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SECTION AGE ESTIMATION

A Comparative Evaluation Of The Applicability Of Two Adapted Häävikko Methods For Age Estimation Of 5-15 Year Old Indian Children

Sapna Hegde[1], Kanksha Shah[1], Uma Dixit

[1]*Department of Paediatric Dentistry, Pacific Dental College and Hospital, Udaipur, Rajasthan, India*
[2]*Department of Pediatric and Preventive Dentistry, Dr. D. Y. Patil Dental College and Hospital, Navi Mumbai, Maharashtra, India*
Corresponding author: ***drsapnahegde@yahoo.co.in***

The authors declare that they have no conflict of interest.

ABSTRACT
Dental age determination methods that require the assessment of all teeth are tedious and time-consuming. Adapted methods that assess fewer teeth may be more easily applicable. The present study compared the applicability of two adapted Häävikko methods which evaluate seven mandibular teeth (HAM1) and four reference teeth (HAM2) in a population of 5 to 15 year-old Indian children. The HAM1 method underestimated age by -0.17 ± 0.80 years, -0.29 ± 0.83 years and -0.22 ± 0.82 years in boys, girls and the total sample respectively, while the HAM2 method underestimated age by -0.34 ± 0.88 years, -0.51 ± 0.82 years and -0.41 ± 0.86 years in boys, girls and the total sample, respectively. Significant gender-based differences were observed in mean DA-CA with both methods ($p < 0.05$). While both methods could be used for age estimation of the present population, the HAM1 method was the more accurate of the two.

KEYWORDS: Häävikko method, Adapted Häävikko method, Age estimation, Indian children

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INTRODUCTION

As early as 1935, Schour and Hoffman[1] observed that the pattern of calcification of the dentition under normal conditions acts as a reliable indicator of the pattern of growth. Since then it has been established that dental development by reference to calcification of the developing teeth is an appropriate measure of dental maturity, having high reliability, low variability and resistance to environmental effects, and thereby, allowing for improved prediction of dental maturity.[2-5]

In an attempt to quantify the process of dental maturation from the first traces of cusp mineralization to closure of the root apex, different methods of staging have been suggested, such as the eight-stage, fifteen-stage, sixteen-stage and possibly forty-stage methods of Demirjian, Goldstein and Tanner,[6] Gleiser and Hunt,[7] Moorrees et al.[8] and Nolla,[9] respectively. It should be noted that the methods cited above differ regarding the teeth used for radiographic evaluation; for example, Gleiser and Hunt[7] evaluated the permanent mandibular first molar and Demirjian, Goldstein and Tanner[6] assessed the seven left permanent mandibular teeth (with the exception of the third molar), while Nolla[9] assessed all the permanent teeth in both the jaws.

Häävikko[10] utilized a modified version of the dental developmental stages of Gleiser and Hunt[7] with the number of stages reduced from 15 to 12 (six each for crown and root formation) to study the ages of tooth formation in Finnish children. From data derived by evaluating all the maxillary and mandibular teeth, Häävikko[10] constructed gender-specific tables of age medians and dispersions for each stage of tooth development. Age medians for each tooth assessed were summed and divided by the number of teeth assessed to directly give the dental age. In a later study,[11] the author concluded that it is possible to make reliable estimates of the dental age using only a few specific teeth.

Globally, the few studies testing the applicability of the Häävikko method have reported either age overestimations,[12,13] or underestimations[14-18] or both,[19] using fourteen[12] or seven[13,14] mandibular teeth, four reference teeth[15,16,18] or developing teeth of the left mandible.[19] Studies on Indian populations have been very few with sample sizes ranging from 75 to 660[20-22] and have employed either the original (using all maxillary and mandibular teeth)[20,21] or the adapted Häävikko[22] (using four reference teeth) methods. The dental literature does not contain any reports of comparisons between adaptations of the Häävikko method for applicability in age determination and hence, this study aimed to provide this information using two methods which evaluate seven mandibular teeth and four reference teeth on a population of 5 to 15 year-old Indian children.

MATERIALS AND METHODS

This study was designed as a cross-sectional observational study. Ethical clearance was obtained from the Ethical Committee, Pacific Dental College and Hospital, Udaipur, India (Ref. No. PDCH/13/EC-106). Parents/ guardians had signed an agreement with the dental institution that dental records and radiographs could be used only for

research and educational purposes without the possibility of personal identification.

Sampling method: A convenience sampling method was employed, all radiographs were captured during the period from January 2012 to September 2015 of children aged between 5.0 and 15.9 years who had sought treatment at the Department of Paediatric Dentistry, Pacific Dental College and Hospital, Udaipur, Rajasthan, India, and required an orthopantomograph (OPG) as part of the investigation protocol.

