children was screened for the investigation from those who attended orthodontic check-ups at the Unit of Milan in the period between 1992 and 2003. For each subject, a medical and dental history and orthodontic records were available. Children with a history of congenital anomalies, genetic or acquired syndromes, metabolic disorders, malignancies and previous chemotherapy, or ionizing radiation treatment were excluded, since it has been shown that such conditions may change the rate of dental development (Midtbø and Halse, 1992; Souren and Prahl-Andersen, 1994; Cantu et al., 1997; Gaethofs et al., 1999; Lehtinen et al., 2000; O'Connell et al., 2000; Hauk et al., 2001). Subjects with poor quality radiographs were also excluded. Children of unknown origin, with a non-Italian surname or a non-Caucasian appearance on photographs taken prior to orthodontic treatment, were regarded as non-Italian and excluded from the sample.

From the initial group, the 500 most recent DPTs of healthy Italian children aged between 5 and 15 years were selected. The study group included 267 girls [53 per cent,

mean age 9.6 years, standard deviation (SD) 2.1, range 5.29–15.41] and 233 boys (47 per cent, mean age 9.9 years, SD 2.1, range 4.50–14.60), all of them born between 1981 and 1997.

#### Methods

All dental ages were determined by the same examiner (AT) on the DPTs using the method of Häävikko (1974). This method is based on the evaluation of four reference teeth and on the recognition of 12 radiographic stages for each tooth. These stages are transformed into dental age with the use of tables. Chronological age is then calculated as the mean of all the estimates. The reference teeth are as follows: lower right first molar, lower right first premolar, lower right canine, and upper right central incisor in children younger than 10 years; the lower right second molar, lower right first premolar, lower right canine, and upper right canine, and upper right canine, and upper right canine in subjects older than 10 years.

For each subject, chronological age was obtained by subtracting the birthdate from the date of the DPT.

#### Statistical analysis

To evaluate the reproducibility of dental age measurements, 48 DPTs were randomly selected and measured by a second examiner (ACB) 4 months after the initial assessment. Agreement between dental and chronological age, rounded to the nearest year, was expressed as a percentage and as Cohen's weighted kappa statistic (Landis and Koch, 1977). Such statistics were computed for each tooth and for the mean (global score), which represented the estimated dental age. The significance of differences between the estimated dental and chronological age was determined by paired *t*-tests. Due to multiple testing, the exact probability for each evaluated difference is reported. Tests with a P value less than 0.002 can be considered significant according to Bonferroni correction (Snedecor and Cochran, 1980).

To evaluate the relationship between Häävikko's dental age and chronological age, the graphical method proposed by Bland and Altman (1986) was used. This method plots the difference (D) between the two ages (dental and chronological) against their average (A) and allows age calculation if the two methods of measurement agree sufficiently (or are comparable). The relationship between D and A was modelled with the LMS (L = skewness, M = median, S = coefficient of variation) method (Cole and Green, 1992) and expressed as the 5th, 50th, and 95th centiles of D distribution as a function of A.

The LMS method summaries the data in terms of three smooth age-specific curves called L, M, and S. The M and S curves correspond to the median and the coefficient of variation of the dental age in each chronological age, while the L curve allows for the age-dependent skewness of the distribution of the same trait. The LMS method was also used to trace a dental age reference for Italian girls and boys based on Häävikko's method. It provides normalized centile curves considering the possible skewness that may be present in the distribution of the measurements. Centile curves are generally used to describe the standards for a defined auxometric trait and/or to compare each subject with a reference centile distribution.

#### Results

#### Reliability

Comparison of dental age estimated according to the method of Häävikko (1974) from two different measurements performed by two different investigators is shown in Table 1. Kappa values were in the range regarded as substantial (0.61–0.80) or almost perfect (0.81–1.00) agreement beyond chance (Landis and Koch, 1977); the agreement was lowest for the upper right central incisor (0.69), highest for the upper right canine (1.00), and as high as 0.95 for the global score. The agreement, expressed as the degree of percentage for each tooth, varied from 74 to 100 per cent. The difference between the two estimated dental ages did not exceed 1 year for any tooth.

