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Forensic Anthropology Population Data

Accuracy of the estimation of dental age in comparison with chronological age in a Spanish sample of 2641 living subjects using the Demirjian and Nolla methods

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ABSTRACT

Age estimation is an important procedure in forensic medicine and is carried out for a number of reasons. For living persons, age estimation is performed in order to assess whether a child has attained the age of criminal responsibility, in scenarios involving rape, kidnapping or marriage, in premature births, adoption procedures, illegal immigration, pediatric endocrine diseases and orthodontic malocclusion, as well as in circumstances in which the birth certificate is not available or the records are suspect. According to data from the UNHCR (United Nations High Commissioner for Refugees), the number of people seeking refugee status continued to increase in the last years, driven by the wars in Syria and Iraq, as well as by conflict and instability in Afghanistan, Eritrea and elsewhere. The objective of this study is to compare the accuracy of estimating dental age versus chronological age using the Nolla and Demirjian methods in a Spanish population. A final sample of 2641 panoramic X-rays corresponding to Spanish patients (1322 males and 1319 females) between 7–21 years of age was analyzed. Dental age was assessed using the Nolla and Demirjian methods, establishing comparisons with mean chronological age based on the Student t-test for paired samples, followed by the generation of a linear regression model. Both methods showed slight discrepancy between dental and chronological age. On examining the reproducibility of the Nolla and Demirjian methods, technical errors of 0.84% and 0.62%, respectively, were observed. On average, the Nolla method was found to estimate an age 0.213 years younger than the chronological age, while the Demirjian method estimated an age 0.853 years older than the chronological age. Linear combination of the mean Nolla and Demirjian estimates increased the predictive capacity to 99.2%. In conclusion the Nolla and Demirjian methods were found to be accurate in estimating chronological age from dental age in a Spanish population. The error was found to be greater in males than in females, and involved an over-estimation of age with the Demirjian method and under-estimation of age with the Nolla method. Combination of the Nolla and Demirjian methods for estimating chronological age from dental age affords a predictive capacity of over 99%, and is fast and easy to perform, and inexpensive.

1. Introduction

Age estimation is an important procedure in forensic medicine and is carried out for a number of reasons. Age estimation of cadavers, for example, is performed in criminal cases, as well as for the identification of mutilated victims of mass disasters such as fires, crashes, accidents, etc. [1]. For living persons, age estimation is performed in order to assess whether a child has attained the age of criminal responsibility, in scenarios involving rape, kidnapping or marriage, in premature births, adoption procedures, illegal immigration, pediatric endocrine diseases and orthodontic malocclusion, as well as in circumstances in which the birth certificate is not available or the records are suspect [2,3].

According to data from the UNHCR (United Nations High Commissioner for Refugees) [4], the number of people seeking refugee status continued to increase in the first half of 2014, driven by the wars in Syria and Iraq, as well as by conflict and instability in

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Afghanistan, Eritrea and elsewhere. Thirty-eight European countries recorded 264,000 asylum applications, representing an increase of 24% versus the same period of 2013. A total of 216,300 of these applications were made in the 28 European Union Member States. The top 5 European Union countries to receive asylum applications were Germany, France, Sweden, Italy and the United Kingdom. In comparison, the Russian federation registered an additional 168,000 people seeking protection from conflict in Ukraine, and Turkey has received more than half a million asylum-seekers and refugees from Syria, Iraq and other countries. Many of these people lack documentation allowing reliable confirmation of their birth date. In this regard, when the authorities suspect that an undocumented asylum-seeker may be a minor, medical examinations are requested in order to estimate the chronological age of the individual.

A number of methods have been developed for estimating the age of an individual based on evaluation of the maturation or eruption of the permanent teeth, including the procedures developed by Morrees, Kvaal, Willems, Haavikko or Liliequist and Lundberg [5–9]. In this regard, special mention should be made of the methods proposed by Nolla and by Demirjian et al. The Demirjian method [10] is one of the most widely used options, and was first applied in a French Canadian population in 1973. Nolla [11] in 1960 also developed one of the methods most widely used to identify the dental development of individual teeth (based on the so-called Nolla stages) and to estimate dental age.

To our knowledge, the present study involves the largest patient sample reported to date in the European Union, with the exception of some isolated scientific publication [10], and aims to examine the reproducibility and validity of the Nolla and Demirjian methods in estimating the chronological age of an individual. The study also examines whether the simultaneous use of both methods is able to increase the predictive capacity in estimating chronological age.

