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Age estimation in children by measurement of open apices in tooth roots: Study of a Mexican sample

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ABSTRACT

The aim of this cross-sectional study was to test the accuracy of Cameriere's European formula for age assessment in a large sample of Mexican children. The accuracy of dental age estimation was defined as how closely real age, measured as the difference between chronological age (CA) and dental age (DA), could be predicted. Digitalized orthopantomographs of 502 Mexican children (254 girls and 248 boys), aged between 5 and 15 years, were analyzed. The seven left permanent mandibular teeth were evaluated using Cameriere's method. Intra- and inter-observer variability for this technique was tested on a small random sample. Dental age was estimated for each individual and compared with known chronological age. Accuracy was measured as the difference between known chronological age and dental age and tested for significance with the mean prediction error (ME). The standard deviation and 95% confidence interval of the mean difference were also calculated. ME was 0.63 years for girls and 0.52 years for boys. ME was found to be slightly overestimated by 0.10 years for girls, but was correctly estimated for boys with an accuracy of 0.00. In conclusion, this method is very useful and may be recommended for practical application both in clinical dentistry and forensic procedures on the Mexican population.

1. Introduction

Age estimation in children and adolescents is essential to answer a variety of legal questions, including status of majority and criminal liability [1,2]. In the last few years, as a result of the global increase in cross-border migration, many countries report increasing numbers of foreigners who cannot provide documentary evidence of their date of birth [1–3].

In the United States of America (USA), by far the most important source of immigration is Mexico [4,5]. Geographic proximity allows unauthorized migrants from Mexico to move to the USA relatively quickly. In the border state of Arizona, for example, more than 600 illegal immigrants are arrested every day. Also of concern are the increasing levels of violence and risk linked with organized illegal immigration [4–6]: according to Azaola [6], in Mexico there is an approximate total of 16,000 children, victims of commercial sexual exploitation. In Mexico City alone, the estimated number of subjugated children is 2500. Regarding the age of the children who are being exploited, most of them are 11–16. It is certainly possible to find younger girls and boys who can be exploited from the age of 7 or 8, but these cases do not represent the majority [7,8].

Because of this development, age estimation of unaccompanied minors, individuals less than 18 years of age who are unlawfully in the USA without a parent or other legal tutor, has increasingly become an integral part of forensic practice [2–5,9–11]. In addition, according to the USA Minor Law, in most States under common law, the age threshold of relevance to criminal prosecution is 7 years. In all such cases, the prosecutor or the corresponding administrative authority is obliged to establish the age of the purported minor.

To separate unaccompanied children from adults, the Immigration and Customs Enforcement (ICE) of the Department of Homeland Security (DHS) attempts to establish the date of birth for any apprehended person not readily identifiable as an adult or child. The persons to whom forensic examination is to be applied are persons without valid identity documents, whose birth certificate may be suspected to be forged, and whose real age must be known in order to decide whether they can be charged. ICE

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uses various forms of information for age estimation purposes, including interview statements and documentation such as birth certificates. When ICE has difficulty assessing whether an individual is a child or an adult, it may also obtain a professional medical opinion [11].

Today, in line with the recommendations of the Study Group on Forensic Age Diagnostics (AGFAD; http://agfad.uni-muenster.de) [2], the examination of three independent development systems are combined in criminal proceedings, to increase diagnostic accuracy and to improve the identification of age-relevant development disorders [1–3]. During the growth of a person, skeletal, dental, anthropological and psychological methods allow an approximate assessment of age. The most frequently used method for age estimation in children is the study of radiographs of teeth and hand-wrist [12–24]. Some of the most accurate methods of age estimation in juveniles and young adults are based on assessment of the degree of dental development [25,26]. The teeth are useful indicators of age in this age-group, principally because of their relative accuracy and also because of the lack of other reliable predictors [2,27]. Of these, tooth formation is probably the method most frequently used: it is thought to be a less variable measure than eruption, unaffected by factors such as malnutrition, premature loss of primary teeth, crowding, and dental decay. Tooth formation also has high heritability, a low coefficient of variation, and is more resistant to environmental effects [28].

Several studies have been carried out to establish age, assessing formation and mineralization within acceptable error limits [29]. Basically, these techniques define the stages of mineralization of teeth observed in radiographs and code them according to predetermined scores [12–15]. The most common method for dental age assessment was first published by Demirjian et al. [12] and since then the technique has been widely applied to various populations [25,27,30–36]. The score system of Willems et al. [36] is the best adaptation of Demirjian's method and is the recommended method of choice to assess maturity or estimate age if all seven teeth are available [25]. In Mexico, although some works about skeletal age in children (6–13 years) have been published [37], there are still few published articles about estimating age on growing teeth in this population [38]. In one of the most recent works, only Guatemalan children were studied [39].

