ACCURACY OF DENTAL AGE ESTIMATION IN VENEZUELAN CHILDREN: COMPARISON OF DEMIRJIAN AND WILLEMS METHODS

Aída C. Medina[1], Lucila Blanco[2]

[1] Department of Pediatric Dentistry and Orthodontics, School of Dentistry, Central University of Venezuela.
[2] School of Medicine, Central University of Venezuela.

ABSTRACT

Dental age is a somatic maturity indicator with importance in clinical and forensic dentistry. The purpose of this study is to compare the applicability of the Demirjian and Willems methods for dental age estimation in a group of Venezuelan children. Panoramic radiographs of 238 Venezuelan children aged 5-13 years were used to assess dental age using the methods described by Demirjian and Willems. Children with unclear panoramic radiographs, dental agenesis, and premature loss of primary teeth were excluded. Mean differences between dental age and chronological age by gender and age groups were estimated (ANOVA, Student tests p= 0.05). For the Demirjian method, the mean difference between dental age and chronological age was 0.62 ± 0.93 years, statistically significant. The mean overestimation was lower for females than for males (females 0.56 ± 0.96 years, males 0.67 ± 0.93 years). For the Willems method, the mean difference between dental age and chronological age was 0.15 ± 0.97 years, not statistically significant. Accuracy was significantly different between genders, performing best for females (females 0.01 ± 0.96 years, males 0.29 ± 0.96 years). The Willems method for age estimation was found to be more accurate than the Demirjian method in this sample of Venezuelan children.

Keywords: *age determination by teeth; children; radiography; dental*

PRECISIÓN DE LA ESTIMACIÓN DE LA EDAD DENTAL EN NIÑOS VENEZOLANOS: COMPARACIÓN ENTRE LOS MÉTODOS DE DEMIRJIAN Y WILLEMS

RESUMEN

La edad dental es un indicador de la maduración somática con importancia tanto para la odontología clínica como forense. Este estudio tiene como objetivo comparar la aplicabilidad de los métodos propuestos por Demirjian y por Willems para la estimación de la edad dental en un grupo de niños Venezolanos. Fueron evaluadas 238 radiografías panorámicas de niños venezolanos con edades de 5 a 13 años para determinar la edad dental utilizando los métodos de Demirjan y de Willems. Fueron excluidos casos con radiografías defectuosas, agenesia dental y pérdida prematura de dientes primarios. Las medias de las diferencias entre la edad dental y la edad cronológica fueron estimadas, distribuyendo por género y por grupo de edad. Fueron utilizadas las pruebas estadísticas ANOVA y T de Student (p=0,05). Para el método de Demirjian, la media de la diferencia entre la edad dental y la edad cronológica fue 0,62 ± 0,93 siendo estadísticamente significativa. La media de la sobrestimación para el género femenino fue menor que para el género masculino (hembras 0,56 ± 0,96 años; varones 0,67 ± 0,93 años). Para el método de Willems la diferencia entre la edad dental y la edad cronológica fue 0,15 ± 0,97 sin significancia estadística. La precisión de este método presentó variación estadísticamente significativa entre géneros (hembras 0,01 ± 0,96 años, varones (varones 0,29 ± 0,96 años). El método de estimación de edad dental de Willems presentó mayor precisión para esta muestra de niños Venezolanos.

Palabras clave: *Estimación de edad según la dentición; niños; radiografías; dental*

INTRODUCTION

Estimation of biological age is extremely important in several fields such as forensic medicine, pediatric endocrinology, archaeology, and clinical dentistry. Biological age indicates an individual's progress towards full maturation and may be estimated by studying one or more tissue systems such as skeletal, body mass, secondary sexual characters or dental system.[1-9]

Dental development is under strong genetic control,[10] and may be altered by preterm birth,[11-13] systemic diseases or syndromes, malnutrition,[14] chemotherapy or radiotherapy.[15,16] On a local basis, permanent tooth eruption and tooth formation may be affected

by dental injuries to the primary dentition, caries, [17] apical infections, pulp therapy[18] or premature extractions.[19-22] Dental age may be estimated either by tooth eruption or tooth formation, [2] and hence appropriate study groups and accurate methods that include observation of dental buds in dental panoramic or lateral cephalic radiographs[4, 23,24] are required for its determination.