Inclusion criteria: Both parents of all the children included in the study were of Indian origin and nationality. Only patients with a documented date of birth and date of capture of the appropriate radiograph in the oral health record were included to facilitate verification of the chronological age (in completed years) for each subject.

Exclusion criteria: Panoramic radiographs showing image distortion due to improper position or movement of the patient during exposure, and incomplete image or lack of clarity resulting from an improper exposure technique were excluded. Also, radiographs were excluded from the study if the patient had any history of surgical/medical treatment or systemic illness with the potential to cause significantly delayed or early development, significant numbers of teeth other than third molars missing either congenitally or due to disease and trauma, malformation of teeth or obvious dental pathology that could affect tooth development.

Final sample: Of the 1303 radiographs collected, 103 did not meet the selection criteria owing to either congenital absence of several teeth (22), lack of image clarity (08) or inadequate information regarding the date of birth (73). Thus, a final sample of 1200 OPGS of 699 male and 501 female Indian children aged 5 to 15 years was selected for the study. The distribution of radiographs by age and gender is presented in Table 1. Radiographs of patients aged 5.0 to 5.9 years were included in age group 5, of those aged 6.0 to 6.9 years in age group 6 and so on. Thus, age group 15 consisted of children aged 15.0 to 15.9 years.

Calculation of chronological age: The dates of birth and of panoramic radiography were obtained from the hospital records. A function of Microsoft Excel was used to calculate the difference between the recorded date of birth and the date on which the panoramic radiograph was made, to obtain the chronological age (CA) in decimal years.

Data collection: All digital radiographs meeting the selection criteria were viewed on the same LCD monitor using a magnifying glass for improved visualization. Each OPG was coded with a numerical ID to avoid examiner bias. Age and sex of the subjects were thus unknown to the examiner. Nomenclature for teeth assessed was assigned according to the FDI system. In Häävikko's adapted method 1 (HAM1), seven mandibular teeth of the left side (excluding the third molar) were evaluated by Häävikko's dental staging method.[10] Once the stage that most accurately described the stage of development of the tooth in question was identified, the corresponding code was assigned to that tooth.

Table 1: Distribution of the study sample by age and gender

Chronological age (years)		Females		Males		Total	
Age group	Age range	N	%	N	%	N	%
5	5.0 - 5.9	24	4.79	23	3.29	47	3.92
6	6.0 - 6.9	39	7.78	40	5.72	79	6.58
7	7.0 - 7.9	46	9.18	58	8.30	104	8.67
8	8.0 - 8.9	50	9.98	58	8.30	108	9.00
9	9.0 - 9.9	55	10.98	78	11.16	133	11.08
10	10.0 - 10.9	55	10.98	100	14.31	155	12.92
11	11.0 - 11.9	40	7.98	82	11.73	122	10.17
12	12.0 - 12.9	55	10.98	91	13.02	146	12.17
13	13.0 - 13.9	57	11.38	82	11.73	139	11.58
14	14.0 - 14.9	59	11.78	58	8.30	117	9.75
15	15.0 - 15.9	21	4.19	29	4.15	50	4.17
Total sample	5.0 - 15.9	501	100	699	100	1200	100

These codes were converted to the gender-specific numerical scores (age medians) of Häävikko.[10] The individual scores were summed and divided by the number of teeth assessed to directly obtain the dental age in years. In adaptation 2 of Häävikko's original method (HAM2), the procedure remained the same with the exception that only four reference teeth were evaluated - 47, 46 (16), 44 and 41 for children aged 0 to 9 years and 47, 44, 13 and 43 for those aged 10 years and above.[11]

Reproducibility of measurements: Two well-trained examiners independently evaluated 100 radiographs using Häävikko's method of dental staging, after a period of mutual calibration without any knowledge of age or gender, in order to allow an analysis of inter-examiner agreement. Ultimately, a single examiner assessed all radiographs. Intra-examiner agreement was assessed by having one examiner re-evaluate the same 100 radiographs after a period of 2 months without any knowledge of gender or age or of the stages assigned in the first evaluation.

Data analysis: All statistical analyses and data management were performed using SPSS 19.0 (SPSS Inc., Chicago, IL, USA) for Windows and MS-Excel (Microsoft Office 2010). Analyses were made for each gender and age group, and for the total sample. Kolmogorov-Smirnov and Shapiro-Wilk tests were performed to test the normality of the data. As the sample size was less than 30 and having non-normal distribution in some age groups, non-parametric tests were indicated. However, to be consistent across the age groups, both parametric and non-parametric tests were applied. For all tests, a p value ≤ 0.05 was considered statistically significant.

