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# Accuracy of the Demirjian and Willems methods of age estimation in a Black Southern African population

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ABSTRACT

The accuracies of the original Demirjian, modified Demirjian and Willems dental age estimation methods were compared for a Black Southern African population to determine their usefulness for forensic and anthropological purposes.

Data were collected using a community-based prospective study design. Panoramic radiographs of seven left mandibular teeth from 540 children aged 5–15.99 years were scored using the three methods. Obtained estimates were compared to the chronological ages and mean absolute errors were calculated.

The original Demirjian method significantly overestimated ages (males 0.85 years, female 1.0 years; mean absolute errors of 1.1 years for both sexes), as did the modified Demirjian method (males 0.90 years, females 1.21 years; mean absolute errors of males 1.1 years, females 1.4 years). The Willems method was the most accurate for Black Southern Africans, with the lowest significant mean difference (males 0.2 years, females 0.3 years) between dental and chronological age, with the least mean absolute errors (males 0.70 years, females 0.68 years).

## 1. Introduction

The accuracy of methods used in the assessment of growth and developmental age is very important in biological anthropology and health research. Accuracy is also critical for forensic purposes, especially with the increasing global incidences of mass deaths and disasters [1,2]. Estimation of age with certainty is necessary where birth records are unreliable or lost, where people seek asylum, where specific aging is needed to prevent cheating in age-graded sports competitions, or where individuals seek favorable outcomes in civil or criminal cases [3–8]. The age at death is usually the only biological parameter that can be determined for unidentified juvenile remains with any degree of accuracy [9].

### 1.1. Age estimation

Methods developed for estimating physiological age utilize one, or a combination, of the four main indices of growth and development: stature, secondary sex characteristics, bone growth and dental development [4,6–8,10]. Tooth formation is less variable compared to other growth defining events such as the appearance of bone ossification centers, tooth emergence and root apical closure, with a stronger correlation found between chronological age and dental age than between skeletal age and dental age [11–13]. There is general agreement that dental development, especially tooth formation, is the most reliable method of estimating age and that it should be adopted as the standard for estimating biological age [12,14].

### 1.2. Methods of estimating dental age

Several methods are available for estimation of dental age in children and adults. Morphological techniques are based on cementum apposition and root resorption [15], occlusal wear [16,17], periodontosis, or translucency of the apical zone [18,19]. Other methods include the evaluation of aspartic acid racemization in the dentin [20,21], telomere shortening in the DNA of the dental pulp [22], the amount of radiocarbon in the enamel [23], attrition levels, secondary dentin formation and periodontal attachment [24]. All these methods necessitate extraction and require preparation of microscopic sections of at least one tooth per individual. These methods cannot be used in living individuals for ethical reasons. Another method involves visual identification of the type and number of teeth emerged in an individual and

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extrapolating the age based on the known age range for the appearance of such teeth (tooth emergence). This method may not estimate age accurately, but it may be a useful guide in age estimation where facilities such as radiography do not exist. Radiological assessment of tooth development has gained worldwide acceptance because of its accuracy and use in clinical practice. It is non-destructive and other clinical information can be obtained.

### 1.3. Radiological methods of age estimation

There is a lack of consensus on the accuracy and applicability of the existing radiographic methods used in estimating age. The most widely used method, developed by Demirjian and colleagues (the original Demirjian method) [25], was subsequently modified to improve the accuracy of estimation [26,27]. A previous study on Black South African children found Demirjian's original method overestimated the chronological age [28]. However, a recent publication on a Black South African population found clinically insignificant differences between the Willems BC method and a South African specific reference derived from the Willems method [29]. The accuracy and validity of the revised Demirjian method [27] has never been tested on a Black Southern African population.