Demirjian, Goldstein and Tanner[4] proposed a method for dental age estimation based on the development stages of seven left mandibular tooth buds (central and lateral incisors, canine, first and second premolars and first and second molars) from panoramic radiographs of a large group of French Canadian children. This method has been applied in populations around the world, with reports of wide variation from the known chronological age of the cases studied; usually with consistent overestimation of dental age.[5, 9, 25-33]

Willems et al.[7] adapted the method developed by Demirjian in a Belgian Caucasian population. This method has proven more accurate for estimating dental age, although only a few studies assessing it have been published.[8, 33, 34]

Although there are available data on the applicability of the Demirjian method in Latin American children, there is no published data comparing the Demirjian and Willems methods in these populations.[5,9] Thus, the data set analyzed in the present study provides a unique opportunity to compare the applicability of the Demirjian and Willems methods for dental age estimation in a group of Venezuelan children.

MATERIAL AND METHODS

This is a retrospective study of 238 panoramic dental radiographs of healthy Venezuelan children (117 males, 121 females), aged 5 to 13 years, with mean chronological age 8.86 ± 2.34 years; 8.85 ± 2.36 years for males, 8.87 ± 2.33 years for females (Fig. 1), collected from 2000 to 2010 in the Caracas region.

A convenience sampling method was applied to select the panoramic radiographs from children attending a Pediatric Dental Clinic in Caracas, Venezuela. Gender and age stratification was performed to segregate the radiographs and those in compliance with the inclusion criteria (healthy children, free from any disorder affecting growth, good quality radiograph, presence of all seven left mandibular teeth) were considered in the study. Children with unclear panoramic radiographs, preterm birth, dental agenesis, supernumerary teeth, and orthodontic treatment of premature loss of primary teeth were excluded.

Chronological age was calculated by subtracting the date of birth from de date of the panoramic radiograph after converting them to decimal points, using Microsoft® Office Excel 2007© 2008 Microsoft Corporation software.

Dental age was assessed by one observer using the Demirjian method [4] with Willems adjusted scoring.[7] The left mandibular tooth buds (central and lateral incisors, canine, first and second premolars and first and second molars) were assessed and graded according to the 8 stages previously defined by Demirjian et al. Each stage was allocated a score, and the sum of the stages was converted into a maturity score using tables and percentile curves provided by the authors.[4]

Accuracy was estimated by calculating how close the estimated dental age was to the actual chronological age. The chronological age was subtracted from the dental age; thus, a positive result indicated an overestimation and negative result an underestimation.

The differences between chronological age and dental age, and gender differences were analyzed using paired t-test and Wilcoxon signed-rank test. Association between chronological age and dental age was explored by correlation analysis (Pearson). Kruskall-Wallis and ANOVA were used to measure mean age group differences. Homogeneity and normality were tested. Consistency between significance levels of the parametric methods and non-parametric methods were found, parametric

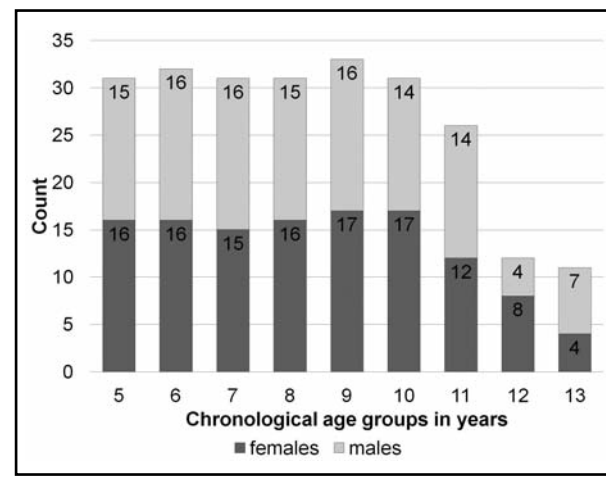

Fig.1: Age and gender distribution.

results are shown. A *P* value of less than 0.05 was considered to be statistically significant. Data analyses was performed using PASW® Statistics 18 (SSPS18) © 2009 SPSS Inc. USA software.

