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ORIGINAL ARTICLE

Dental age assessment by tooth emergence counts its chronological age predictive value in normal occlusion Bogotanians (mestizos)

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ABSTRACT

Objective: (1) To test Hägg–Taranger's method of dental age assessment (DAA) in Bogotanian children comparing findings by sex with Swedishes' standards and (2) to investigate its chronological age predictive value for identification purposes.

Material and methods: Dental age was assessed in 5–14-year-old Bogotanians, 2075 girls and 2032 boys and compared with the method's standards. For statistical analysis, matched-pair signed-rank tests were used, and a regression model was used for investigating value as chronological age predictor from dental age.

Results: No significant difference was found between means of dental ages of Bogotanians and Swedishes, except for the lower central incisors' and second molars' emergences. Differences by sex between dental age means were seen at all stages especially, in mixed dentition ($p<.01$), being Bogotanian girls earlier maturers than boys. The established regression model as chronological age predictor, was tested by the coefficient of determination, which was found $r^2=0.979$ for girls, and 0.957 for boys.

Conclusions: Sexual dimorphism in dental age suggests Hägg–Taranger's method for identification by sex at mixed dentition. Additionally, high coefficients of determination show its reliability as chronological age predictor for ages from 5 to 12 years in girls, and to 13 years in boys.

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Biologic age; dental age assessment; tooth formation and emergence timing; chronological age predictor; necropsy identification

Introduction

Several methods for interpretation of tooth maturation in radiographs have been described, and tested in different populations although, validity and accuracy varies among them [1–4]. On the other hand, Björk, Kreps and Solow described dental maturation by dental stages of eruption (DSs), five for anterior teeth and four for molars [5], classification that was used as dental development criterion by Hägg in Swedishes in a longitudinal study [6]. Afterwards, using the same sample, Hägg and Taranger developed a method of dental age assessment (DAA) by means of 28 indicators, based on counts of the total emerged and/or erupted permanent teeth in 5–16-year-old children. Relationships of the index, so obtained, to various features of somatic development at puberty, and skeletal maturity were studied finding statistically significant correlation coefficients only in girls [7], as also reported in other studies [8]. Regardless of the method or system selected, dental age has become the indicator most used in children in:

- Chronological age estimation when date of birth is unknown [9];
- Studies of growth disturbances and syndromes [10];
- Necropsy identification and forensic purposes [11].

Currently, due to world-wide political unrests conducive to diaspora, immigration policies and international adoptions, the chronological age of a child under scrutiny has become paramount for identification purposes

Therefore, the aim of the present study was twofold: first, to test Hägg–Taranger's method of DAA in Bogotanian children comparing findings, by sex, with Swedish standards of the method, and second, to investigate its predictive value of chronological age for identification purposes.

Materials and methods

Sample of the present cross-sectional study was history charts of 2075 girls and 2032 boys pertaining to children of 5–16 years of age with an urban background, at least for two generations, similar socio-economic level, pertaining to working and middle class, and an ethnic mestizo background that attended for dental consultation to the Pediatric Clinic of Colsubsidio in Bogota from 1994 to 1996. Dental eruption stage was registered by counting erupted teeth, except for third molars, by the examiners four Orthodontists, who had passed inter and intracalibration tests in 15 plaster models at various DSs (differences were found not significant statistically ($p \leq .01$)). Criterion for tooth emergence was that at least, 2 mm of the incisal edge and/or molar cusp was visible at

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clinical examination, and dental age was assessed according to Hägg–Taranger's method.

A subsample of 149 girls and 150 boys with normal occlusion out of the 4107 examined, were selected for studying the predictive value of chronological age from dental age assessed by the method tested. Criteria for exclusion were traits associated with crowding, as premature loss of a deciduous tooth [12,13]. Furthermore, by panoramic radiographic observation, dental anomalies as persistence of temporal teeth due to anquilosis, and the presence of aplasia, impacted, ectopic and supernumerary teeth in permanent dentition, were also identified, and registered, not only as malocclusion traits, but also, risk factors for arresting normal eruption in the future [14,15]. IRB Committee approved the project by statements DME-042-99 and DA-48-99.

