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Age estimation: Cameriere's open apices methodology accuracy on a southeast Brazilian sample

Luiz Eugenio Nigro Mazzilli[a,*], Rodolfo Francisco Haltenhoff Melani[a], Cesar Angelo Lascala[b], Luz Andrea Velandia Palacio[c], Roberto Cameriere[d]

[a] Department of Community Dentistry, School of Dentistry, University of São Paulo, OFLab (anthropology and Forensic Dentistry Laboratory), Brazil
[b] Department of Radiology, School of Dentistry, University of São Paulo, Brazil
[c] AgEstimation Project, University of Macerata, Italy
[d] Department of Anthropology – Institute of Legal Medicine, AgEstimation Project, University of Macerata, Italy

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ABSTRACT

Age estimation plays an important role in clinical and forensic dentistry. Cameriere's 2007 open apices method for age estimation was applied in a sample of 612 digital panoramic orthopantomographs from Brazilian subadult individuals of known age and sex. The sample was composed of 290 males and 322 females individuals aged between four and 16 years of age from São Paulo metropolitan area who had undertaken radiographs for clinical purposes. Participant's ethnicity data was not available. An open code computer-aided drafting software (ImageJ) was used to measure the variables according to the author's published guidelines. Subjects' age was firstly estimated under the application of the European formula (2007) showing under-estimation (−1.24yr). On the other hand, the linear regression analysis modeled for this specific population was able to explain 91.2% of the chronological age variation with a standard error of 0.91yr. Residual analyses confirmed independent errors and a normal distribution. In conclusion, the present results support Cameriere's method for age estimation in Brazilian subadults to be a reliable method, although correlations may vary between specific groups and, hence, specific formulae may be useful for an accurate prediction.

1. Introduction

Apart from its importance to therapeutic decisions, accessing and correlating the physiological age of a person to their chronological age (CA) help clarify many other relevant issues. Decisions involving legal and civil matters, for example, depend on the person's chronological age, but, due to many circumstances, the age is frequently unknown and must therefore be estimated in order to support these decisions. Dental age is one of the most reliable age estimation parameters applied to forensic sciences,[1] as it is less affected by endocrine diseases or nutritional variations than other morphologic references[2]. In general, the different methodologies used to access the dental age are based on developmental teeth characteristics and subsequently on regressive changes like abrasion, secondary dentin deposition, root reabsorption, among other factors. In fact, both developmental and regressive changes to the teeth are related to chronological age.[1]

The main techniques used to estimate subadult age by means of their dental maturation may be summarized in two groups: those based on stages of tooth mineralization or dental eruption and those based on specific dental measures, both accessed via image exams.[3–12]

When using stages of tooth mineralization, the expert compares the teeth development shown in radiographs with a set of developmental stages chart.[3–10] Covered in several separate studies, the pre-defined stages are presented with examples and descriptions by their authors and vary in number from one researcher to another. The major reference studies for four-to-fifteen-year range come from Nolla,[3] with 11 stages; Moorrees, Fanning and Hunt,[4] with 13–14 stages; Haavikko,[5,6] with 12 stages; Liliequist and Lundberg,[7] with 8 stages; Demirjian et al.,[8] with 8 stages; Anderson, Thompson and Popovich,[9] with 13–14 stages and Willems et al.,[10] with 8 stages. One good reason for its widespread use is the simplicity of the method and the fact that it requires minimal resources.[1] The problem is the inevitable result variations depending on each examiner's interpretation.[1,11,12] Even if the criteria and both intra and inter-observer agreement may be adjusted and controlled in research environment, this is not what actually happens during daily practice.[1]

On the other hand, estimates based on dental radiological measures use regression formulae to estimate age directly from the measured

* Corresponding author.
E-mail addresses: lenmazz@usp.br (L.E.N. Mazzilli), rfmelani@usp.br (R.F.H. Melani), cesaralascala@usp.br (C.A. Lascala), luza98@gmail.com (L.A.V. Palacio), r.cameriere@unimc.it, roberto.cameriere@unimc.it (R. Cameriere).

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ratios rather than stage classification. Although the application of these techniques requires a computer, specific software and training of the skills necessary for the measurements, the main advantage seems to be its more reliable age assessment and minor agreement variation (as the results are based on measures). This does not mean that intra and inter-examiners disagreement can be dismissed or neglected, surely being an important issue on age estimation based on dental measures.[13] In 1994, Mörnstad et al.[11] published a method of age estimation based on objective measures of teeth development. The structures involved were crown height, apex width and root length. The authors concluded there was a strong correlation between some of these measures and the age factor, thus permitting a multiple regression analysis to be modeled. But the results, although hopeful, expressed limitations and a standard error close to 2 yr.

In 2006, Cameriere et al.[12] published their method for assessing chronological age in Italian children based on open apices ratios. The results were very encouraging. In 2007, Cameriere et al.[13] collected and analyzed data from 2652 European Caucasian children, obtaining a regression formula based on open apices to predict age. From 2007 on, several researches based on Cameriere's methodology were successfully applied to other populations, although requiring, in some cases, specific regression modeling.[14,15,18–22] The main reason for testing the same methodology on multiethnic samples is to get the best possible prediction accuracy to support expert's conclusions.