A random sample of 10% of the panoramic radiographs was re-examined by the observer. Within-observer agreement was measured using Kappa statistic and was found to be 0.75, indicating substantial agreement.

The study was approved by the institutional review board and ethics committee of the Bioethics Committee of the School of Dentistry at the Central University of Venezuela (# 0112-2010).

RESULTS

For Demirjian and Willems methods correlations were consistently high for chronological age and dental age (r^2= 0.93 for either method, *P*=0.01) (data not shown).

Mean age of dental formation stages for total sample, males and females and mean accuracy in years using the Demirjian method are shown in Table 1 and Table 2, respectively. Females were earlier than males in all stages of tooth formation (Table 1, Fig. 2), although the differences were not statistically significant. An overestimation of age by 0.62 ± 0.93 years was observed for the total sample (Table 2, Fig. 3). Accuracy was better for females, the average difference between chronological age and dental age was 0.56 ± 0.96 years in females and 0.67 ± 0.90 years in males. The results indicated that there was no statistically significant gender difference (Table 2, Fig. 4). For the total sample, overestimation occurred across age groups. The greatest differences between chronological age and dental age were at 6, 10 and 14 years of age, with significant results reported at 6 (*P*=0.01) and 11 (*P*=0.04) years of age (Table 3, Fig. 5). For males and females, overestimation occurred at any

Table 1: Demirjian's Method: Mean age of dental formation stages in Venezuelan children by gender.

		Left central mandibular incisor		Left lateral mandibular incisor		Left mandibular canine		Left mandibular first premolar		Left mandibular second premolar		Left mandibular first molar		Left mandibular second molar	
Stage	*Gender*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
B	F									5.42	0.17			5.42	0.17
	M											6.76	-	6.13	0.90
	Total									5.42	0.17	6.76	-	5.93	0.82
C	F					5.74	-	5.24	0.15	6.27	0.83	-	-	6.39	0.86
	M					6.13	0.33	6.25	0.53	6.26	0.83	-	-	6.60	0.96
	Total					6.03	0.33	5.88	0.66	6.27	0.82	-	-	6.50	0.92
D	F			5.47	0.53	6.09	0.73	6.75	0.98	7.29	0.98	5.29	0.05	8.15	0.95
	M			5.93	0.74	6.31	0.82	6.66	1.02	7.43	1.14	-	-	8.56	1.07
	Total			5.70	0.64	6.21	0.78	6.70	1.00	7.35	1.05	5.29	0.05	8.29	1.00
E	F	5.45	0.47	5.86	0.53	7.24	1.02	8.01	0.89	8.96	1.05	5.54	0.52	10.50	1.06
	M	5.65	0.47	6.02	0.58	7.76	1.27	9.01	0.97	9.72	0.92	5.85	0.56	10.18	1.05
	Total	5.58	0.46	5.95	0.56	7.48	1.15	8.46	1.04	9.39	1.04	5.76	0.55	10.32	1.05
F	F	6.13	0.67	6.67	0.77	8.78	1.33	9.60	1.10	10.41	1.02	6.30	0.67	10.85	0.58
	M	6.37	0.74	6.55	0.79	9.21	0.93	9.69	1.03	10.12	1.39	6.44	0.85	10.93	0.99
	Total	6.26	0.71	6.61	0.77	8.99	1.16	9.66	1.05	10.28	1.19	6.36	0.75	10.89	0.80
G	F	7.25	0.80	7.81	0.98	10.54	1.03	10.83	0.93	11.72	1.12	7.90	1.32	12.26	1.05
	M	7.03	0.71	8.14	1.01	11.12	1.26	11.67	1.12	11.91	0.86	7.71	1.22	12.75	0.80
	Total	7.16	0.76	7.94	1.00	10.83	1.18	11.16	1.08	11.81	1.01	7.82	1.28	12.43	0.98
H	F	10.07	1.88	10.96	1.39	12.18	1.20	12.45	0.96	12.78	1.03	10.90	1.47	-	-
	M	10.20	1.78	10.79	1.54	12.97	0.84	12.80	0.78	13.26	0.49	10.77	1.58	13.67	0.30
	Total	10.13	1.83	10.88	1.46	12.39	1.15	12.58	0.89	13.05	0.76	10.83	1.52	13.67	0.30

chronological age, except at age 12 for females. These figures were not statistically significant (Fig. 4).

