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ORIGINAL ARTICLE

Dental age estimation in Spanish and Venezuelan children. Comparison of Demirjian and Chaillet's scores

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Abstract Orthopantomographs taken from 308 Spanish Caucasian and 200 Venezuelan Amerindian children, aged between 2 and 18 years, were analysed following the Demirjian's method. The aims of this study were to test the applicability of the Demirjian's method to two different sample populations, and to develop age prediction models for both populations using the original French Canadian scores described by Demirjian (1976) and the new multi-ethnic dental scores proposed by Chaillet et al. (2005) when the ethnic origin is unknown. Results showed that despite the good correlation between dental and chronological age, Demirjian's method overestimates the age in the Spanish Caucasian sample using both scores, the mean overestimation being higher when the Demirjian's scores were used than when the Chaillet's scale was applied. In the Venezuelan Amerindian sample, the opposite was found: Demirjian's method underestimates the age using both scores, the underestimation being higher when the Chaillet's scale was applied than when Demirjian's scale was used. New graphs were produced to convert the maturity scores to dental age for Spanish and Venezuelan children. With these graphs, the Demirjian's scores showed to be inadequate after the age of 12 in both populations, while Chaillet's scores offered useful information until 14 years of age.

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Introduction

Age estimation plays an important role in forensic medicine, paediatric endocrinology, archaeology and clinical dentistry [1]. The estimation of age at a time of death is an important step in the identification of human remains and has a long tradition in forensic sciences. Age estimation of living individuals is a current focus of forensic research, especially important in a multicultural society where legal and illegal immigration are rising, with an increasing demand for age calculation [2]. During the growth of a person, skeletal, dental, anthropological and psychological methods allow an approximate assessment of age [3]. Today, in accordance with the recommendations of the Study Group on Forensic Age Diagnostics, the examination of three independent development systems are combined in criminal proceedings to increase the diagnostics accuracy and to improve the identification of age-relevant development disorders [4, 5]. Some of the more accurate methods of age estimation in the juvenile and young adult have been based on the assessment of the degree of dental development. Later, when all teeth are fully formed, regressive age-related changes might be used for this purpose [6–8]. Dental emergence and mineralization are the main dental parameters applied in forensic age estimation in children and young adults [9]. Several methods for the determination of dental development have been carried out to establish age, assessing mineralization within acceptable error limits [3]. One widely used method is that of Demirjian et al., first described in 1973 and based on a large number of French Canadian children [10, 11]. The

method evaluates the development of seven mandibular teeth from a panoramic radiograph and calculates dental age. Since then, numerous studies in this issue have been carried out for other populations showing a great variability in the dental maturation process. Several authors [1, 12–22] showed that the results are less accurate if another population is computed with Demirjian's standards. This shows the necessity to create representative databases for each population in order to reach a better comprehension of human dental maturation. Some authors [1, 12, 17–22] proposed polynomial or multiple regression analysis to obtain a predicted age with confidence interval, as a function of maturity score. Chaillet et al. [23] provided new dental developmental tables and curves when the ethnic origin is unknown. Few data are known about this method's applicability in Spanish and Venezuelan children. For that reason, the aim of this study was to evaluate the applicability of Demirjian's method for dental age estimation in both populations. In particular, the objectives of the study were: (1) To test the applicability of both, Demirjian and the Chaillet's scores in two different sample populations, Spanish Caucasian and Venezuelan Amerindian. (2) To develop age prediction models (polynomial or multiple regression models) for both populations using the original French Canadian scores described by Demirjian (1976) [11] and the new multi-ethnic dental scores proposed by Chaillet et al. (2005) [23] when the ethnic origin is unknown.

Materials and methods

Subjects

The study sample consisted of 508 conventional orthopantomograms from individuals of two different ethnic origins (Table 1). The first sample group was composed of orthopantomograms of 308 Spanish Caucasian children (Galicia, Northwestern Spain) with known chronological age and gender, collected between the years 2001 and 2006, both included. Of these, 151 were male and 157 were female, and their ages ranged from 4 to 17 years. Both parents were also of Spanish Caucasian origin. All of them attended the School of Dentistry of the University of Santiago de Compostela (Spain). The second group was composed of orthopantomograms of 200 Venezuelan Amerindian children, 103 boys and 97 girls, with ages ranging from 2 to 18 year old, collected between the years 2001 and 2007, both included. Both parents were also Venezuelan Amerindian. Most of the orthopantomographs were obtained from the medical history archives of the Faculty of Dentistry of the University of Los Andes (Venezuela) and from some private dental clinics. Exclusion criteria were: unclear orthopantomographs, systemic diseases, premature birth, congenital anomalies, agenesia of at least two corresponding teeth bilaterally in the mandible, and lack of birth date on the medical history or lack of date on the orthopantomographs. The distribution of dental panoramics by age and sex is given in Table 1.