For statistical analysis, a normal curve was chosen as model for the sampling distribution, and a matched-pair signed-rank test was applied by calculating the standard error of the difference *s diff* of the means of both Bogotanians and Swedishes groups. A magnitude of *z* ($\geq$2.58) was selected in order to find out whether statistical difference existed between their means at a level of confidence of 99% ($p \leq .01$). Under the same criteria, this test was also used to compare means of dental ages rendered by the Bogotanian girls and boys, and to define in which of their indicators, the difference with chronologic age would be minimal. Additionally, a linear regression analysis was used for predicting chronologic age scores from the known values of dental age given by the Hägg–Taranger method's indicators (Y'). Thus, one special use of the general algebraic formula for a straight line was selected to minimized the square deviations between the regression line (predicted scores), and the obtained scores (X_j) (Equation (1)):

$$Y' = a + b_1x_1 + \ldots + b_kx_k \quad (1)$$

where Y': predicted chronologic age; X_j: jth predictor indicator of dental age $j = 1, 2, \ldots, k$; b_j: regression coefficient associated with jth predictor (rate of change in Y per unit of change of X); a: constant for each indicator; k: number of predictor indicators of dental age used: 0, 2, 8, 12, 16, 18, 24, 26 and 28.

Then, the established regression model was tested by the coefficient of determination r^2 (Equation (2)):

$$r^2 = \text{explained variation} = \sum (Y\prime - Y')^2 \quad (2)$$

$$\text{total variation} \sum (Y - Y')^2$$

In addition, by squaring and summing up the deviations of the scores around the regression line $\sum(Y - Y')^2$, being Y' the predicted chronological age and Y the observed chronologic age, the residual variance was calculated: $\sum(Y - Y')^2/n$, and its square root made possible the standard error of estimate ($s\ est\ y$)$=sy_{\surd}1 - r^2$ [16].

Table 1. Comparison of dental ages between 2075 Bogotanian girls and 2032 boys from 5 to 14 years of age by Hägg–Taranger's method*.

	Girls					Boys							
	Chronological age					Chronological age							
Emerged teeth	*n*1	%	Mean	*s*1	$s1^2$	*n*2	%	Mean	*s*2	$s2^2$	*X*1–*X*2 *x*\bar	Standard difference of means	*Z* *x*\bar/st.diff.
0	148	7.13	5.50	0.42	0.18	158	7.78	5.50	0.43	0.18	0.00	0.049	0.00
1	17	0.82	5.90	0.55	0.30	14	0.69	6.50	0.92	0.85	−0.60	0.280	−2.14
2	138	6.65	6.20	0.63	0.40	40	1.97	6.00	0.49	0.24	0.20	0.094	2.12
3	12	0.58	6.00	0.40	0.16	18	0.89	6.50	0.66	0.44	−0.50	0.194	−2.58
4	31	1.49	6.20	0.58	0.34	31	1.53	6.40	0.57	0.32	−0.20	0.146	−1.37
5	19	0.92	6.40	0.70	0.49	19	0.94	6.60	0.54	0.29	−0.20	0.203	−0.99
6	55	2.65	6.70	0.69	0.48	66	3.25	6.80	0.83	0.69	−0.10	0.138	−0.72
7	23	1.11	6.90	0.82	0.67	23	1.13	7.20	0.86	0.74	−0.30	0.248	−1.21
8	49	2.36	7.10	0.76	0.58	43	2.12	7.50	0.74	0.55	−0.40	0.157	−2.55
9	32	1.54	7.60	1.01	1.02	28	1.38	7.70	0.83	0.69	−0.10	0.238	−0.42
10	82	3.95	7.50	0.68	0.46	112	5.51	7.90	0.84	0.71	−0.40	0.109	−3.66**
11	53	2.55	8.10	0.90	0.81	57	2.81	8.60	0.78	0.61	−0.50	0.161	−3.10**
12	229	11.04	8.47	0.97	0.94	240	11.81	9.20	1.08	1.17	−0.73	0.095	−7.71**
13	44	2.12	9.50	0.92	0.85	54	2.66	10.00	0.88	0.77	−0.50	0.183	−2.73**
14	35	1.69	9.70	0.75	0.56	45	2.21	10.20	1.12	1.25	−0.50	0.210	−2.39
15	27	1.30	9.90	0.69	0.48	27	1.33	10.30	0.83	0.69	−0.40	0.208	−1.93
16	18	0.87	10.40	1.18	1.39	28	1.38	11.10	1.32	1.74	−0.70	0.374	−1.87
17	23	1.11	10.40	0.81	0.66	24	1.18	11.00	0.98	0.96	−0.60	0.262	−2.29
18	27	1.30	10.50	1.02	1.04	40	1.97	11.00	1.09	1.19	−0.50	0.261	−1.91
19	32	1.54	10.60	0.96	0.92	34	1.67	11.00	0.87	0.76	−0.40	0.226	−1.77
20	39	1.88	10.90	1.18	1.39	29	1.43	11.20	1.38	1.90	−0.30	0.318	−0.94
21	28	1.35	10.90	1.17	1.37	26	1.28	11.80	1.26	1.59	−0.90	0.332	−2.71**
22	34	1.64	11.30	1.30	1.69	22	1.08	11.70	0.89	0.79	−0.40	0.293	−1.37
23	30	1.45	11.40	0.98	0.96	29	1.43	12.10	1.00	1.00	−0.70	0.258	−2.71**
24	55	2.65	12.20	1.84	3.39	58	2.85	12.00	0.97	0.94	0.20	0.279	0.72
25	37	1.78	12.60	1.66	2.76	36	1.77	12.30	1.53	2.34	0.30	0.373	0.80
26	80	3.86	13.20	1.97	3.88	75	3.69	13.00	1.53	2.34	0.20	0.282	0.71
27	116	5.59	13.90	1.96	3.84	81	3.99	14.20	1.94	3.76	−0.30	0.282	−1.06
28	562	27.08	14.40	1.79	3.20	575	28.30	14.70	1.62	2.62	−0.30	0.101	−2.96**
*N*1	2075					2032						*x*\bar=0.75 ≈>9 mo.	*z*= ±2.58
Hägg–Taranger, 1984*													$p \leq .01$