The Willems method showed an average overestimation of age by 0.15 ± 0.97 years for the whole sample (Table 2, Fig. 3). This method yielded a mean overestimation of 0.01 ± 0.96 years for females and 0.29 ± 0.96 years for males. Gender showed statistically significant

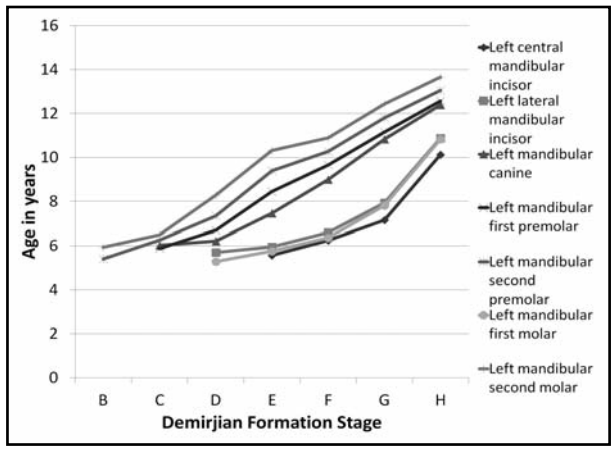

Fig.2: Demirjian Method: mean age of dental formation stages in children from total sample.

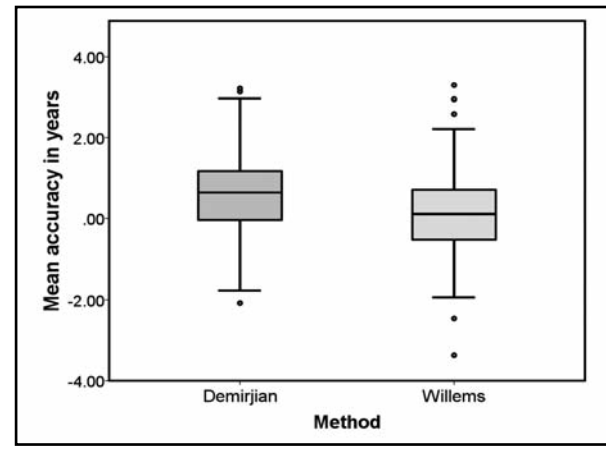

Fig.3: Mean accuracy (in years) by method in children from total sample.

Table 2: Mean accuracy (in years) by method and gender.

Method		N	Mean	SD	SE	Minimum	Maximum
Demirjian	Female	121	0.55	0.95	0.09	-2.08	3.22
	Male	117	0.68	0.91	0.08	-1.34	3.14
	Total	238	0.62	0.93	0.06	-2.08	3.22
Willems	Female	121	0.01	0.96	0.09	-3.37	2.96
	Male	117	0.29	0.96	0.09	-1.75	3.30
	Total	238	0.15	0.97	0.06	-3.37	3.30

Table 3: Mean differences between chronological and dental age estimation by method and age group in children from total sample.

Age group	Chronological age	Dental age Demirjian	Mean difference	SD	Dental age Willems	Mean difference	SD
5.00 - 5.99	5.55	6.49	0.94**	0.66	5.93	0.38	0.83
6.00 - 6.99	6.50	7.09	0.59	0.50	6.60	0.11	0.67
7.00 - 7.99	7.37	7.74	0.37	0.74	7.43	0.06	0.94
8.00 - 8.99	8.50	8.81	0.31	0.89	8.49	0.05	0.82
9.00 - 9.99	9.46	10.13	0.66	1.08	9.70	0.23	1.02
10.00 - 10.99	10.47	11.36	0.86*	0.76	10.67	0.19	0.82
11.00 - 11.99	11.54	12.09	0.55	1.15	11.70	0.16	1.11
12.00 - 12.99	12.62	12.93	0.31	1.46	12.21	-0.41	1.40
13.00 - 13.99	13.52	14.42	0.89	1.47	13.84	0.32	1.63
TOTAL		0.62*	0.93		0.15	0.97	

ANOVA *P=0.05 ** P=0.01

differences (Table 2, Fig. 4). Across age groups, for total sample, males and females, slight overestimations were observed between chronological age and dental age (Table 3, Fig. 5).