That being said, the main purpose of the present research was to test Cameriere's methodology in subadults residing in São Paulo metropolitan area, as well as to enhance age prediction accuracy by means of a specific regression formula for this population spot.

2. Materials and methods

A sample of 645 digital orthopantomographs from Brazilian subadults aged between four and 16 years old, residents in the Sao Paulo metropolitan area, was obtained from a private institute of radiology whose main particularity is encompass a wide variability of patients of both low to high socio-economic status (Table 1).

The radiographs, taken as part of routine general treatment between 2011 and 2013, were obtained in accordance to an ethical committee approval (Approval: 626.260/2014 CAAE: 27418514.7.0000.0075/CEP-CONEP-Brazil). In order to preserve participant's confidentiality, the institute provided information regarding exclusively the sex, the date of birth and of the date of the exam. Any information about participant's ethnicity was available. Radiographs presenting unclear content, gross dental or osseous pathology were excluded. Over the 645 orthopantomographs obtained, 29 did not fit the inclusion criteria and were excluded, originating a preliminary sample of 616 images. Later on, four of them were discovered to be outliers and were also excluded, resulting in a final sample of 612 subjects (322 females, 290 males). The chronological age of each subject was calculated by subtracting the date of the radiograph exam from the date of birth. All the radiographs were produced by the same radiological equipment (Cranex D - Soredex)[16] and were in digital format (jpg extension).

Two well-trained examiners experienced in the ImageJ software performed the measures.

After opening the “jpg file” on ImageJ,[17] the first procedure was to set the image scale (analyze - > set scale). Although scaling does not affect the measures of interest (as they are ratios), the images were set in units of measure, being 79 pixels equivalent to 0.71 units in this research. Contrast and brightness settings were defined according to the examiners' preferences and zooming was at least adjusted to 100% image size in a 22-inch high-resolution monitor. The straight-line tool was used to perform and register the measures (Ctrl + M = register). Reference lines (Ctrl + B saves the line in a layer) were used before taking measures of interest (Fig. 1).

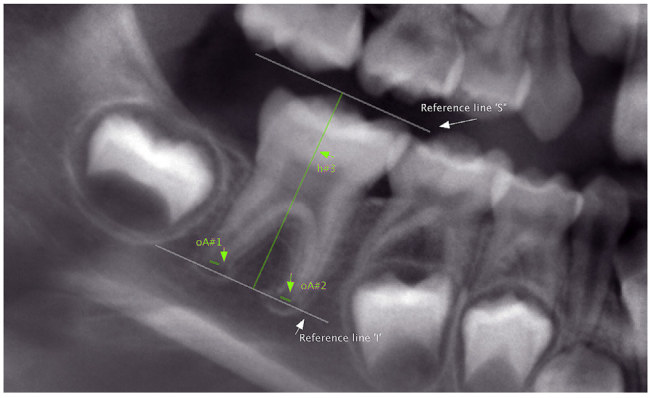

Fig. 1. Reference lines and measures (oA#1 distal root inner side length; oA#2 mesial root inner side length; h#3 tooth length; reference lines – > ‘S’ superior ‘I’ inferior).

All seven permanent mandibular teeth from preferably the same side, except for the wisdom teeth, were examined following original Cameriere's[12] guidelines: tooth length, open apices length and closed apex taken (Fig. 1). The right side was elected as default. Nonetheless, when a tooth was missing, decayed, extensively filled, crowded or in spin, the corresponding tooth on the other side was scored. In order to avoid examiners' doubts to consider an apex closed or not, critical ones were measured under image magnification (zooming 150%) and lately computed as opened if over 0.048 units of measure (a consensus value between examiners considering the adopted scale).

An Excel spreadsheet was used for initial data processing. Linear regression predictors (sex, X_5, N_0, S and $S*N_0$) were calculated from the registered and processed measures.

Statistical Package for Social Sciences (SPSS) Version 17 was used to perform a linear regression analysis. The significance threshold was set at 5%. Age was modeled as a function of sex and morphological predictors, which were: (X_5), representing the distance between the inner sides of the open apex of the mandibular second premolar tooth divided by its length; (S), representing the normalized open apices sum of the seven mandibular permanent teeth; (N_0), representing the number of teeth with complete root development; and (N_0*S), representing the product of these variables. Normalized ratios were obtained by dividing open apices inner measures by the tooth height. On bi-radicular teeth open apices represented the sum of distal and mesial roots openings (Fig. 1). Multicollinearity tests were performed to verify Tolerance (t) and variable inflation factor (VIF), and so were residual tests and plots performed to confirm linearity and homoscedasticity. Durbin–Watson

Table 1
Sex and age distribution.

	Statistics						Age Class (yr.)			
	n	Mean	Median	Std. Dev.	Minimum	Maximum	4–6.99 (yr.)	7–9.99	10–12.99	13–17
Sex										
Female	322	9.86	9.79	3.06	4.25	16.43	72	97	95	58
Male	290	10.16	10.32	3.00	4.58	16.45	53	82	96	59
Total	612	10.00	10.05	3.04	4.25	16.45	125	179	191	117