Methods

A record card was designed in order to evaluate the characteristics of dental maturity of each individual. This record card comprised two sections. In the first one the following data were included: medical history number, sex, birth date, and orthopantomograph date. Chronological age of children and youngsters, unknown at the moment of registering the medical history, was calculated from birth and orthopantomograph dates. The second section was filled out with the development information obtained from the orthopantomograph.

Each radiography was digitized using a Canon 5 Mega pixel powershot camera, taking digital photos of orthopantomographs on a negatoscope, then loaded into a computer and subsequently analyzed using Adobe Photoshop 7.0. This method enabled magnification of selected regions of interest in order to achieve more accurate evaluation of teeth developmental stages.

Table 1 Age and gender distribution of the samples

Age (years)	Spanish sample (n=308)			Venezuelan sample (n=200)		
	Girls	Boys	Total	Girls	Boys	Total
2–3	–	–	–	2	6	8
4–5	6	10	16	4	4	8
6–7	23	19	42	20	13	33
8–9	32	27	59	28	41	69
10–11	29	32	61	19	15	34
12–13	27	26	53	5	8	13
14–15	32	26	58	10	6	16
16–18	8	11	19	9	10	15

In accordance with the rules of Demirjian's method [10, 11] the development of the seven left permanent mandibular teeth (31 to 37) was assessed. Dental age was calculated using standard tables (separate for boys and girls) from Demirjian et al. [11], and from Chaillet et al. [23].

Intra- and inter-observer reproducibility

All measurements were carried out by one observer. Thirty randomly selected radiographs, 15 of each sample were re-examined 6 months after the initial examination by the same observer, and later by a second one. Cohen's kappa coefficient was used to measure the intra- and inter-observer reproducibility for Demirjian's stages for each tooth. The intra- and inter-observer reproducibility of calculated dental ages was studied with the intra-class correlation coefficient (ICC) [24].

Statistical analysis

Statistical analysis was performed using the SPSS package, version 15.0. First, the correlation between chronological and dental age was obtained by lineal regression analysis. Secondly, the differences between dental age obtained by applying Demirjian or Chaillet's scores and chronological age were calculated and statistically tested using paired *t* test. Differences in dental growth rate between both population groups were also statistically evaluated. In all tests, $p<0.05$ was considered statistically significant. Finally, different regression models were explored in calculations of dental age (taken as the dependent variable) as a function of maturity score for both samples. In each population calculations were done for boys and girls, separately.

Results

In relation to the reproducibility studies, the difference between the two readings did not exceed one stage for any tooth. The kappa coefficient ranged from 0.80 to 0.89. With regards to the reproducibility of the calculated dental age, the estimated ICC (95% confidence intervals) was: intra-individual Demirjian's scores 0.984 (0.968–0.992) and Chaillet's scores 0.972 (0.944–0.987); Inter-individual Demirjian's scores 0.972 (0.942–0.986) and Chaillet's scores 0.964 (0.927–0.983).

Demirjian's scores

Results showed a strong linear correlation between dental age, estimated according to Demirjian's standards, and chronological age in the Spanish and Venezuelan population samples, for both sexes. The slopes of the curves were close to one (ranging from 0.906 to 1.068), and the coefficients of determination higher than 0.81 (ranging from 0.82 to 0.88). Despite this good correlation, Demirjian's method over-estimates the age in the Spanish Caucasian sample (mean overestimation was 0.76±1.01 years for boys and 0.88±1.09 for girls) while underestimates it in the Venezuelan sample (−0.23±0.93 years for boys and −0.1±1.04 years for girls, respectively). Figure 1 shows the distribution of differences between the calculated dental age and the chronological age for both populations in females. Similar distribution was obtained for males.