DISCUSSION

Dental age is an indicator of somatic maturation with importance in fields such as law, medicine, and dentistry, particularly in treatment planning for the growing child. Diverse methods have been proposed and used for dental age assessment, with varying results. Some are consistent within their population and some describe divergent results and the need to develop new tables in order to convert dental maturity to dental age.[4, 6-8, 32, 35]

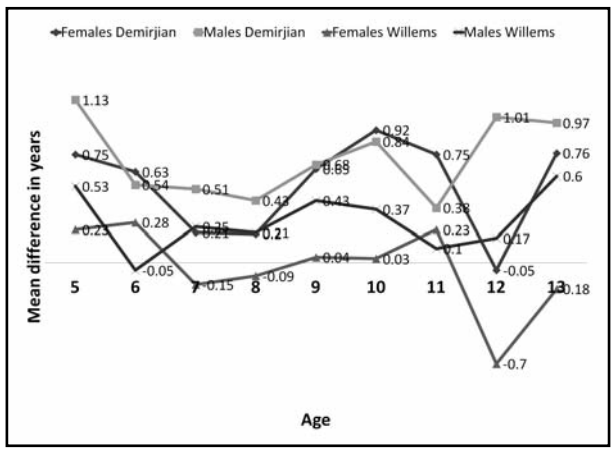

Fig.4: Mean differences between chronological age and dental age estimated by method and gender.

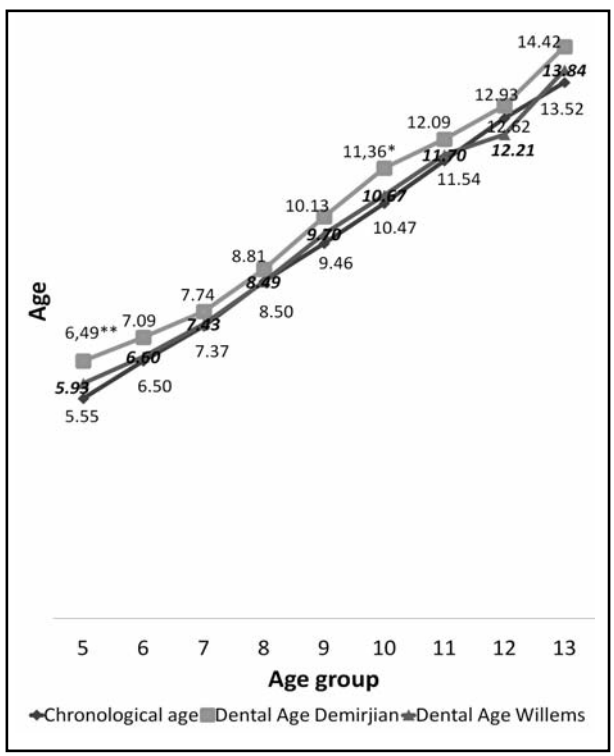

Fig.5: Chronological age and dental age estimation by method and age group in children from total sample.

Basically, these methods define the stages of mineralization of teeth examined in panoramic radiographs and code them in accordance with scores. For the present study, good quality panoramic radiographs were selected, using strict exclusion criteria.[19-22]

In the current study, the Demirjian [4] and Willems [6] methods showed a high correlation between chronological age and dental age. Several studies have reported similar results.[27-37]

In the present study, left mandibular tooth buds were evaluated and classified according to Demirjian's criteria. Within-observer agreement was consistent with previous studies.[38] This method has high reproducibility due to very clear and detailed description of stages proposed, that include relative lengths of crown and root.

