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TECHNICAL NOTE

ODONTOLOGY; ANTHROPOLOGY

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Age Estimation by Measurements of Developing Teeth: Accuracy of Cameriere's Method on a Brazilian Sample

ABSTRACT: Developing teeth are commonly the criteria used for age estimation in children and young adults. The method developed by Cameriere et al. (Int J Legal Med 2006;120:49-52) is based on measures of teeth with open apex, and application of a formula, to estimate chronological age of children. The present study evaluated a sample of panoramic radiographs from Brazilian children from 5 to 15 years of age, to evaluate the accuracy of the method proposed by Cameriere et al. The results has proven the system reliable for age estimation, with a median residual error of −0.014 years between chronological and estimated ages ($p = 0.603$). There was a slight tendency to overestimate the ages of 5–10 years and underestimate the ages of 11–15 years.

KEYWORDS: forensic science, forensic odontology, human identification, age estimation, teeth, method

Age estimation plays a key role in the human identification process, guiding police investigations. In a mass disaster, the accurate age estimation narrows the search within the possible victims (1). In living people, especially in children and juveniles, age estimation is required for civil purposes like adoption (2), or criminal reasons, as to determine whether the accused is underaged (3).

Among the methods of age assessment for nonadults, dental development has been strongly recommended (2,4,5). In addition to following a regular sequence of formation and eruption, dental structures do not undergo mineral remodeling as in bones and are only slightly affected by nutritional or hormonal variation (1,6,7), providing the method a high accuracy on indicating the chronological age (1,8–11).

In 2006, Cameriere et al. (12) presented a linear regression formula for assessing chronological age in children, based mainly on measurements of open apices in teeth. The authors, working with a sample of 455 Italian children from 5 to 15 years old, obtained a satisfactory result, slightly underestimating the age of boys and girls, with a median of residual errors of −0.035 years. The method has been tested by Cameriere himself, and by other researchers, with different samples, yielding good results (13) and more accurate estimates than the methods proposed by Demirjian (6,14) and by Willems (14).

The aim of this study is to assess the accuracy of the Cameriere method on estimating chronological age of a Brazilian sample of 5- to 15-year-old children, considering the relationship between age and measurements of open apices teeth.

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Materials and Methods

Orthopantomographs from 160 children (66 boys and 94 girls) aged between 5 and 15 years were analyzed by two examiners previously trained, and calibrated and blinded to the chronological ages. The radiographs were taken as part of the routine treatment they were receiving in dental offices from southeast Brazil. Patients with hypodontia, chronic medical condition, or obvious pathology were excluded from the sample, as well as unclear or distorted images.

To assess intra- and inter-examiner reproducibility, 20 radiographs were reexamined by the observers after a 2 week interval.

The method is fully explained in the original article by Cameriere et al. (12). Briefly, seven left permanent mandibular teeth were considered, excluding the third molar. The number of teeth with closed apical ends (N) was determined. For teeth with open apices, the distance between the inner sides of the open apex was measured (A_i, being i the number of the element). For those teeth with two roots ($i = 6$ and 7), the sum of the distances between the inner sides of both apices was calculated. To avoid distortions by possible differences in magnification and/or angulation, the measure A was divided by the tooth length (L_i), so that $x_i = A_i/L_i$. The measures obtained were used to estimate chronological age, according to the following formula:

$$\text{Age} = 8.971 + 0.375g + 1.631.x_5 + 0.674.N - 1.034.S - 0.176.S.N$$

where g is a variable, 1 for boys, and 0 for girls; $x_5 = A_5/L_5$; N = number of teeth with closed apical end; and S = sum of normalized open apices ($S = x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7$).

Statistical Analysis

All measures and variables were entered in an Excel file, containing also the sex and the real age of each child. The real age was obtained by subtracting the date of birth from the date of the radiograph. The accuracy of the method was evaluated by comparing the estimated age with the chronological age, with analysis of variance (ANOVA), and Tukey's test. The intra- and inter-observer accuracy was assessed by the Student's *t*-test for paired samples.

Results

There were no significant differences inter-observer ($p = 0.254$), as well as intra-observer, calculated by the set of panoramic radiographs reexamined after 2 weeks ($p = 0.315$ and $p = 0.193$, for the two examiners, respectively).

The distribution of the sample by sex and chronological age groups (in years) is shown on Table 1. The mean chronological age of each sex group can be seen on Table 2.