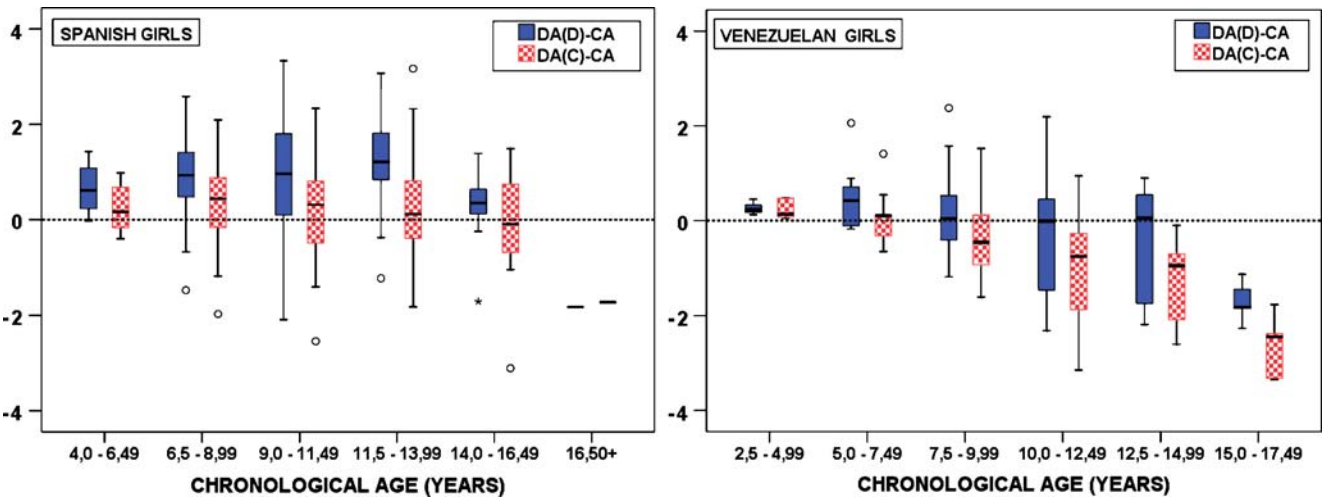

Fig. 1 Boxplots of differences between dental and chronological ages for girls using the Demirjian method. *Horizontal line inside boxes* is located at the median of data, and the *height of boxes* gives interquartile range (IQR); *whiskers* indicate range. DA(D) − CA = Dental Age (Demirjian Scores) − Chronological Age. DA(C) − CA = Dental Age (Chaillet Scores) − Chronological Age

Figure 2 shows the relationship between mean maturity score and mean age (age 5, for example, includes children between 4.51 to 5.50 years old) for girls. As can be seen, 100% of maturity is achieved at the age of 12 in the Spanish sample and at the age of 14.1 in the Venezuelan sample. For boys, a similar distribution with a median delay of 1 year in relation to the girl development was obtained for both populations.

Chaillet's scores

Results also showed a strong linear correlation between dental age estimated according to Chaillet's standards and chronological age in the Spanish and Venezuelan population samples, for both sexes. The slopes of the curves were close one 1 (ranging from 0.922 to 1.136) and the coefficients of determination higher than 0.84 (ranging from 0.85 to 0.88). Chaillet's method also overestimates the age in the Spanish Caucasian sample, but in a lower amount than the Demirjian's (0.37±1.04 years for boys and 0.21± 1.07 for girls). On the contrary, the underestimation in the Venezuelan sample was higher (−0.48±0.92 years for boys and −0.61±1.07 years for girls, respectively). Figure 1 shows the distribution of differences between the calculated dental age and the chronological age for both populations, in girls.

Figure 2 shows the relationship between mean Chaillet's maturity score and mean age, for girls. As can be seen, in the Spanish sample, a 100% maturity is achieved at a mean age of 14.7, 2.7 years later than with Demirjian's scores. In the Venezuelan sample, a 100% maturity is achieved after the age of 16.8. Therefore, Chaillet's scores allow the estimation of dental age in a wider range. For boys, a similar distribution with a median delay of 0.6 years in relation to the girls, development was obtained for both populations.