2. Material and methods

A retrospective, cross-sectional study was conducted involving the analysis of panoramic radiographs of 2641 Spanish patients (1322 females and 1319 females). All patients underwent a panoramic X-ray study due to clinical indications in the dental clinic of the University of Valencia (Valencia, Spain) between 2010 and 2014. An experienced X-ray technician obtained all the X-rays using an Orthopantomograph® OP100 (Instrumentarium Dental, Tuusula, Finland). The X-rays were randomly sampled (consecutive non-probabilistic sampling), limiting the age range to 21 years. An evaluation was made of all the teeth of the third quadrant in all the patients included in the study. We included all those X-rays of sufficient quality for the required dental study. The exclusion criteria were: X-rays of poor quality not allowing dental crown and/or root evaluation, and patients with a history of facial trauma or orthodontic treatment. Eighty panoramic X-rays failed to meet the inclusion criteria and were excluded from the analysis. Ethnicity of the patients was established from their Spanish surname, with the exclusion of individuals without such a surname. The study was conducted in accordance with the declaration of Helsinki, and was approved by the institutional review board of the University of Valencia (H1422858921172).

Chronological age was calculated based on the time from date of birth to the day of the panoramic X-ray study. The Nolla method [11] describes 10 maturation stages: stage 0 (absence of a crypt, with no evidence of calcification), stage 1 (presence of a crypt), stage 2 (initial calcification), stage 3 (one-third of complete crown), stage 4 (two-thirds of complete crown), stage 5 (almost complete crown), stage 6 (complete crown), stage 7 (one-third of complete root), stage 8 (two-thirds of complete root), stage 9 (almost complete root, with open apex) and stage 10 (complete root, with full apical closure).

Demirjian et al. in turn developed a method for analyzing tooth maturation and calculating dental age [10]. The proposed stages are: (A) Single- and multiple-root teeth show the start of cone-shaped calcifications in the upper portion of the crypt. The points of calcification do not fuse in this stage. (B) Fusion of the points of calcification produces one or more cusps that merge to conform a regular occlusal surface. (C) Enamel forms on the occlusal surface, and dentin depositing starts to appear. The pulp chamber has a curved shape at the occlusal margin. Up to this stage the criteria are the same for single- and multiple-root teeth. (D) Crown formation is complete up to the cementoenamel junction. The upper portion of the pulp chamber is curved in single-root teeth, while in molars the pulp chamber is trapezoidal in shape. Root formation begins. (E) In single-root teeth the pulp chamber walls form straight lines disrupted by the presence of the pulp horn. The root length is shorter than the height of the crown. Initial furcal formation is observed in molars as a semilunar image, and the root length is still shorter than the height of the crown. (F) In single-root teeth the pulp chamber walls now form a triangle, and the root length equals or exceeds the height of the crown. In molars the calcified furcal zone is now funnel-shaped, and the root length equals or exceeds the height of the crown. (G) The walls of the root canal are now parallel, and the apex is still partially open. (H) The apex is fully closed.

An observer (MM) performed the measurements and estimated the age based on the mentioned methods. A second measurement was made in all patients between 2–4 weeks after the first measurement, with the purpose of estimating the error of the measurements and the intra-observer reproducibility of each method. The observer was blinded to this second measurement and was unaware of the previous record made two weeks earlier. The Dahlberg formula was used to assess the error of the method:

$$d = \sqrt{\frac{\sum_{i=1}^{n} (Age_{1i} - Age_{2i})^2}{2n}}$$

where n represents the number of measurements made. The estimated relative error of the method was likewise calculated from the following equation:

$$relative\ error = \frac{d}{age} \times 100$$

where final age is the mean of the 2n age estimation results. This indicator allows us to compare the error of the method between different dimensions. The intraclass correlation coefficient (ICC) is the concordance indicator between the different pairs of results. After evaluating reproducibility, a single estimate is calculated for each method, based on the average of the two intra-observer measurements.

Comparison was made of the age estimates obtained with the Nolla and Demirjian methods versus the mean chronological age, based on the Student t-test for paired data. This allowed us to identify possible sources of bias, with a view to confirming validity. The analysis of validity was also carried out stratifying by gender, age groups (under 14, between 14–18, and over 18 years of age) and combinations. Lastly, the results obtained with the Nolla and Demirjian methods were contrasted against chronological age using a linear regression model with estimation of the confidence intervals of the coefficients. The SPSS version 17.0 statistical package (Chicago, IL, USA) was used for the statistical analysis. The significance level was 5% ($\alpha = 0.05$). The statistical power reached was 99% with a 95% confidence interval.