TABLE 1—*Age and sex distribution of the sample.*

	Sex					
	Female		Male		Total	
Age Groups in Years	*n*	%	*n*	%	*n*	%
5	5	100.0	–	–	5	100
6	7	58.3	5	41.7	12	100
7	5	83.3	1	16.7	6	100
8	9	50.0	9	50.0	18	100
9	10	71.4	4	28.6	14	100
10	9	52.9	8	47.1	17	100
11	13	50.0	13	50.0	26	100
12	14	58.3	10	41.7	24	100
13	12	52.2	11	47.8	23	100
14	10	66.7	5	33.3	15	100
Total	94	58.8	66	41.3	160	100

TABLE 2—*Mean chronological age (in years) by gender.*

Sex	Number of Cases	Mean Chronological Age (in Years)	Standard Deviation
Male	66	10.6	2.3
Female	94	10.2	2.7

The number of teeth with closed apical ends (*N*) determined for each child was, as expected, progressively greater as older was the child, representing 0% of the teeth for the younger group (5–6 years) and 26.3% for the oldest group (13–14 years). The relation between chronological age and number of teeth with closed apices is shown on Table 3.

By Student's *t*-test for paired samples, there was no statistically significant difference between chronological and estimated ages ($p = 0.603$). On considering boys and girls separately, the results are $p = 0.644$ and $p = 0.266$, respectively.

However, on analyzing each age group, the estimated age was significantly higher than chronological age from 5 to 10 years old and significantly lower from 11 to 14 years old. The graphic in Fig. 1 shows the mean of chronological and estimated ages for each age group.

On comparing positive and negative variation between chronological and estimated ages, there were 87 cases of underestimation (54.4%) and 73 cases of overestimation (45.6%).

As proved by ANOVA, the method was less precise for age group of 13–14 years, which showed the higher difference between chronological and estimated ages. The best results were obtained on age groups of 5–6 and 11–12 years. The mean variation between chronological and estimated ages, distributed by sex and age group, can be seen on Fig. 2.

The Student's *t*-test for independent samples demonstrated no significant difference for the variations between male and female groups.

Discussion

The accurate age estimation is an important issue for human identification, both for human remains and for living individuals. Dental development is a reliable source of information for age estimation, especially precise for subadults, and commonly used by forensic experts around the globe (1,12).

Cameriere et al. (12) developed an age estimation method based on the relationship between age and measures of open apices of seven permanent teeth, in an Italian sample with children from 5 to 15 years of age. Since then, the method has been tested in other parts of the world, including Europe, Croatia, Slovenia, and Spain (12–14). A Brazilian sample had never been studied.

The method eliminates any distortions caused by magnification and angulation issues using proportions (apex aperture by tooth length) instead of absolute numbers. The present study followed the method suggested by Cameriere et al. (12) and thereby used

TABLE 3—*Number of teeth with closed apices by chronological age groups.*

	Chronological Age Groups											
	5–6 Years		7–8 Years		9–10 Years		11–12 Years		13–14 Years		Total	
Number of Teeth with Closed Apices	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
0	17	100	9	37.5	2	6.5	–	–	–	–	28	17.5
1	–	–	5	20.8	2	6.5	–	–	–	–	7	4.4
2	–	–	7	29.2	4	12.9	5	10.0	1	2.6	17	10.6
3	–	–	3	12.5	21	67.7	22	44.0	–	–	46	28.8
4	–	–	–	–	1	3.2	6	12.0	6	15.8	13	8.1
5	–	–	–	–	1	3.2	10	20.0	6	15.8	17	10.6
6	–	–	–	–	–	–	6	12.0	15	39.5	21	13.1
7	–	–	–	–	–	–	1	2.0	10	26.3	11	6.9
Total	17	100	24	100.0	31	100.0	50	100.0	38	100.0	160	100.0

Age group 56 indicates children from 5.00 to 6.99, etc.