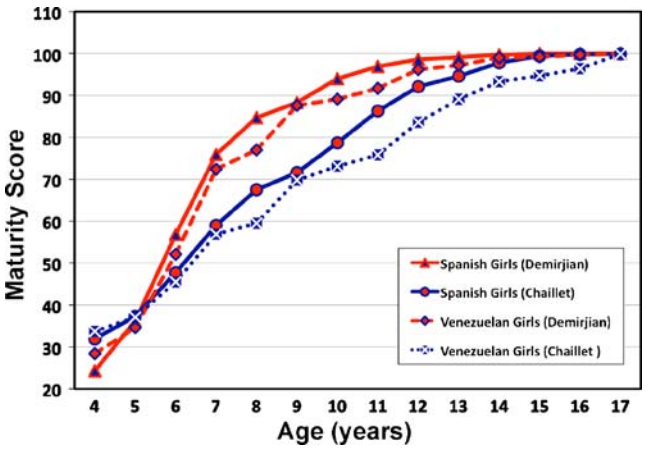

Fig. 2 Relationship between mean maturity score and mean age for girls

Comparative analysis of the growth rate in both populations

For any chronological age after 5, Spanish population (girls and boys) achieved always a higher maturity score, meaning an early dental development. The differences between both populations were statistically significant between 8–15 years. Results also proved that for the Spanish population, the lowest error in the estimation was obtained applying Chaillet's scores, while Demirjian's scores offered better results in the Venezuelan sample.

Polynomial functions

As stated previously, both Demirjian and Chaillet's scores underestimate chronological age in the Spanish sample and overestimate it in the Venezuelan one. We explored the relationship between chronological age (taken as the dependent variable) and maturity score (taken as the independent variable) by calculating different polynomial functions. Finally, two models were selected: the compound and the cubic. Table 2 summarizes the main parameters of such functions. When applying Demirjian's scores to these data, the regression model with the best results was the compound one, in both populations. Cubic regression lines are not a good representation of maturity increase with age, since age is constant or even decreases for maturity scores between 55 and 80, especially in the Spanish sample (Fig. 3a). Nevertheless, when applying Chaillet's scores, the cubic model proves to be the best, in both samples. This statement can be verified both in the numeric parameters (Table 2) and the plots. Scatterplot in Fig. 3b shows a more stepped distribution of maturity scores regarding the chronological age in the Spanish sample. Similar distribution was obtained for the Venezuelan population.

Discussion

The Demirjian's method to estimate dental age has been used in different populations with similar results. In general, most authors agree that it is a useful method and easy to use, but that overestimates the age of children [1, 13–15, 17–22]. Most of them also state that specific studies should be done to adapt the method to a specific population. Little information is available regarding the dental development of Spanish or Venezuelan children.

In relation to the Spanish population, Hernández et al. [25] have recently published the eruption chronology of the permanent dentition in children and their results are in agreement with similar studies performed in other groups of Caucasian children. Cameriere et al. [26, 27] included a sample of Spanish children in two European studies applying their own method and comparing it with Demi-

Table 2 Main parameters of compound and cubic functions

Sample	Sex	Score	Function	Equation	EE	R	R2
Spanish	Boys	Demirjian	Cubic	$Y = -8.971 + 0.623x - 0.0084x^2 + 0.000046x^3$	1.010	0.950	0.909
			Compound	$Y = 2.788^{*}1.0168^{x}$	0.098	0.955	0.911
		Chaillet	Cubic	$Y = -8.879 + 0.614x - 0.008x^2 + 0.000044x^3$	1.058	0.941	0.884
			Compound	$Y = 2.895^{*}1.0160^{x}$	0.108	0.940	0.883
	Girls	Demirjian	Cubic	$Y = -20.589 + 1.460x - 0.0248x^2 + 0.000136x^3$	1.265	0.898	0.806
			Compound	$Y = 2.285^{*}1.0170^{x}$	0.151	0.891	0.789
		Chaillet	Cubic	$Y = -9.679 + 0.692x - 0.010x^2 + 0.000055x^3$	1.050	0.930	0.865
			Compound	$Y = 2.969^{*}1.0160^{x}$	0.108	0.927	0.859
Venezuelan	Boys	Demirjian	Cubic	$Y = -5.164 + 0.584x - 0.010x^2 + 0.000060x^3$	1.016	0.928	0.863
			Compound	$Y = 2.676^{*}1.0160^{x}$	0.137	0.902	0.815
		Chaillet	Cubic	$Y = -8.228 + 0.589x - 0.008x^2 + 0.000043x^3$	0.935	0.940	0.884
			Compound	$Y = 2.628^{*}1.0190^{x}$	0.134	0.917	0.841
	Girls	Demirjian	Cubic	$Y = -12.567 + 1.014x - 0.017x^2 + 0.000097x^3$	1.303	0.892	0.797
			Compound	$Y = 2.585^{*}1.0110^{x}$	0.121	0.932	0.870
		Chaillet	Cubic	$Y = -16.153 + 1.006x - 0.015x^2 + 0.000079x^3$	1.022	0.935	0.874
			Compound	$Y = 2.672^{*}1.0180^{x}$	0.122	0.923	0.852