Accuracy of each method of age estimation was determined by mean difference between estimated dental age and the chronological age (DA–CA) for each gender and age group, and the total sample. A positive result indicated an over-estimation, and a negative result indicated an under-estimation of age. Box-plot graphs are used to present the mean DA-CA of each gender and age group, and the total sample, with whiskers indicating the range. Absolute accuracy was determined by means of the absolute differences between DA and CA of girls and boys and the total sample for each method. Paired t test and Wilcoxon Signed Rank test were applied to assess the significance of DA-CA for both methods for each gender and age group, for the total sample and between methods. Independent t-test was employed for intra-method comparisons of DA-CA between genders. The correlation between DA and CA was analysed using Spearman's rank correlation coefficient for each gender and for the total study sample. Inter- and intra-examiner agreements are expressed as percentages. Cohen's kappa coefficient was used to calculate the degree of reliability of these agreements. Regression analyses were performed and gender-specific equations were derived for both the methods.

RESULTS

The mean age (± SD) of the entire sample was 10.75 ± 2.72 years, those of girls and boys being 10.68 ± 2.87 and 10.81 ± 2.60, respectively. Inter- and intra-examiner agreements were 86% and 93% respectively, with Kappa values of 0.81 and 0.90 indicating almost perfect agreement.

In the present study, the mean HAM1 dental ages obtained were 10.39 ± 2.93 years and 10.64 ± 2.80 years for girls and boys, respectively (Fig.1). The mean differences between dental and chronological ages for boys, girls and the total sample (-0.17 ± 0.80, -0.29 ± 0.83 and -0.22 ± 0.82 years, respectively) were statistically significant ($p < 0.05$). Significant differences between mean dental and chronological ages were observed in age groups 6, 7, 9, 10, 11, 12 and 15 for girls and 6, 7, 11, 12, 13 and 14 for boys ($p < 0.05$). In girls, the method underestimated age by -0.03 to -0.64 years in all age groups with the exception of group 14 for which an overestimation of +0.01 years was obtained. In boys, underestimations ranged from -0.15 to -0.61 years in most age groups, with

overestimations by +0.04 to +0.36 years in age groups 5, 13, 14 and 15 (Table 2).

Table 2: Comparison of chronological and HAM1 dental ages by gender and age

Gender	Age group (years)	N	Mean age ± SD (years)		Mean DA-CA (years)	p value*	p value#
			CA	DA			
GIRLS	5	24	5.46 ± 0.33	5.43 ± 0.70	-0.03 ± 0.65	0.811	0.808
	6	39	6.57 ± 0.32	6.37 ± 0.58	-0.20 ± 0.49	**0.014**	**0.010**
	7	46	7.52 ± 0.26	7.13 ± 0.82	-0.39 ± 0.87	**0.005**	**0.007**
	8	50	8.51 ± 0.31	8.42 ± 0.73	-0.09 ± 0.73	0.373	0.449
	9	55	9.48 ± 0.30	9.27 ± 0.77	-0.21 ± 0.81	**0.046**	**0.048**
	10	55	10.55 ± 0.32	10.04 ± 0.66	-0.51 ± 0.78	**< 0.001**	**< 0.001**
	11	40	11.44 ± 0.32	10.80 ± 0.77	-0.64 ± 0.91	**< 0.001**	**< 0.001**
	12	55	12.49 ± 0.32	12.00 ± 0.81	-0.49 ± 0.83	**< 0.001**	**< 0.001**
	13	57	13.46 ± 0.30	13.22 ± 0.89	-0.24 ± 1.04	0.087	0.105
	14	59	14.48 ± 0.28	14.49 ± 0.74	0.01 ± 0.83	0.911	0.623
	15	21	15.48 ± 0.27	15.00 ± 0.63	-0.48 ± 0.71	**0.005**	**0.007**
	Total	501	10.68 ± 2.87	10.39 ± 2.93	-0.29 ± 0.83	**< 0.001**	**< 0.001**
BOYS	5	23	5.56 ± 0.29	5.60 ± 0.61	0.04 ± 0.53	0.809	0.843
	6	40	6.52 ± 0.31	6.12 ± 0.61	-0.40 ± 0.61	**< 0.001**	**0.001**
	7	58	7.48 ± 0.29	7.18 ± 0.74	-0.30 ± 0.74	**0.002**	**0.004**
	8	58	8.47 ± 0.29	8.32 ± 0.71	-0.15 ± 0.77	0.136	0.103
	9	78	9.46 ± 0.28	9.30 ± 0.85	-0.16 ± 0.91	0.115	0.098
	10	100	10.45 ± 0.29	10.30 ± 0.79	-0.15 ± 0.87	0.082	0.051
	11	82	11.51 ± 0.30	10.90 ± 0.46	-0.61 ± 0.53	**< 0.001**	**< 0.001**
	12	91	12.44 ± 0.30	11.87 ± 0.68	-0.57 ± 0.76	**< 0.001**	**< 0.001**
	13	82	13.41 ± 0.31	13.77 ± 0.64	0.36 ± 0.68	**< 0.001**	**< 0.001**
	14	58	14.47 ± 0.31	14.83 ± 0.52	0.36 ± 0.62	**< 0.001**	**< 0.001**
	15	29	15.24 ± 0.25	15.30 ± 0.63	0.06 ± 0.70	0.646	0.721
	Total	699	10.81 ± 2.60	10.64 ± 2.80	-0.17 ± 0.80	**< 0.001**	**< 0.001**
Total sample		1200	10.75 ± 2.72	10.53 ± 2.86	-0.22 ± 0.82	**< 0.001**	**< 0.001**

