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Validity of Demirjian's and modified Demirjian's methods in age estimation for Korean juveniles and adolescents

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ABSTRACT

In estimating age of juveniles and adolescents, the teeth are employed primarily because of its low variability and less affection by endocrine and nutritional status in development. Demirjian established criteria for evaluating maturity of teeth and his method has been used throughout the world. However, several studies showed the inappropriateness of Demirjian's method on populations other than the one it is based on. Consequently some researchers modified Demirjian's method using data of several different populations. Demirjian himself also published a revised method to overcome other shortcomings of his original method. The aim of this study was to test the validity of Demirjian's and the modified methods (Demirjian's revised, Willems', Chaillet's and new Korean methods) for Korean juveniles and adolescents.

1483 digital orthopantomograms which consist of 754 males and 729 females in the age range of 3–16 years were collected. New age estimation method based on Korean population data was calculated. Dental age was estimated according to each method and the validity was evaluated using the differences between chronological and dental age. The inter- and intra-observer reliability was evaluated to be excellent. Statistically significant difference was observed between chronological and dental age in all the methods for both sexes except new Korean method for both sexes and Demirjian's revised method for males. However, when analyzing absolute and squared value of difference, Willems' method was found to be most accurate followed by new Korean method with slight difference for Korean population for both sexes. In conclusion, both Willems' method and new Korean method conducted by present study were proven to be suitable for Korean population.

1. Introduction

Age of juveniles and adolescents is estimated using skeletal, dental, anthropological and physiological methods [1]. Dental development is a useful indicator of maturation because of its high reliability, a low coefficient of variation, and resistance to environmental effects [2–5]. Several age estimation methods based on dental development pattern using radiographs were created and standards have been established [6–16]. Currently, the most common method for children is Demirjian's method [6] which is based on French-Canadians. This method utilizes orthopantomograms to estimate the extent of mineralized dental tissues and the shape of the chamber of seven left permanent lower teeth. A few years after publishing the original method, Demirjian revised it with Goldstein [7] to overcome limitations in its application to inborn or acquired teeth-lacking children and also to provide percentile standards for extremely young and old age groups. However, the revised method has not been widely used compared to its original.

Dental maturation pattern is variable among different populations. Several authors [8,10,17–23] state that Demirjian's method was less accurate on populations other than that of French-Canadian. These results demonstrated the necessity to create standard representative of each population thus leading to some researchers modifying Demirjian's method based on their own population data. Willems et al. [8] tested the validity of Demirjian's method on Belgian Caucasian population and observed consistent overestimation of the dental age in both sexes. They presented new tables for each sex with age score directly expressed in years. Although they concluded that their method may not be valid on

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other populations, validation studies about age estimation methods using degree of development of teeth for Bangladeshi and British Caucasian populations [24] showed that Willems' method was most accurate and may be suitable for other populations. Chaillet et al. [9] conducted a research with 9577 dental panoramic radiographs of eight different ethnicities and implemented new international dental developmental weighted scores and curves for children with unknown ethnic origin. Cruz-Landeira et al. [25] tested the applicability of Demirjian's and Chaillet's method for Spanish and Venezuelan populations. It was found that when used on different populations, same method could produce a different result which means applicability of each method varies with a population used.

There were a number of validation studies of Demirjian and 'modified Demirjian's methods' – which consist of revised Demirjian's, Willem's, Chaillet's method for the purpose of this article–on Korean population. Lee et al. [26] reported the inapplicability of Demirjian's original method [6] on Korean population but suggested further study with larger sample size in order to confirm the applicability of Demirjian's original method for Koreans. Hence this study was conducted with relatively larger sample size to develop a new method for Korean population to test the applicability of Demirjian's original and the modified methods. Also, the chronology of seven lower left permanent teeth mineralization in Korean population was investigated for forensic and clinical applications.

2. Materials and methods

2.1. Subjects

A total of 1483 digital orthopantomograms of Korean nationality and ethnicity were selected from the collection at the Seoul St. Mary's Hospital, the Catholic University of Korea. It consists of 754 males and 729 females of 3–16 years-old. Note this article uses 'old' and 'young' within age range of 3–16, thus groups close to age of 16 are referred to as 'old' and groups close to age of 3 are referred to as 'young' in this article. The chronological age of the orthopantomograms was recorded in years and decimal parts. All the orthopantomograms were categorized according to sex and chronological age. Fourteen groups (1 year apart and equally divided into age categories between 3 and 16 years) were made for each sex (Table S1). Exclusion criteria included: image deformity affecting lower permanent tooth visualization, systemic diseases, premature birth, congenital anomalies, agenesia, large dental caries, or endodontic treatment of at least two corresponding teeth bilaterally in the mandible, and gross pathology in mandible. Protocols for the study were approved by the Institutional Review Boards of the Catholic University of Korea, College of Medicine (#CUMC10U076) because it was performed with human samples. Also, it was conducted in accordance with the ethical standards laid down by the Declaration of Helsinki.