Cubic model $Y = aX^3 + bX^2 + cX + d$ where Y is age and X is maturity score, *Compound model* $Y = a^{x} * b$ where Y is age and X is maturity score

rjian's method. Some results have also been presented for the third molar development in the Spanish population, according to Demirjian's standards [28–30]. Recently, Landa et al. [31] applied the Kvaal's method to dental age estimation in a Spanish sample. But as far as we know, this is the first study using Demirjian's method to estimate dental age in children involving exclusively a Spanish sample. Our results indicate that the Spanish Caucasian children are, in general, advanced in dental development compared with French Canadian children. Overestimation ranged from 0.21±1.07 to 0.88±1.09, depending on the sex and on the scale used (Fig. 1a). This is in agreement with other authors who obtained an overestimation of dental age ranging from 0.02 to 3.04 years in their populations [22]. Therefore, our results are in accordance with previously published data for Caucasian populations [1, 13–15, 17–22]. A possible explanation for the differences between Spanish and French Canadian children might be attributed to the different ethnic group (Spanish=Caucasian, French Canadian=Caucasian+Amerindian) and/or the effect of the considerable time gap between the two studies. Both factors can also contribute to explain why the overestimation found in our study was lower when applying Chaillet's scores (more Caucasian influence and less time gap).

Little information is also known about dental development in Amerindian populations. Cameriere et al. [32] studied the effects of nutrition on timing of mineralization in teeth in a Peruvian sample by the Cameriere and Demirjian's methods. They found that Demirjian's dental maturity in the Peruvian sample was advanced compared with that of the original study, which shows an overestimation of age in Peruvian Amerindian children. In our sample of Venezuelan Amerindian children, the overestimation was only found in children under 8-year old, while those older were delayed in development, in both sexes. The delay ranged from −0.1± 1.04 to −0.61±1.07 years, depending also on the sex and on the scale used (Fig. 1b). Our results are in disagreement with the general tendency, but also with the specific Cameriere's results for the Peruvian population. This underestimation can be due to a small sample size, but in our opinion, the ethnics could contribute to explain the differences with the original study because the French Canadian population has a strong Amerindian genetic contribution but also European influence [23]. It is possible that the dental development in the French Canadian population is in an intermediate point between the delayed Amerindian (Venezuelan) and the advanced Caucasian (Spanish). Olze et al. [33] also found population differences in the wisdom tooth mineralization, with Caucasoid populations occupying the middle position while Mongoloid populations display a comparative delay and African populations a relative acceleration.