## Comparison between Häävikko's dental age and chronological age

The mean difference between dental and chronological age tended to decrease with increasing age with a maximum of +0.61 and +0.67 and a minimum of -1.72 and -2.31 for girls and boys, respectively. In girls, the only positive difference was at 6 years, while in boys the difference was positive up to 8 years (Table 2). An increase in the variability of Häävikko's dental age with respect to chronological age was observed.

The Bland–Altman plot (Figure 1) showed both a shift of the difference between dental and chronological age towards a negative value and an increase in the variability of estimates in boys and, to a lesser extent, in girls. In particular, dental age was below chronological age by 3 months at 8 years, 6 months at 10 years, and 10.5 months at 13 years in girls. In boys, the delay in dental maturation was 2, 3.5, and 7 months, respectively, at 8, 10, and 13 years.

Figure 2 shows the reference curves for Italian girls and boys. This demonstrates that a girl whose dental maturation followed the mean maturation of a girl in Häävikko's reference set was on the 50th centile of the dental age distribution of the Italian reference set at 6 years and on the 95th centile at 14 years. Likewise, the 'average' boy in Häävikko's reference set was on the 25th centile at 6 years and between the 75th and 90th centiles at 14 years. This suggests that, for example, 14-year-old girls are expected to have a dental age of 13.1 years and 90 per cent are expected to have a dental age between 11.8 and 14.0 years. While 14-year-old boys are expected to have a dental age of per cent are expected to have a dental age between 11.8 and 14.0 years. While 14-year-old boys are expected to have a dental age of 13.2 years and 90 per cent

	lst		2nd	3rd	4th		Global score
	Lower right 1st molar	Lower right 2nd molar	Lower right 1st premolar	Lower right canine	Upper right central incisor	Upper right canine	
ρ	0.99	0.98	0.96	0.93	0.95	0.99	0.99
Cohen's kappa Degree of percentage ( <i>n</i> )	0.84 87 (27)	0.75 82 (14)	0.84 85 (41)	0.71 77 (37)	0.69 74 (23)	1.00 100 (17)	0.95 94 (45)

 Table 1
 Comparison of dental age estimated according to the method of Häävikko (1974) from two different measurements performed by two different investigators. Data from 48 dental pantomograms.

1st: lower right first molar, for children younger than 10 years or lower right second molar, for subjects older than 10 years.

2nd: lower right first premolar.

3rd: lower right canine.

4th: upper right central incisor in children younger than 10 years or upper right canine in subjects older than 10 years.

**Table 2** Chronological and dental age [mean and standard deviation (SD)] estimated with the method of Häävikko (1974) and difference between dental and chronological age. Paired *t*-test.

	п	Chronological age		Dental age		Dental-chronological age		t value	prt
		Mean	SD	Mean	SD	Mean	SD		
All	500	9.73	2.12	9.38	1.95	-0.35	0.72	-10.97	< 0.0001
Girls age	267	9.59	2.11	9.18	1.93	-0.41	0.71	-9.49	< 0.0001
5	2	4.69	0.26	4.68	0.81	-0.01	1.07	-0.02	0.99
6	7	6.15	0.35	6.76	0.36	0.61	0.39	4.1	0.01
7	37	7.05	0.29	7.00	0.67	-0.05	0.60	-0.53	0.60
8	47	7.96	0.28	7.62	0.62	-0.34	0.57	-3.98	0.0003
9	41	9.00	0.27	8.51	0.71	-0.49	0.67	-4.71	< 0.0001
10	38	9.93	0.27	9.57	0.74	-0.36	0.64	-3.49	0.001
11	45	10.93	0.27	10.51	0.57	-0.41	0.60	-4.57	< 0.0001
12	24	12.06	0.30	11.59	0.65	-0.47	0.70	-3.24	0.004
13	17	13.01	0.30	12.10	0.54	-0.91	0.47	-7.95	< 0.0001
14	9	13.94	0.37	12.23	0.67	-1.72	0.77	-6.70	0.00015
Boys age	233	9.90	2.12	9.61	1.96	-0.29	0.73	-6.02	< 0.0001
5	2	5.39	0.14	5.74	0.37	0.35	0.51	0.98	0.51
6	6	6.31	0.24	6.98	0.56	0.67	0.45	3.62	0.02
7	19	7.11	0.27	7.16	0.49	0.05	0.49	0.42	0.68
8	37	8.03	0.28	7.84	0.49	-0.18	0.49	-2.27	0.03
9	48	8.92	0.28	8.53	0.67	-0.39	0.65	-4.18	0.00012
10	41	9.96	0.29	9.86	0.68	-0.10	0.60	-1.11	0.28
11	20	10.96	0.28	10.78	0.71	-0.18	0.66	-1.20	0.24
12	29	12.05	0.25	11.74	0.69	-0.31	0.73	-2.29	0.03
13	15	13.04	0.21	12.33	1.03	-0.71	1.06	-2.58	0.02
14	14	13.90	0.25	12.81	0.63	-1.09	0.67	-6.11	< 0.0001
15	2	14.98	0.61	12.68	0.81	-2.31	0.21	-15.82	0.04