2.2. Evaluation of the dental maturity and estimation of dental age

Seven lower left permanent teeth visible on orthopantomograms were observed and rated according to the eight-stage scheme presented by Demirjian et al. [6]. A specific, biologically weighted score taken from the tables was prepared separately for males and females, which was then assigned to each of the evaluated stages. Each method had its own maturity score. The maturation curves for Korean population were calculated using chronological age and summed scores derived from Demirjian's original method. Dental age was calculated using separate standard tables or curves for males and females from Demirjian et al. [6], Demirjian and Goldstein [7], Chaillet et al. [9] and present study. Willems et al. [8], only summation of maturity scores was used for estimation because its scores were expressed directly in years. The difference between chronological and dental age was calculated to evaluate accuracy of each method. The chronological age was subtracted from the dental age and a positive figure indicated an overestimation and a negative figure an underestimation. Absolute and squared values of differences between chronological and dental age were also analyzed to clarify the accuracy of each method.

2.3. Statistical analysis

The statistical data of the ages for each maturation stages of seven lower left teeth for both sexes were calculated. Intra- and inter-observer reliability was tested using calculation of Cohen's Kappa coefficient for Demirjian's stages for each tooth based on the data from each examiner. The maturation curves for Korean population were plotted using spline regression analysis. The significance of the difference between chronological and dental age was tested using paired t-test. This was carried out for each method and for the entire range for males and females separately. All statistical analysis was performed using SAS system, Version 9.1 (Cary, NC, USA).

3. Results

Descriptive statistics for individual stages of each tooth are shown in Tables S2–S8. Nearly all the mean age of attainment tooth developmental stages was earlier in females as compared to males (Fig. S1). Agreement between duplicate scores of the mineralization stages by the same observer varied from 96.33% to 98.67%, and by two different observers, from 90.33% to 95.01%, for the various teeth. The difference between the two scores did not exceed one stage for any tooth. The Cohen's Kappa coefficient ranged from 0.953 to 0.980 and from 0.887 to 0.922 in intra- and inter-observer reliability test respectively, thus indicating "almost perfect" level of inter- and intra-observer reliability according to guidelines by Landis and Koch [27].

The maturation curves for Korean population were plotted in Fig. 1. The results of overall accuracy tests of five methods were shown in Table 1. The mean and standard deviation of difference between chronological and dental age for each method is presented in Fig. 2. The central lines give the means and box endings ± one standard deviation. Statistically significant difference was observed between chronological and dental age ($p < 0.0001$) in

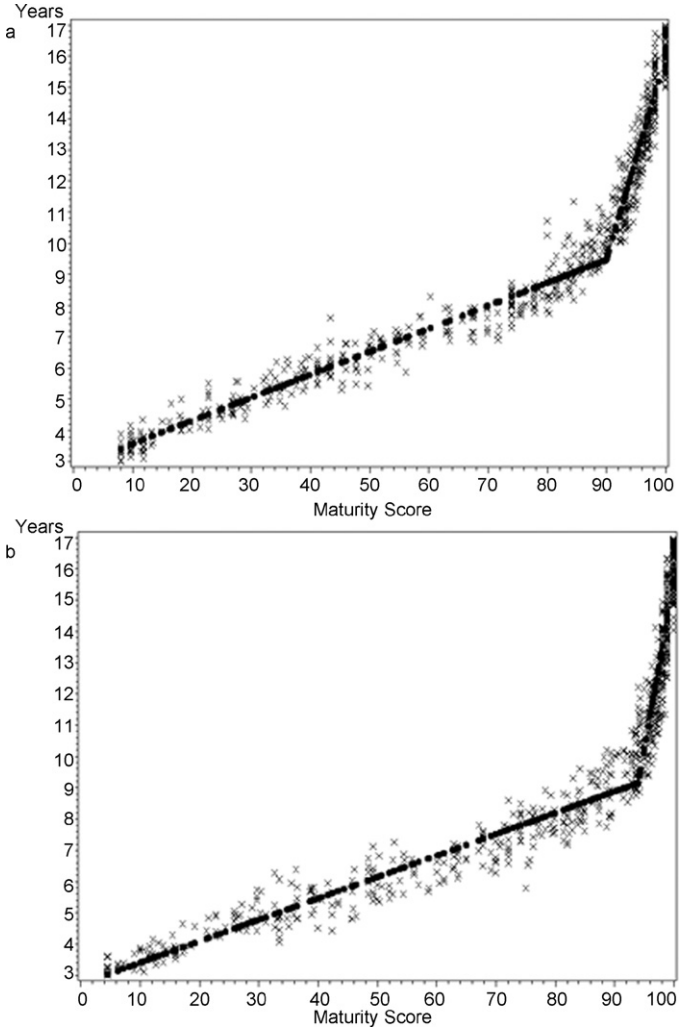

Fig. 1. Spline regression of New Korean method of present study – (a) male (b) female.