**Paired t test, #Wilcoxon Signed Rank test: $p \leq 0.05$ = significant*

The mean HAM2 dental ages were 10.17 ± 2.74 years and 10.47 ± 2.63 years, for girls and boys, respectively (Fig.2). The mean differences between dental and chronological ages for boys, girls and the total sample (-0.34 ± 0.88, -0.51 ± 0.82 and -0.41 ± 0.86 years, respectively) were statistically significant ($p < 0.001$). Significant differences between mean dental and chronological ages were observed in all age groups ($p < 0.05$) except groups 5, 6 and 10 for girls and 6 and 8 for boys ($p > 0.05$). In girls, the HAM2 method underestimated age by -0.01 to -1.10 years in all age groups except group 5 for which an overestimation of +0.05 years was obtained. In boys, underestimations ranged from -0.05 to -0.74 years in most age groups, with overestimations by +0.28 and +0.05 years in age groups 5 and 6 (Table 3).

Significant gender-based differences were observed in mean DA-CA with both the HAM1 ($p < 0.05$) and HAM2 ($p < 0.001$) methods (Table 4). In girls, the differences between mean DA-CA obtained by the HAM1 and HAM2 methods were significant in most age groups ($p < 0.05$) with the exception of groups 5, 7, 10, 11 and 12 ($p > 0.05$). In boys, significant differences were observed in most age groups ($p < 0.05$) except group 11 and 12 ($p > 0.05$) (Table 5).

Although strong linear correlations between CA and DA were observed for both methods ($p < 0.001$) (Table 6), significantly lower DA-CA values were observed with the HAM1 method compared to the HAM2 method in girls, boys as well as in the total sample ($p < 0.001$) (Table 7).

Regression analyses were performed and the following equations were derived:
For the HAM1 method:
Males: $CA = -0.507 + 1.031 \times DA$
Females: $CA = -0.91 + 0.98 \times DA$
For the HAM2 method:
Males: $CA = 0.175 + 0.953 \times DA$
Females: $CA = 0.39 + 0.915 \times DA$

DISCUSSION

While several methods of dental age estimation have been introduced, some common drawbacks include complicated calculations for obtaining the dental age and increased number of stages that make assessments tedious and age estimations less accurate. The convenience of Häävikko's method lies in the fairly small number of stages that are used to assess dental development and in the simple addition of scores that is required to calculate dental age. Studies testing this method have variously used fourteen[12] or seven[13,14] mandibular teeth, four reference teeth,[15,16,18,22] all maxillary and mandibular teeth[21] or developing teeth of the left mandible.[19] Adapted methods that require the assessment of fewer numbers of teeth would make the age estimation process simpler and less time-consuming. Hence, the present study compared adapted Häävikko methods that utilize seven mandibular teeth and four reference teeth on a sample of

orthopantomographs of 1200 Indian children, 501 female and 699 male, aged 5 to 15 years, obtained by a convenience sampling method. This method is preferred by most researchers because it is fast, inexpensive, easy and the subjects are conveniently accessible.