### 1.4. The Demirjian method

Demirjian and colleagues developed an age estimation methodology based on eight (A–H) developmental stages of the seven left mandibular teeth [25]. The reference population was French-Canadian children. This method has gained wide acceptance and is globally utilized [30]. Biological weights, which are numerical scores derived using the same method for measuring skeletal maturity [31], are assigned to the developmental stages for each of the seven teeth. The weights are added together to provide the total maturity score, which is converted to dental age using tables and percentile charts. The Demirjian method is described as simple, easy and highly reproducible [32]. A study applying it to German children concluded that the Demirjian method yielded appropriate age estimates [33]. However, numerous studies [26,28,34–37] including two systematic reviews using different populations [38,39], found overestimation of age by Demirjian's method. Hence some authors have questioned its applicability in forensic science where highly predictable and accurate results are required [40,41].

### 1.5. Modifications of the Demirjian method

Demirjian revised his original method because of two shortcomings [27]. Firstly, all teeth may not be present in the mouth and it may not be possible to use corresponding antimeres. So he devised two modifications using only four teeth. The first evaluated the molars and premolars ($M_2$ $M_1$ $PM_2$ and $PM_1$), while the second considered the second molar, the premolars, and the central incisors ($M_2$ $PM_2$ $PM_1$ and $I_1$) [27]. Secondly, there was a lack of sufficient numbers of very young and the oldest children in the first sample [27]. The inclusion of more children led to a change in the biological weighted score in the modified Demirjian method. The modified method was tested in many populations, with overestimation being reported for most groups [40,42,43].

### 1.6. The Willems method

Willems and colleagues [26] adapted the maturity score format of the original Demirjian method [25], but discarded the use of the biological weights for each stage [26]. Instead, new biological weights were generated so that when the weights are summed the estimated age is given. This eliminates the step of converting the maturity scores to dental age. The use of this method on a Belgian reference population found no significant difference between the mean dental age and the chronological age of the population [26].

Studies utilizing the Willems method in Egypt [44], Malaysia [30,45], Serbia [46], France [47], China [48], Macedonia [40] and India [49] reported considerable accuracy in the estimation of chronological age of individuals in their populations. Akkaya and colleagues [43], in a study of Turkish children, concluded that Willems' method can be recommended for dental age estimation for forensic purposes. However, another study from China [50] found the Demirjian method to be more accurate than the Willems method.

Studies utilizing the modified Demirjian method have not been conducted in sub-Saharan Africa. Recently a retrospective study was conducted using Willems method on a Southern African population. It is important to determine the accuracy of these methods, in view of the overestimation of dental age by the original Demirjian method previously reported for a Black South African population [28]. Therefore, the aim of this paper is to evaluate the accuracy of the original Demirjian, the modified Demirjian and the Willems methods in a Black Southern African population using a prospective community-based study to determine their usefulness for forensic and anthropological purposes.

## 2. Materials and methods

### 2.1. Study design

This was a community-based prospective cross-sectional study of 540 Southern African children comprising of 233 (43.1%) males and 307 (56.85%) females. The sample population was drawn from Black children whose parents and grandparents are indigenous Southern Africans.

### 2.2. Study population

The sample population was randomly selected from primary and secondary schools in Johannesburg Municipality, South Africa. Children screened for dental diseases by the Community Oral Health Outreach Program (COHOP) of the Department of Community Dentistry, School of Oral Health Sciences, University of the Witwatersrand were evaluated for participation in the study. Permission to carry out the study was obtained from the local education authority and respective school heads. Written consent was obtained from the parent/guardian and assent from the child was required before participation. Ethical clearance (NO. M141001) was obtained from the Human Research Ethics Committee (Medical) of the University of the Witwatersrand.

### 2.3. Data collection

A panoramic X-ray machine, specially fitted into a mobile dental treatment van, was used to take radiographs of children screened for treatment during visits of the Community Oral Health Outreach Program.

### 2.4. Inclusion and exclusion criteria

Radiographs showing gross pathology or low image quality were excluded. Children with systemic diseases that can affect the development of teeth, mandibular hypodontia (except third molars), and those who had lost their teeth on both sides of the mandible were excluded. Also, children age 16 years and above were also excluded because the Demirjian maturity scores do not include children over 16 years.

### 2.5. Sample size

A total of 11 age cohorts were sampled for ages 5 to 15.99 years. The sample size formula is $N = 4z_{\alpha}{}^{2}S^{2} \div W^{2}$, where the S = standard