are expected to have a dental age between 11.7 and 14.6 years. Conversely, Italian girls of unknown age but characterized by Häävikko's dental age of 10 years are expected to be aged 10.5, with 90 per cent of them expected to be aged between 9.3 and 11.9 years. Italian boys with a dental age of 10 years are expected to be aged 10.7, with 90 per cent of them expected to be aged 10.7, with 90 per cent of them expected to be aged 5.1 and 11.8 years. From age 6 to 14 years, the interquartile range, which expresses interindividual variability, increases from 8.6 to 10.5 months in girls and from 7.1 to 14.2 months in boys.

#### Discussion

The aim of this study was to determine if Häävikko's maturation standards are applicable to Italian children. This method was used as it has not previously been tested in Italian children. It is based on the recognition of 12 radiographic stages of four reference teeth. The limited number of age stages is an advantage of Häävikko's method over that of Nolla (1960), which involves up to 40 stages and may result in decreased precision (Fanning, 1961; Maber *et al.*, 2006).



**Figure 1** Bland–Altman plot. The difference between the two ages (dental and chronological) is plotted against their mean (dental + chronological/2; dots). Black lines mark the 5th,  $50^{th}$ , and  $95^{th}$  centiles computed with the LMS (L = skewness, M = median, S = coefficient of variation) method.



**Figure 2** Centile curves defined for girls and boys using the LMS (L = skewness, M = median, S = coefficient of variation) method. Dental age estimated by Häävikko's standards is plotted against chronological age. Black lines show the 5th, 10th, 25th, 50th, 75th, 90th, and 95th centiles. The dotted line is the median in Häävikko's reference set where dental age is equal to chronological age.

The method devised by Demirjian *et al.* (1973) is the most widely used. Several studies have investigated whether it is suitable for populations which differ from French Canadians, such as Indian, British, German, Colombian, Belgian, Scandinavian, and Korean populations (Koshy and Tandon, 1998; Liversidge *et al.*, 1999; Frucht *et al.*, 2000; Caro and Contreras, 2001; Teivens and Mörnstad, 2001; Willems *et al.*, 2001; Prabhakar et al., 2002). The findings show that the difference was quite small for Norwegian children (Nykänen *et al.*, 1998), greater, but less than 1 year, for Finnish and Dutch children (Nyström *et al.*, 1986; Leurs *et al.*, 2005), and more than 1 year for Chinese children (Davis and Hägg, 1994).

A few investigations have evaluated the method of Demirjian *et al.* (1973) in Italian samples (Malagola *et al.*, 1989a,b; Leonardi *et al.*, 1990; Cameriere *et al.* 2008b). Leonardi *et al.* (1990) observed subjects with Cooley's disease, so their results cannot be compared with those in the present study. Malagola *et al.* (1989a,b) did not show the statistical correlation between chronological and dental age, but found the method to be inaccurate for Italian children, whose growth completion occurred earlier, while Cameriere *et al.* (2008b) found Demirjian's method to overestimate age in both girls and boys.