Table 3: Comparison of chronological and HAM2 dental ages by gender and age

Gender	Age group (years)	N	Mean age ± SD (years)		Mean DA-CA (years)	p value*	p value#
			CA	DA			
GIRLS	5	24	5.46 ± 0.33	5.51 ± 0.76	0.05 ± 0.68	0.494	0.875
	6	39	6.57 ± 0.32	6.56 ± 0.82	-0.01 ± 0.62	0.508	0.599
	7	46	7.52 ± 0.26	7.11 ± 1.01	-0.41 ± 1.04	**0.025**	**0.022**
	8	50	8.51 ± 0.31	8.01 ± 1.01	-0.50 ± 0.95	**0.003**	**0.002**
	9	55	9.48 ± 0.30	8.99 ± 0.80	-0.49 ± 0.75	**<0.001**	**<0.001**
	10	55	10.55 ± 0.32	10.32 ± 0.96	-0.23 ± 0.89	0.086	0.159
	11	40	11.44 ± 0.32	11.21 ± 0.65	-0.23 ± 0.61	**0.025**	**0.036**
	12	55	12.49 ± 0.32	11.67 ± 0.63	-0.82 ± 0.70	**<0.001**	**<0.001**
	13	57	13.46 ± 0.30	12.36 ± 0.51	-1.10 ± 0.49	**<0.001**	**<0.001**
	14	59	14.48 ± 0.28	13.75 ± 0.85	-0.73 ± 0.74	**<0.001**	**<0.001**
	15	21	15.48 ± 0.27	14.83 ± 0.75	-0.65 ± 0.69	**<0.001**	**<0.001**
	Total	501	10.68 ± 2.87	10.17 ± 2.74	-0.51 ± 0.82	**<0.001**	**<0.001**
BOYS	5	23	5.56 ± 0.29	5.84 ± 0.64	0.28 ± 0.53	**0.011**	**0.014**
	6	40	6.52 ± 0.31	6.57 ± 0.99	0.05 ± 0.90	0.521	0.888
	7	58	7.48 ± 0.29	7.13 ± 0.89	-0.35 ± 0.83	**0.005**	**0.007**
	8	58	8.47 ± 0.29	8.35 ± 0.89	-0.12 ± 0.88	0.457	0.448
	9	78	9.46 ± 0.28	8.86 ± 0.90	-0.60 ± 0.83	**<0.001**	**<0.001**
	10	100	10.45 ± 0.29	10.00 ± 1.13	-0.45 ± 1.09	**<0.001**	**<0.001**
	11	82	11.51 ± 0.30	11.21 ± 1.09	-0.30 ± 1.05	**0.008**	**0.022**
	12	91	12.44 ± 0.30	12.36 ± 0.71	-0.08 ± 0.68	**0.002**	**0.020**
	13	82	13.41 ± 0.31	13.00 ± 0.64	-0.41 ± 0.62	**<0.001**	**<0.001**
	14	58	14.47 ± 0.31	13.86 ± 0.92	-0.61 ± 0.81	**<0.001**	**<0.001**
	15	29	15.24 ± 0.25	14.50 ± 0.73	-0.74 ± 0.69	**<0.001**	**<0.001**
	Total	699	10.81 ± 2.60	10.47 ± 2.63	-0.34 ± 0.88	**<0.001**	**<0.001**
Total sample		1200	10.75 ± 2.72	10.35 ± 2.68	-0.41 ± 0.86	**<0.001**	**<0.001**

Table 4: Intra-method comparison between genders of mean DA-CA

Gender	N	HAM1		HAM2	
		Mean DA-CA ± SD (years)	p value	Mean DA-CA ± SD (years)	p value
Girls	501	-0. 29 ± 0.83	**0.012**	-0.51 ± 0.82	**< 0.001**
Boys	699	-0.17 ± 0.80		-0.34 ± 0.88	

Independent t-test; p≤ 0.05 = significant

Table 5: Inter-method comparison of mean DA-CA by gender and age group

Age group	Girls					Boys				
	N	Mean DA-CA ± SD (years)		p value*	p value#	N	Mean DA-CA ± SD (years)		p value*	p value#
		HAM1	HAM2				HAM1	HAM2		
5	24	-0.03 ± 0.65	0.05 ± 0.68	0.412	0.250	23	0.04 ± 0.53	0.28 ± 0.53	**<0.001**	**<0.001**
6	39	-0.20 ± 0.49	-0.01 ± 0.62	**0.020**	**0.002**	40	-0.40 ± 0.61	0.05 ± 0.90	**0.002**	**<0.001**
7	46	-0.39 ± 0.87	-0.41 ± 1.04	0.642	0.566	58	-0.30 ± 0.74	-0.35 ± 0.83	0.922	**0.023**
8	50	-0.09 ± 0.73	-0.50 ± 0.95	**0.029**	0.333	58	-0.15 ± 0.77	-0.12 ± 0.88	0.497	**0.014**
9	55	-0.21 ± 0.81	-0.49 ± 0.75	**0.016**	0.235	78	-0.16± 0.91	-0.60 ± 0.83	**<0.001**	0.121
10	55	-0.51 ± 0.78	-0.23 ± 0.89	0.391	0.121	100	-0.15 ± 0.87	-0.45 ± 1.09	**0.013**	0.281
11	40	-0.64 ± 0.91	-0.23 ± 0.61	0.487	0.196	82	-0.61 ± 0.53	-0.30 ± 1.05	0.312	0.189
12	55	-0.49 ± 0.83	-0.82 ± 0.70	0.069	0.166	91	-0.57 ± 0.76	-0.08 ± 0.68	0.358	0.075
13	57	-0.24 ± 1.04	-1.10 ± 0.49	**<0.001**	**<0.001**	82	0.36 ± 0.68	-0.41 ± 0.62	**<0.001**	**<0.001**
14	59	0.01 ± 0.83	-0.73 ± 0.74	**<0.001**	**<0.001**	58	0.36 ± 0.62	-0.61 ± 0.81	**<0.001**	**<0.001**
15	21	-0.48 ± 0.71	-0.65 ± 0.69	**<0.001**	**<0.001**	29	0.06 ± 0.70	-0.74 ± 0.69	**<0.001**	**<0.001**
Total	501	-0.29 ± 0.83	-0.51± 0.82	**<0.001**	**<0.001**	699	-0.17 ± 0.80	-0.34 ± 0.88	**<0.001**	**<0.001**