For the present investigation, Demirjian's age estimation reported an average overestimation of 0.62 years for the total sample. Compared to other Venezuelan data from a similar time period, this overestimation is fairly similar to that found by Tineo et al. (0.9 years)[36] in various groups of Venezuelan children from the Maracaibo lake region. However, Cruz-Landeira et al. reported underestimation of age by 0.23 years in a Venezuelan Amerindian sample from the Andes region. [5] This difference might be due to effect of nutrition on dental age. It is a fact that Venezuela is ethnically very homogenous and that the economy of the Venezuelan Andean region is primarily based on agriculture. In this regard, in a study aimed at determining the effect of nutrition on estimation of dental age by Demirjian's method in a group of Venezuelan children, Espina et al.[39] found that mean dental age estimation for undernourished children was 1.52 years less than for well nourished children. When contrasting our results to those obtained in diverse populations abroad, Europeans showed similar overestimation.[25,26] Brazilian, South Africans,[27, 28] Eastern Europeans,[29-31] Australians, Saudi Arabians,[9, 40] Indians [37, 41] and Iranians [42] have reported lower overestimation.

The difference between chronological age and dental age estimated by Demirjian was lower for females than for males by 0.11 years. For female and males, overestimations were reported at all ages with varying differences, without statistically significant results. The lack of significance may be due to small sample sizes. This finding is consistent with other studies.[8, 26, 43, 44] The varying differences in the magnitude of overestimation of age between males and females suggests that dental growth may not be a steady, uniform process, but is probably correlated with the variation in patterns of pubertal development.[8]

Willems adapted Demirjian's method for dental age estimation in a Belgian population and modified the scoring system when a significant overestimation was reported.[7] This adjustment has been evaluated in various populations and has been found to be more accurate. [8, 32] In the current study, the Willems method showed no significant difference between chronological age and dental age for the total sample, males and females. Age estimation produced an average overestimation by 0.15 years for the total sample. This difference was greater for males (0.29 years) than for females (0.01 years). Comparable findings had been described by El-Bakary et al. (males 0.29 years, females 0.14 years).[33] For a Malian sample, Mani et al.[34] compared the Demirjian and Willems methods, finding differences using the Demirjian method to be 0.75 for males and 0.61 for females. The Willems method yielded a mean overestimation of 0.55 years for males and 0.41 years for females. Nevertheless, underestimation has been reported by other authors. Camariere et al.[25] applied the Willems method on Italian, Spanish and Croatian children, and found that it underestimated the age for females by 0.07 years and overestimated the age for males by 0.25 years. Maber et al.[8] studied the accuracy of the Willems method on Bangladeshi and British Caucasian children, and their results indicated underestimation of 0.20 and 0.05 years for females and males, respectively.

When using a dental age estimation technique, differences may arise between populations. There is documentation that has attributed these discrepancies to population differences (ethnic differences, nutrition, socio-economic level, age structure) and/or a secular trend in growth and development of the subjects studied.[32] Regarding population differences, a study carried out by Liversidge[32] found evidence of similarity in maturity of individual tooth formation stages in children from eight countries of different ethnic background. According to Liversidge, this finding strongly suggests that the significant differences in estimated dental maturity scores do not denote any biological difference in the timing of tooth formation stages at the population level. With regard to the secular trend in growth and development, several studies [4, 7, 24, 34, 40] support the idea that the rate of dental development varies among different populations. Moreover, a statistically significant positive secular trend in acceleration of dental development has been described by some authors, [45] which suggests that maturity scores obtained in the 1960's and 1970's may not be applicable to growing individuals in the 2010's.

Liversidge [32] recognizes that the Demirjian method is a valid, useful and widely applicable technique to assess maturity of an individual child, and that the Willems score system is the best adaptation of the Demirjian method and the recommended method of choice to estimate age when all seven mandibular left teeth are available. Results obtained in the present investigation support the latter. Therefore, the Willems method should be used to estimate dental age accurately.

The results of the current investigation support other work showing that the reliability of the Demirjian method as it stands may be applied satisfactorily to assess tooth formation stages in any ethnic group. However, the Willems method proved to be more accurate for estimating dental age in Venezuelan children.

CONCLUSION

The Willems method was more accurate than the Demirijan method for assessing dental age in Venezuelan children.