*Authorship of the method used for dental age assessment; **level of confidence at 1% (*p* value).

Table 2. Chronological ages at tooth emergence timing by Hägg–Taranger's* method in 4107 Bogotanian girls and boys from 5 to 14 years.

Girls								Boys						
	Chronological age				Stand. error	.01 level	Score interval	Chronological age				Stand. error	.01 level	Score interval
Erupted tooth	Mean *X*1	*S*1	*N*1 = 2075	$\sqrt{N1}$	Means distribution	Confidence	Range	Mean *X*2	*s*2	*N*2 = 2032	$\sqrt{N2}$	Means distribution	Confidence	Range
0	5.50	0.42	148	12.17	0.03	0.09	≈2 mo.	5.50	0.43	158	12.57	0.03	0.09	≈2 mo.
1	5.90	0.55	17	4.12	0.13	0.34	≈8 mo.	6.50	0.92	14	3.74	0.25	0.63	≈15 mo.
2	6.20	0.63	138	11.75	0.05	0.14	≈3 mo.	6.00	0.49	40	6.32	0.08	0.20	≈5 mo.
3	6.00	0.40	12	3.46	0.12	0.30	≈7 mo.	6.50	0.66	18	4.24	0.16	0.40	≈10 mo.
4	6.20	0.58	31	5.57	0.10	0.27	≈6 mo.	6.40	0.57	31	5.57	0.10	0.26	≈6 mo.
5	6.40	0.70	19	4.36	0.16	0.41	≈10 mo.	6.60	0.54	19	4.36	0.12	0.32	≈8 mo.
6	6.70	0.69	55	7.42	0.09	0.24	≈6 mo.	6.80	0.83	66	8.12	0.10	0.26	≈6 mo.
7	6.90	0.82	23	4.80	0.17	0.44	≈11 mo.	7.20	0.86	23	4.80	0.18	0.46	≈11 mo.
8	7.10	0.76	49	7.00	0.11	0.28	≈7 mo.	7.50	0.74	43	6.56	0.11	0.29	≈7 mo.
9	7.60	1.01	32	5.66	0.18	0.46	≈11 mo.	7.70	0.83	28	5.29	0.16	0.40	≈10 mo.
10	7.50	0.68	82	9.06	0.08	0.19	≈5 mo.	7.90	0.84	112	10.58	0.08	0.20	≈5 mo.
11	8.10	0.90	53	7.28	0.12	0.32	≈8 mo.	8.60	0.78	57	7.55	0.10	0.27	≈6 mo.
12	8.47	0.97	229	15.13	0.06	0.17	≈4 mo.	9.20	1.08	240	15.49	0.07	0.18	≈4 mo.
13	9.50	0.92	44	6.63	0.14	0.36	≈9 mo.	10.00	0.88	54	7.35	0.12	0.31	≈7 mo.
14	9.70	0.75	35	5.92	0.13	0.33	≈8 mo.	10.20	1.12	45	6.71	0.17	0.43	≈10 mo.
15	9.90	0.69	27	5.20	0.13	0.34	≈9 mo.	10.30	0.83	27	5.20	0.16	0.41	≈10 mo.
16	10.40	1.18	18	4.24	0.28	0.72	≈17 mo.	11.10	1.32	28	5.29	0.25	0.64	≈15 mo.
17	10.40	0.81	23	4.80	0.17	0.44	≈11 mo.	11.00	0.98	24	4.90	0.20	0.52	≈12 mo.
18	10.50	1.02	27	5.20	0.20	0.51	≈6 mo.	11.00	1.09	40	6.32	0.17	0.44	≈11 mo.
19	10.60	0.96	32	5.66	0.17	0.44	≈11 mo.	11.00	0.87	34	5.83	0.15	0.38	≈9 mo.
20	10.90	1.18	39	6.24	0.19	0.49	≈12 mo.	11.20	1.38	29	5.39	0.26	0.66	≈16 mo.
21	10.90	1.17	28	5.29	0.22	0.57	≈14 mo.	11.80	1.26	26	5.10	0.25	0.64	≈15 mo.
22	11.30	1.30	34	5.83	0.22	0.58	≈14 mo.	11.70	0.89	22	4.69	0.19	0.49	≈12 mo.
23	11.40	0.98	30	5.48	0.18	0.46	≈11 mo.	12.10	1.00	29	5.39	0.19	0.48	≈12 mo.
24	12.20	1.84	55	7.42	0.25	0.64	≈15 mo.	12.00	0.97	58	7.62	0.13	0.33	≈8 mo.
25	12.60	1.66	37	6.08	0.27	0.70	≈17 mo.	12.30	1.53	36	6.00	0.26	0.66	≈16 mo.
26	13.20	1.97	80	8.94	0.22	0.57	≈14 mo.	13.00	1.53	75	8.66	0.18	0.46	≈11 mo.
27	13.90	1.96	116	10.77	0.18	0.47	≈11 mo.	14.20	1.94	81	9.00	0.22	0.56	≈14 mo.
28	14.40	1.79	562	23.71	0.08	0.19	≈4 mo.	14.70	1.62	575	23.98	0.07	0.17	≈4 mo.
						0.25= 6 mo. range							0.25 = 6 mo. range	
					sx\bar= *s*1/$\sqrt{N1}$	*z*=±2.58						*sx\bar*=*s*2/$\sqrt{N2}$	*z*=±2.58	
Hägg–Taranger, 1984*														