**Paired t test, #Wilcoxon Signed Rank test: p ≤ 0.05 = significant*

Table 6: Correlation between chronological and dental ages by method

Method	r / p values	Females	Males	Total sample
HAM1	r value	0.962	0.959	0.961
	p value	**< 0.001**	**< 0.001**	**< 0.001**
HAM2	r value	0.855	0.851	0.853
	p value	**< 0.001**	**< 0.001**	**< 0.001**

Spearman's rank correlation coefficient: r = Spearman's rho, p = significant

Table 7: Comparison of accuracy of HAM1 and HAM2 methods

Gender	N	HAM1		HAM2		HAM 1 vs 2				
		Mean DA-CA ± SD (years)	Absolute Difference	Mean DA-CA ± SD (years)	Absolute difference	I – II ± SD (years)	Absolute Difference	95% CI	p value*	p value#
Girls	501	- 0.29 ± 0.83	0.67	-0.51±0.82	0.79	0.22±1.09	0.81	-0.303 to -0.111	**<0.001**	**<0.001**
Boys	699	- 0.17 ± 0.80	0.68	-0.34±0.88	0.76	0.16±1.14	0.86	-0.427 to 0.144	0.330	**<0.001**
Total	1200	- 0.22 ± 0.82	0.71	-0.41±0.86	0.77	0.18±1.12	0.84	-0.391 to 0.053	0.135	**<0.001**

**Paired t test, #Wilcoxon Signed Rank test; p≤ 0.05 = significant*

Unlike the developing maxillary permanent teeth whose radiographic views are often obstructed by bony structures of the maxilla, the teeth of the mandible are quite clearly visible in an some previous OPG. Hence, only the mandibular teeth were evaluated in the present study unlike some previous studies.[6,9] Against the background that it is already well-established that a very high degree of symmetry exists between the teeth of the left and right sides,[6,9,23] only the seven mandibular teeth of the left quadrant were assessed. Third molar tooth germs were excluded from assessment because of the high degree of variability observed in third molar genesis and development.[24,25]

Whilst assessing dental age, it is important to consider the proximity of the estimated age to the actual or chronological age as well as the reproducibility of the age estimation method. In the present study, agreements between and within examiners for Häävikko's method of dental staging were obtained in percentages and measured by Cohen's kappa coefficient. This coefficient is a more robust measure rather than a simple percent agreement calculation, taking into account the agreement occurring by chance.[26] Kappa values for inter- and intra-examiner agreements in the present study were 0.81 and 0.90, respectively. Other studies have reported similar values of 0.84[19] and 0.95,[16] and 0.85[15] and 0.90[19] for inter- and intra-examiner agreements, respectively.

Studies testing Häävikko's method have reported over-estimations of mean age by +0.5 (m) and +1.0 (f) years[12] and by +0.50 (m) and + 0.50 (f) years[13] in Croatian children, and under estimations by -0.94 (m) and -1.59 (f) years,[18] -0.60 (m) and -0.80 (f) years,[14] -0.56 (m) and -0.79 (f) years,[17] -0.09 (m) and -0.23 (f) years[15] and -0.29 (m) and -0.41 (f) years[16] in Malay,[18] Turkish,[14] British Caucasian and Bangladeshi,[17] Bosnian-Herzegovian[15] and Italian[16] children, respectively. Mean over- and under-estimations of +0.07 (m) and -0.19 (f) years, respectively, have been reported in Chinese[19] children.