In 2006, Cameriere et al. [40] developed a new method for assessing chronological age in children, based on the relationship between age and measurement of open apices in tooth roots. The same authors also published a paper with additional samples from Kosovo and Slovenia, for a total number of 1100 children [41]. In 2007, the technique was tested in a large sample of children from various European states, providing a common formula useful for all these countries [42]. Recently, it has been reported that Cameriere's method is more accurate than other methods for estimating the age of children in age groups 6–13 years [43–45]. Marques Fernandes et al. [45] showed the great accuracy of this method in a Brazilian sample of 160 children aged between 5 and 15 years.

The aim of the present paper is two-fold: first, to evaluate a Mexican sample by means of Cameriere's formula [42]; second, if this formula turns out to be unsuitable, to study a specific formula for Mexican children. This is because one of the most important questions, in order to assess age, is whether the reference data normally used for forensic diagnosis, derived from North Americans on one hand and Central and Northern Europeans on the other, can also be applied to members of other ethnic groups [1,2].

2. Materials and methods

2.1. Sample

A sample of 502 orthopantomographs (254 girls and 248 boys) of healthy children with no obvious developmental abnormalities, aged between 5 and 15 years, and taken during a course of diagnosis and treatment, was selected at random from patients at the Faculty of Odontology, UNAM (Universidad Nacional Autónoma de México) and regional community dental clinics in Mexico City (Mexico).

Table 1
Age groups and gender distribution of the Mexican sample.

Age groups	Girls	Boys	Total
5–6	26	2	28
6–7	41	14	55
7–8	17	23	40
8–9	17	34	51
9–10	26	29	55
10–11	26	40	66
11–12	33	27	60
12–13	25	25	50
13–14	33	35	68
14–15	10	19	29
All	254	248	502

All subjects were divided into 10 groups according to their chronological age. The first group, consisting of 5-year-olds, included patients of ages ranging from 5.00 to 5.99. The next group included 6-year-olds, and so on. Table 1 shows orthopantomogram (OPG) distribution by age and sex. These OPGs were obtained as part of routine treatment between 2000 and 2009.

The inclusion criteria were age between 5 and 14 years at the time the orthopantomograms were obtained, good quality radiographs, and no agenesis or extractions in the left lower quadrant. Exclusion criteria were incomplete dental or medical history, evident systemic diseases and congenital anomalies, premature birth, hypodontia of permanent teeth except third molars, and hyperdontia.

Patients' identification number, gender, date of birth and date of X-rays were recorded. Their parents had signed agreements with dental institutions that dental records and radiographs could be used only for research and educational purposes, without the possibility of personal identification. Protocols to collect radiographs for human subjects were approved by the Ethics Committee for Research Involving Human Subjects of UNAM (Mexico City), and the study was conducted in accordance with the ethical standards laid down by the Declaration of Helsinki (Finland). The World Medical Association (WMA) developed the Declaration of Helsinki as a statement of ethical principles for medical research involving human subjects, including research on identifiable human material and data.

2.2. Measurements

Radiographs were in digital form (Ortopantomograph® Orthoceph® OP200) and images were recorded on computer files, processed by a computer-aided drafting program (Adobe® Photoshop® CS4).

Radiographs of the left permanent developing mandibular teeth, except wisdom teeth, were evaluated. The selected nomenclature to classify the teeth was that proposed by the F.D.I. (Fédération Dentaire Internationale) or a two-digit numbering system. Mandibular teeth were chosen because they can be easily visualized on panoramic radiographs. Several authors [12–18] have shown that there are no significant differences between the right and left sides and that the rate of growth is approximately the same on both sides.

Dental age estimation was performed according to the method of Cameriere et al. [40]. The number of teeth with complete root development, i.e., apical ends of the roots completely closed (N_0), were counted. Teeth with incomplete root development, i.e., with open apices, were also examined and the distance (Ai, $i = 1, \ldots, 7$) between the inner side of the open apex was measured. In order to take into account the effect of possible differences among X-rays in magnification and angulations, measurements were normalized by dividing by the tooth length (Li, $i = 1, \ldots, 7$). Dental maturity was evaluated according to the normalized measurements of the seven left permanent developing mandibular teeth (xi = Ai/Li, $i = 1, \ldots, 7$), the sum of the normalized open apices (s) and the number (N_0) of teeth with complete root development (Fig. 1). Lastly, age was calculated with the formula [39]:

$$Age\ T = 8.387 + 0.282g - 1.692 \times 5 + 0.835N_0 - 0.116s - 0.139s \times N_0$$

where g is a variable, 1 for boys and 0 for girls.

This is the European linear regression formula, also available at the MS Excel template on the website of the Istituto di Medicina Legale, Università degli Studi di Macerata (Italy), AgEstimation Project: http://agestimation.unimc.it. This method enabled magnification of selected regions of interest, in order to achieve more accurate evaluation of the developmental stages of teeth.

2.3. Intra- and inter-observer agreement

As the possibility of replicating measurements reliably is an indispensable component of any metric study, intra- and inter-observer error was tested. All