*Authorship of the method used for dental age assessment that is Hagg- Taranger

Table 3. Chronological age prediction in 1306 girls and 1257 boys by the Hägg–Taranger method.

Chronological age				Girls Dental age				Predicted Chronolog.Age	Stand. error
Index	NY	Mean *Y*	Stand.Dev.	NX	Mean *X*	Stand.Dev.	*A*	*Y′*	$sy\sqrt{1-r^2}$
0	148	5.50	0.42	12	5.32	0.195	–0.2051	5.08	0.08358
2	138	6.20	0.63	18	5.93	0.351	–0.2980	5.60	0.12537
8	49	7.10	0.76	15	7.35	0.441	0.2153	7.53	0.15124
12	229	8.70	0.97	15	8.47	0.391	–0.2700	8.16	0.19303
16	18	10.40	1.18	18	10.05	0.370	–0.3974	9.60	0.23482
18	27	10.50	1.02	18	10.59	0.656	0.0400	10.58	0.20298
24	55	12.20	1.84	19	11.80	0.428	–0.4557	11.28	0.36616
26	80	13.20	1.97	14	12.79	0.397	–0.4704	12.25	0.39203
28	562	14.40	1.79	20	13.85	0.417	–0.6154	13.16	0.35621
	1306			149					
b_{xy}	0.99528	Regression	Coefficient			r^2	Coefficient of determination		0.9792428
						$\sqrt{1-r^2}$			0.199

Chronological age				Boys Dental age				Predicted chronological age	Stand. error
Index	NY	Mean *Y*	Stand.Dev.	NX	Mean *X*	Stand.Dev.	*A*	*Y′*	$sy\sqrt{1-r^2}$
0	158	5.50	0.43	15	5.37	0.221	–0.1858	5.12	0.104533
2	40	6.00	0.49	13	6.10	0.353	0.0366	6.07	0.119119
8	43	7.50	0.74	14	7.75	0.422	0.1695	7.83	0.179894
12	240	9.20	1.08	15	9.58	0.348	0.2805	9.76	0.262548
16	28	11.10	1.32	18	10.68	0.413	–0.5310	10.03	0.320892
18	40	11.00	1.09	15	11.14	0.432	0.0242	11.04	0.264979
24	58	12.00	0.97	22	12.49	0.331	0.3602	12.72	0.235807
26	75	13.00	1.53	18	13.30	0.282	0.1618	13.32	0.371943
28	575	14.70	1.62	20	14.33	0.305	–0.5189	13.66	0.393822
	1257			150					
b_{xy}	0.98961	Regression	Coefficient			r^2	Coefficient of determination		0.957915
									0.2431

Results

Null hypothesis of no difference between means of chronological and dental ages of Bogotanians and Swedishes by Hägg–Taranger's method was accepted since values of *z* were found $\leq$2.58 for sample distribution at 0.01 level of confidence. Ranges of chronological age score interval were $\leq$12 months for both boys and girls in 20 out of the 28 possible indicators of tooth emergence counts.