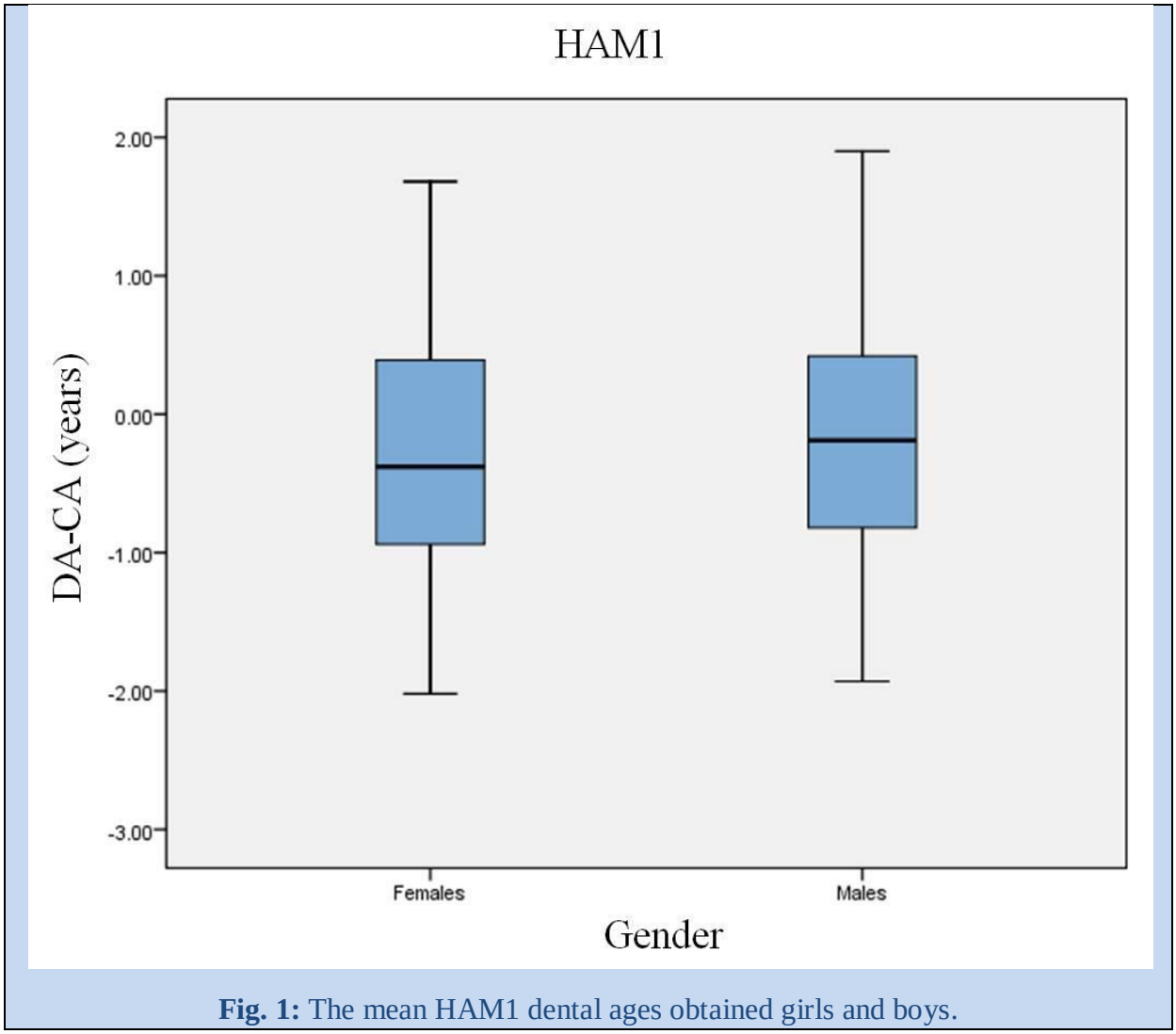

Fig. 1: The mean HAM1 dental ages obtained girls and boys.

Studies on Indian populations have reported mean over-estimations of +0.04 (m) and +0.03 (f) years[20] and under-estimations of -1.78 (m) and -2.12 (f) years[21] and -2.84 (m) and -2.96 (f) years.[22] Two of these studies had very small sample sizes of 75 and 102.[20,21] In the present study, under-estimations of age by -0.17 (m) and -0.29 (f) years were obtained with the seven-teeth method, with significantly higher under-estimations in girls compared to boys. With the four-teeth method, under-estimations of age by -0.34 (m) and -0.51 (f) years were obtained, the under-estimations again being significantly higher in girls than in boys. This gender difference has been attributed to the faster biological and dental maturation in girls, which leads to a higher dental compared to chronological age.[27] However, some other studies[28,29] have reported a higher dental age compared to chronological age in boys than in girls.