Zaborra and Terranova (1989) reported 'a very good conformity between chronological age and dental age' when

using maturation tables from the Forsyth Dental Center (Fanning, 1961) on 200 Italian children aged 7–14 years. Their statement seems somewhat questionable since approximately 20 per cent of their sample differed from the reference by 6 months or more and about 10 per cent by 1 year or more.

There are some interesting recent studies that have investigated a method for assessing chronological age by the measurement of dental apices (Cameriere *et al.*, 2006, 2008a; Cameriere and Ferrante, 2008). Those authors initially studied an Italian sample and subsequently widened their research to other European populations (Cameriere *et al.*, 2007). They concluded that further investigations should be carried out to compare the reliability of their method with these proposed by Demirjian *et al.* (1973) and Häävikko (1974).

While in the present study it was found that Häävikko's standards tended to underestimate chronological age in this Italian sample, both Malagola et al. (1989a,b) and Cameriere et al. (2008b) found that Demirjian's method tended to overestimate age in their Italian samples. These results may be explained by the fact that Häävikko's sample was based on Finnish children and Demirjian's sample on French Canadian children: dental maturation seems to occur earlier in Finns than in French Canadians (Nyström et al., 1986). Maber et al. (2006) also found that the method of Demirjian tended to overestimate while that of Häävikko underestimated chronological age in their sample. Maber et al. (2006), in their study of Bangladeshi and British Caucasian children, observed overestimation in age which is a common finding when a non-French population is evaluated (Nyström et al., 1986; Staaf et al., 1991; Davis and Hägg, 1994; Nykänen et al., 1998; Caro and Contreras, 2001; Teivens and Mörnstad, 2001; Leurs et al., 2005). Foti et al. (2003), on the other hand, found that the method of Demirjian underestimated age, but they studied a French European sample.

Maber *et al.* (2006) found Demirjian's method to be more accurate than Häävikko's method in their British and Bangladeshi samples, while Staaf *et al.* (1991) found the latter to be more suitable for their Scandinavian sample.

There was an increase in interindividual variability of Häävikko's dental age with chronological age in girls and, more markedly, in boys in the present study. Such an increase was also found by Nykänen *et al.* (1998) and Leurs *et al.* (2005) using the method of Demirjian. The increase in variability during the growth period is common to all anthrophometric traits, variability being proportional to the size of the trait (Nicoletti *et al.*, 2004).

Kappa values in the current study were in the range regarded as substantial (0.61–0.80) or almost perfect (0.81–1.00) agreement (Landis and Koch, 1977), with a global score of 0.95. These results are comparable with the data obtained by Maber *et al.* (2006) using Häävikko's method (kappa = 0.90) and by Maber *et al.* (2006) and Nykänen *et al.* (1998) employing Demirjian's procedure (0.86 and 0.73, respectively). Reventlid *et al.* (1996) found similar results using several other methods.

In the present study, it was observed that Häävikko's standards were not directly applicable to Italian children because the difference between dental and chronological age increased with the age of the subjects. Although direct use of Häävikko's standards was inappropriate, the centiles presented (Figure 2) could be used for the estimation of dental age in the Italian population. Two different approaches are possible. In forensic procedures, when the chronological age is unknown, dental age could be determined using the method of Häävikko (1974). The real age of the child is then estimated from the *y*-axis to the *x*-axis (Figure 2). For example, an Italian girl characterized by a dental age of 10 years according to Häävikko is expected, in 90 per cent of cases, to be between 9.3 and 11.9 years of age.

For clinical purposes, when the real age is known, the level of dental maturation can be determined: where the horizontal line corresponding to the estimated dental age obtained with Häävikko's method crosses the line of the chronological age (Figure 2). For example, an 11-yearold Italian boy with an estimated dental age of 10.1 years according to Häävikko's method is on the 25th centile, indicating delayed dental maturation.

#### Conclusions

Since direct use of Häävikko's standards may lead to misclassification of some subjects, the adjusted references (Figure 2) enable unbiased assessment of dental age for clinical purposes when it is useful to know if dental maturity is advanced or delayed. The centile curves presented in this study may also be useful for estimation of the chronological age of a child with an unknown birthdate.

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