When compared by sex, means of chronological age in Bogotanians turned out to be different from 0 ($p<.01$), being larger in boys than in girls, at all stages of eruption, i.e. boys matured later than girls. Although, *z* value of means differences of dental age was found only >2.58 between girls and boys at early mixed dentition indicators (*8–14*). On the other hand, ranges within it is expected the two population mean to lie at the 1% level of confidence, i.e. range of chronological age score interval, were from 6 months to $\leq$12 months for most of the stages, and >12 months but $\leq$17 months at lower cuspid (*16*), lower and upper second bicuspid, and upper canine (*20–24*), and lower second molar emergences (*25,26*) (Tables 1 and 2).

The established regression model for Hägg–Taranger's indicators, as chronological age predictors, was also tested by the coefficient of determination, which was found as high as r^2=0.979 for girls, and 0.957 for boys, i.e. 97% of variance of its predicted chronological ages explained the total variance of the population mean $\sum(Y - Y\backslash bar)^2$. Additionally, the square root of the variance around the regression line (standard error of estimate = $sy\sqrt{1-r^2}$) was less than 25% in most of the indicators, which suggests that only this proportion of variance was not associated with the variance of the other system, thus a reduction of 75% in errors in prediction of chronological age could be expected over predictions based on chance alone (Table 3).

Discussion

Secular trends in acceleration or retardation of dental development have been reported by other methods when tested in different populations from the original [17]. Although, dental age of Bogotanians (mestizos) did not show great differences as compared with Swedishes' in the present study. Only at final stages of the 28 indicators studied, chronological age was overrated, i.e. children were judged older than they actually were, as tooth formation advanced towards total root development and full eruption, which would advise the use of other methods pending on the developmental level of dental [18], and skeletal structures of the child in question [19].

Sexual dimorphism has been seen in dental age, i.e. boys matured later than girls [20]. Indeed, in the present study, *z* value of means differences of dental age by sex was found >2.58 at early mixed dentition indicators, and at late mixed dentition for lower second bicuspid emergence, and at the last possible stage, upper second molar eruption. Therefore, the method tested might be applied for identification purposes, as regards sex, in children at mixed and permanent dentitions, excluding third molars. Extrapolating to clinics, dental age should be the criterion, not chronological age, for an earlier orthodontic intervention in girls as compared with boys for a non-extraction approach by the use of the 'E' space preservation and/or first molar distalization [21–23].

The great variability of DAA based on Björk's nine stages of eruption (DSs), and tested by Hägg–Taranger in 1982, seems to have been related to greater exposure to environmental factors, as development of dentition and occlusion go into more mature stages [24]. Therefore, in the present study, a rigorous proceeding was followed for ensuring an accurate prediction of chronological age from dental age, starting with the subsample configuration that coped with randomization, i.e. the 149 girls and 150 boys with normal occlusion, which excluded possible bias of asymmetric patterns of eruption [25,26], and the need of being adjusted systematically, as warned by Hägg.

The ethics of taking radiographs purely for identification is closely questioned since any exposure to radiation brings with it a health risk to the child that should be balanced by a benefit [27]. Conversely, dental stage of eruption registration by clinical examination, which requires no X-ray exposure, makes of Hägg–Taranger's method not only an efficient system especially for population screenings, but also reliable for DAA. Furthermore, the information given was in detail, in spite of the fact that time elapsed between some stages is, actually, short in duration when cuspids, and bicuspids emerge into the oral cavity (from indicator *13* to *24*).

To conclude, the Hägg–Taranger method of DAA is a reliable predictor of chronological age in children, as found in the present study, and can contribute in identification tasks. Complementary biometric studies are advised, as cephalometrics, tooth size, dental arch length and width standards to cope with identification of alive and deceased children.

Conclusions

Dental age of Bogotanians (mestizos) did not show great differences as compared with Swedishes' in the present study, in spite of differences in race, and/or environmental factors.

Sexual dimorphism was seen in dental age, i.e. boys matured later than girls. Therefore, the method tested might be applied for identification purposes, as regards sex, at mixed and permanent dentitions, excluding third molars.

The high proportion of the coefficient of determination (r^2) is a criterion of reliability of the tested system when used as predictor of chronological age in children from 5 to 12 years in girls, and to 13 years in boys.

Disclosure statement

No potential conflict of interest was reported by the authors.

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