In the present study, while strong linear correlations between CA and DA were observed for both methods, the seven-teeth

method was more accurate in age estimation than the four-teeth method in girls, boys as well as in the total sample. This would indicate that the accuracy of a method increases when more teeth are examined. However, the accuracy or precision of an age estimating method is also affected by the quality of the reference material (sample), reliability of the method and biological variability in dental development.[12,30] Hence, it is important to accept that no age estimation method can predict the exact age of every individual. While differences between chronological and estimated ages of upto 12 months can be considered to be within normal standards,[31] smaller intervals are desirable.[32] In the present study, mean prediction errors ranged from 2.04 to 6.12 months with both methods.

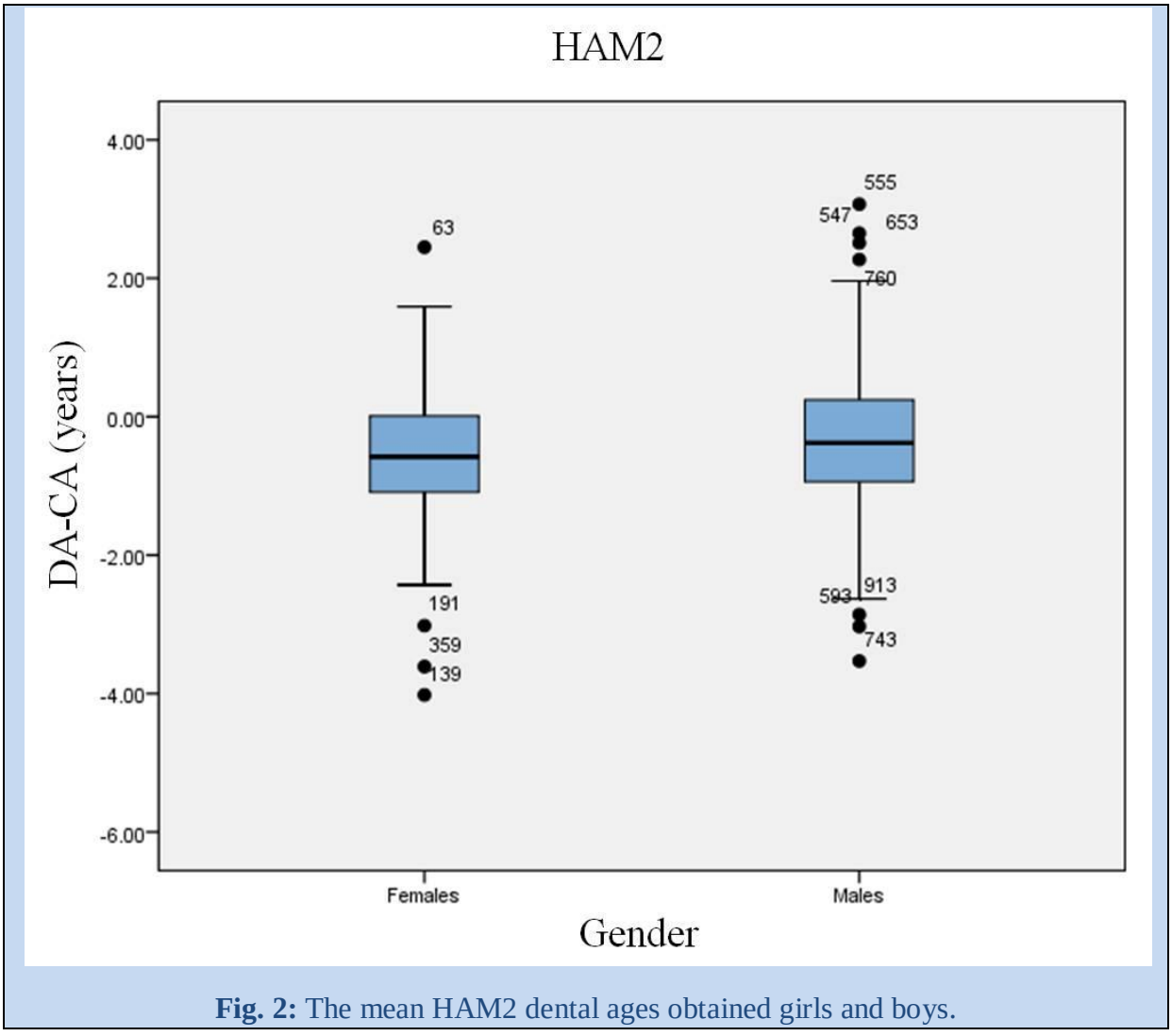

Fig. 2: The mean HAM2 dental ages obtained girls and boys.

CONCLUSIONS

From the results of the present study, it could be concluded that Häävikko's seven-teeth and four-teeth methods underestimated the age of the population studied. While both methods could be used for age estimation of the present population, the former was the more accurate of the two.

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