CORRESPONDENCE
Dr. Aida Carolina Medina
Piso 6, Comisión de Postgrado, Facultad de Odontología,
Ciudad Universitaria UCV, Los Chaguaramos, Caracas,
Venezuela
caromemo@gmail.com

REFERENCES

1. Lewis AB, Garn SM. The relationship between tooth formation and other maturational factors. Angle Orthod 1960; 30:70-77.
2. Moorrees CF, Fanning EA, Hunt EE Jr. Age variation of formation stages for ten permanent teeth. J Dent Res 1963; 42:1490-1502.
3. Green LJ. The interrelationships among height, weight and chronological, dental and skeletal ages. Angle Orthod 1961;31:189-193.
4. Demirjian A, Goldstein H, Tanner JM. A new system of dental age assessment. Hum Biol 1973;45:211-227.
5. Cruz-Landeira A, Linares-Argote J, Martínez-Rodríguez M, Rodríguez-Calvo MS, Otero XL, Concheiro L. Dental age estimation in Spanish and Venezuelan children. Comparison of Demirjian and Chaillet´s scores. Int J Legal Med 2010;124:105-112.
6. Willems G. A review of the most commonly used dental age estimation techniques. J Forensic Odontostomatol 2001; 19:9-17.
7. Willems G, Van Olmen A, Spiessens B, Carels C. Dental age estimation in Belgian children: Demirjian's technique revisited. J Forensic Sci 2001;46:893-895.
8. Maber M, Liversidge HM, Hector MP. Accuracy of age estimation of radiographic methods using developing teeth. Forensic Sci Int 2006;159:S68-73.
9. Maia MC, Martins Mda G, Germano FA, Da Silva CA. Demirjian´s system for estimating the dental age of northeastern Brazilian children. Forensic Sci Int 2010;200:177 e1-4.
10. Pelsmaekers B, Loos R, Carels C, Derom C, Vlietinck R. The genetic contribution to dental maturation. J Dent Res 1997;76:1337-1340.
11. Seow WK. Effects of preterm birth on oral growth and development. Aust Dent J 1997;42:85-91.
12. Viscardi RM, Romberg E, Abrams RG. Delayed primary tooth eruption in premature infants: relationship to neonatal factors. Pediatr Dent 1994;16:23-28.
13. Seow WK, Humphrys C, Mahanonda R, Tudehope DI.. Dental eruption in low birth-weight prematurely born children: a controlled study. Pediatr Dent 1988;10:39-42.
14. Infante PF, Owen GM. Relation of chronology of decicuous tooth emergence to height, weight and head circumference in children. Archs oral Biol 1973;18:1411-1417.
15. Suri L, Gagari E, Vastardis H. Delayed tooth eruption: pathogenesis, and treatment. A literature review. Am J Orthod Dentofacial Orthop 2004;126:432-445.
16. Vasconcelos NP, Caran EM, Lee ML, Lopes NN, Weiler RM. Dental maturity assessment in children with acute lymphoblastic leukemia after cancer therapy. For Sci Int 2009;184:10-14.
17. Leroy R, Cecere S, Lesaffre E, Declerck D. Caries experience in primary molars and its impact on the variability in permanent tooth emergence sequences. J Dent 2009;37: 865-871.
18. Lauterstein AM, Pruzansky S, Barber T. Effect of deciduous molar pulpotomy on the eruption of succedaneous premolar. J Dent Res 1962;41:1367-1372.
19. Korf SR. The eruption of permanent central incisors following premature loss of their anteccedents. J Dent Child 1965;32:39-44.
20. Fanning EA. Effect of extraction of decicuous molars on the formation and eruption of their successors. Angle Orthod 1962;32:44-53.
21. Haralabakis NB, Yiagtzis SC, Toutountzakis NM. Premature or deleyed exfoliation of deciduous teeth and root resorption and formation. Angle Orthod 1994;64:151-157.
22. Brin I, Koyoumdijsky-Kaye E. The influence of premature extractions of primary molars on the ultimate root length of their permanent successors. J Dent Res 1981;60:962-965.
23. Chaillet N, Willems G, Demirjian A. Dental maturity scores in Belgian children using Demirjian's method and polinomial functions: new standard curves for forensic and clinical use. J Forensic Odonto-Stomatol 2004;22:18-27.
24. Chaillet N, Nyström M, Demirjian A. Comparison of dental maturity in children of different ethnic origins: international maturity scores for clinicians. J Forensic Sci 2005;50:1164-1174.
25. Cameriere R, Ferrante L, Liversidge H, Prieto JL, Brkic H. Accuracy of age estimation in children using radiograph of developing teeth. Forensic Sci Int 2008;176:173-177.
26. Leurs IH, Wattel E, Aartman IH, Etty E, Prahl-Andersen B. Dental age in Dutch children Eu J Ortod. 2005;27:309-314.
27. Phillips VM, van Wyk Kotze TJ. Dental age related tables for children of various ethnic groups in South Africa. J Forensic Odontostomatol 2009;27:29-44.
28. Phillips VM, van Wyk Kotze TJ. Testing standard methods of dental age estimation by Moorrees, Fanning and Hunt and Demirjian, Goldstein and Tanner on three South African children samples. J Forensic Odontostomatol 2009; 27:20-28.
29. Čuković Bagić I, Server N, Brkić H, Kern J. Dental age estimation in children using orthopantograms. Acta Stomatol Croat 2008;42:11-18.
30. Tunc ES, Koyuturk AE. Dental age assessment using Demirjian´s method on northern Turkish children. Forensic Sci Intl 2008;175:23-26.
31. Różylo-Kalinowska I, Kiworkova-Rączkowska E, Kalinowski P. Dental age in Central Poland. Forensic Sci Int 2008;174:207-216.
32. Liversidge HM. Interpreting group differences using Demirjian´s dental maturity method. Forensic Sci Int. 2010;: doi:10.1016/j.forsciint.2010.02.032.
33. El-Bakary AA, Hammad SM, Mohammed F. Dental age estimation in Egyptian children, comparison between two methods. J Forensic & Legal Med 2010;: doi:10.1016/j.flm.2010.05.08.
34. Mani SA, Naing L, John J, Samsudin AR. Comparison of two methods of dental age estmation in 7-15-year-old Malays. Int J Paed Dent 2008;18:380-388.
35. Demirjian A, Goldstein H. New systems for dental maturity based on seven and four teeth. Ann Hum Biol 1976;3: 411-421.
36. Tineo F, Espina de Fereira A, Barrios F, Ortega A, Fereira J. Estimación de la edad cronológica con fines forenses, empleando la edad dental y la edad ósea en niños escolares en Maracaibo, Estado Zulia. Estudio preliminar. Acta Odont Venez 2006;44.
37. Hedge RJ, Sood PB. Dental maturity as an indicator of chronological age: radiographic evaluation of dental age in 6 to 13 years children of Belgium using Demirjian Methods. J Indian Soc Pedo Prev Dent. 2002;20:132-138.