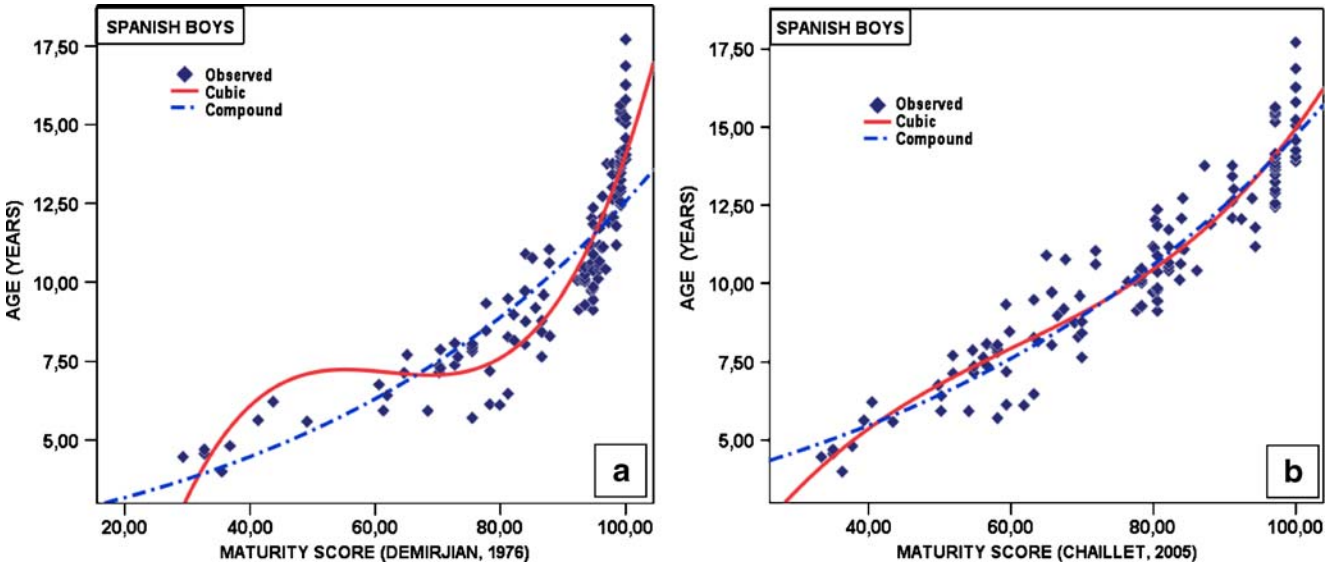

Fig. 3 Scatterplots of maturity score against chronological age in Spanish boys. *Lines* represent mean regression prediction in both function models

The delay of the Venezuelan dental development in relation to the Spanish sample was also studied (Fig. 2). Spanish children were more than 2 years ahead of Venezuelan ones, at certain ages. We also found statistically significant differences between both populations in children older than 8-year old, although the different number of cases in some age groups (12–13 and 14–15) must be taken into account. According to Knell et al. [34], the observed differences can be insufficient evidence to support the premise of ethnically conditional differences, because of the reduced number of Venezuelan cases in some age groups. But our results contribute to know the effect of race and culture in the dental growth, an important issue in forensic sciences [35].

Most of the previously published studies have applied the scores from the original Demirjian's method and found that, in general, are inadequate. Therefore, some authors have calculated new scores. For example, Willems et al. [17] adapted the method for the Belgian Caucasian population creating an updated score. Maber et al. [36] and Cameriere et al. [27] compared both scores and found that Willems's method was better than Demirjian's. Since our sample was composed of two different ethnic population groups, we decided to test the Chaillet's scores [23]. We found that the Demirjian's method overestimates the age in the Spanish Caucasian sample using both scores, but the mean overestimation was lower when the Chaillet's scale was applied. On the contrary, in the Venezuelan Amerindian sample, the underestimation was higher when the Chaillet's scale was used, obtaining better results when applying the Demirjian's scores.

At any rate, our results confirm the necessity of developing specific scores or curves for specific populations, as agreed by most authors. For this purpose, different polynomial functions have been proposed. Most of these studies elaborated the polynomial functions considering the "age" as the independent variable and the score as the dependent one [8, 14, 16–19]. Nevertheless, according to Muñoz et al. [37], when a perfect lineal fit is not possible between both variables, the unknown variable (age, in forensic cases) must be considered the dependent one. Therefore, regression models proposed here differ from most of the previously published up to date. In our case, we have inverted the variables, considering the chronological age (parameter that is wanted to be calculated in a real forensic case) as a function of the maturity score (the known parameter).

After calculating the polynomial functions for both populations, we found that the distribution of maturity scores related to chronological age was much better with Chaillet's scores. As can be seen graphically, using Demirjian's scores at the age of 10 in the Spanish sample (Fig. 3a) a high percentage of children achieved 100% maturity, so little (or any) information could be obtained afterwards. On the other hand, when applying Chaillet's scores, a more gradual distribution is obtained, with graphs offering information until the age of 14–15 years (Fig. 3b). After this age, teeth 31–37 have finished development and only the third molar could give information. Average age at the end of mineralization of this teeth (Demirjian's stage H) is usually reported to be more than 20 years [38].

In general, authors agree at the necessity of having specific population scores, and our results confirm this fact. However, a recent study by Liversidge et al. [39] did not find major differences in the timing of tooth formation stages between children from eight countries. This fails to

explain previous findings of differences using Demirjian's dental maturity method. This is in concordance with the results of Braga et al. [40], who found that the quality of age assessment does not depend predominantly on the use of geographic-specific standards. Despite the significant differences in dental development between the two populations studied, we consider that further studies must be done to achieve a conclusion, especially in the Amerindian population where very few data have been compiled until now. Finally, according to our results, when specific curves are done for a population, Chaillet's updated scores are more adequate than Demirjian ones, thus, we strongly encourage the use of their tables.

Conclusions

In conclusion, we found significant differences between both samples in dental development, with a clear delay in the Venezuelan Amerindian population in relation to the Spanish Caucasian one. Even after obtaining specific population polynomial functions, those calculated using Demirjian's scores showed to be inadequate after the age of 12 in both populations. On the contrary, those calculated using Chaillet's scores offered information until 14 years of age. Demirjian's method is simple, fast and easy to apply, but the use of Chaillet's scores has proved to be more appropriate.

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