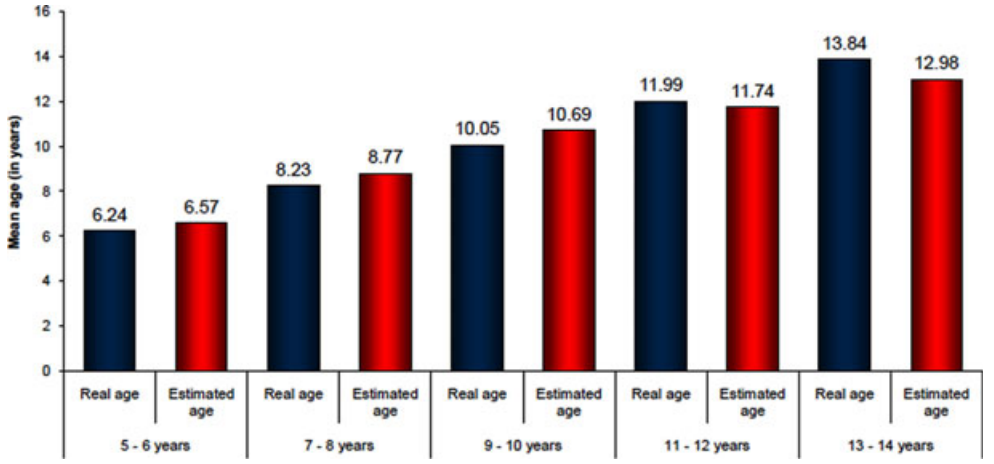

FIG. 1—*Comparison between mean real and chronological ages for each age group.*

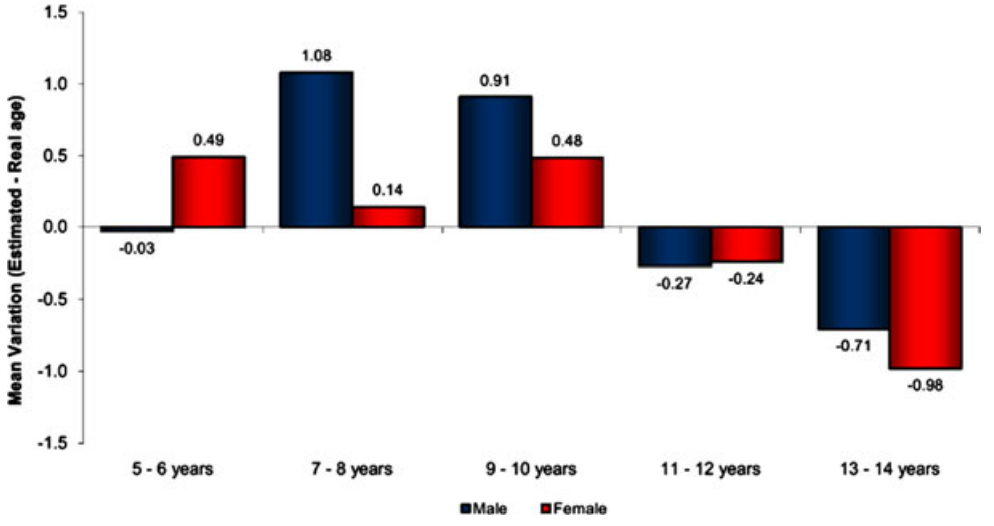

FIG. 2—*Mean of variation between chronological and estimated age, according to sex and age group.*

panoramic radiographs. The accuracy of periapical images for applying this method has not been tested, and further investigation is recommended.

The differences between inter- and intra-observer measurements were not statistically significant. This work has confirmed the accuracy of the method, with a mean difference of −0.04 years between chronological and estimated age, that proportionally represents 14.6 days. According to Student's *t*-test for paired data, when analyzing the total sample, the estimated ages were not statistically different from chronological ages ($p = 0.603$).

Such results can be considered more accurate than the ones from other radiographic method for age estimation through the teeth, as shown by Maber et al. (15), comparing four methods of age estimation—Demirjian, Willems, Nolla, and Haavikko.

The accuracy achieved by this evaluation was compatible to the results of Cameriere et al. (14), who found a median of residuals equals 0.081, after examining a sample of the same age range (5–15 years) as the present study. Likewise, after analyzing a European sample with children from seven different nationalities, the same author (13) has shown a median of residuals of 0.114 years, concluding that geographic origin has no significant value on age estimation.

Meanwhile, according to ANOVA, there was a significant difference between the results for each age range. The results demonstrated a tendency to overestimate the age of children of 5–10 years and to underestimate the ages from 11 years on.

The system has proven accurate as additional criterion for age estimation. However, in children not in the 5–15 year age range, other methods are suggested, because the presence of teeth with open apex becomes a condition, and also a limitation, for the correct application of the formula. Nevertheless, a prior exam of the general stage of dental development can correctly select indicated cases for applying the method.

In a forensic context, every available piece of information must be considered, to make the identification as certain as possible. When estimating chronological age of subadults, odontologic parameters play a key role, becoming the method of choice, given the accuracy achieved.

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