38. Lavesque G, Demirjian A. The inter-examiner variation rating dental formation from radiographs. J Dent Res 1980; 59:1123-1126.
39. Espina de Fereira A, Fereira J, Céspedes M, Barrios F, Ortega A, Maldonado Y. Empleo de la edad dental y la edad ósea para el cálculo de la edad cronológica con fines forenses en niños escolares con valores de talla y peso no comparables con su edad y sexo, en Maracaibo, Estado Zulia. Acta Odont Venez. 2007;45:1-10.
40. Al-Tuwirqi A, Holcombe T, Seow WK. A study of dental development in a Caucasian population compared with non-Caucasianpopulation. Eu Arch Paed Dent 2011;12: 26-30.
41. Rai B, Anand S. Tooth development: an accuracy of age estimation of radiographic methods. World J Med Scien. 2006;1:130-132.
42. Bagherpuor A, Imanimoghaddam M, Bagherpuor M, Einolghozati M. Dental age assessment among Iranian children aged 6-13 years using the Demirjian method. Forensic Sci Intl 2010;197:121.e1-121.e4.
43. Demirjian A, Levesque G. Sexual diferences in dental development and prediction of emergence. Am J Dent Res 1980;59:1110-1122.
44. Camariere R, Ferrante L, Scarpino F, Ermenc B, Zeqiri B. Dental age estimation of growing children: comparison among various european countries. Acta Stomatol Croat 2006;40:256-62.
45. Sasso A, Spalj S, Mady Maričić B, Sasso A, Cabov T, Legović M. Secular Trend in the Development of Permanent Teeth in a Population of Istria and the Littoral Region of Croatia. J Forensic Sci 2013; 58: 673-677.