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The Accuracy and Precision of Third Molar Development as an Indicator of Chronological Age in Hispanics

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ABSTRACT: The accuracy and precision of chronological age estimation based on the stages of third molar tooth development was studied in a sample of 679 radiographs from individuals of Hispanic origin. The age range was 14.0 to 25.0 years. Eight raters from the University of Texas Health Science Center at Houston Dental Branch evaluated the radiographs according to Demirjian's schematic definitions of crown and root formation. The objective of this study was to evaluate the chronology of third molar development in Hispanics following the protocol of a previous study. Within the Hispanic population, the rate of male third molar development is greater than that of female third molar development for ten stages of crown-root formation. Also within this Hispanic population sample, the rate of maxillary third molar development is ahead of mandibular third molar development. The mean absolute difference between chronological age and estimated age was ±3.0 years in females and ± 2.6 years in males.

KEYWORDS: forensic science, third molar, Hispanic population, chronological age, panoramic radiographs, tooth formation

The accuracy of determining chronological age from tooth development (i.e., dental aging) is not uniform from birth to adulthood. The best precision and accuracy for age estimation from tooth development is achieved when individual growth is rapid and many teeth are under development (1). After age 14, estimation becomes more difficult, since most of the dentition is completely developed. Only the developing third molars remain for use in age estimation (2). However, the third molar is frequently the most variable tooth in the dentition with respect to size, (3–5) time of formation and time of eruption (6).

In the United States of America, the Hispanic population is growing rapidly. According to the Census Bureau, Hispanics will surpass African Americans as the largest U.S. minority group by 2005 (7). But along with this increase in immigration is the problem of processing individuals with falsified immigration documents such as their passports or birth records. The problem of illegal immigration is magnified in states that share a common border with Mexico. In many ways, individuals with false or improper documentation are detained by the Immigration and Naturalization Service (I.N.S.) of the United States Department of Justice, for possible deportation.

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According to the I.N.S., adults are defined as individuals who have reached their 18 birthday. Individuals less than 18 years of age are defined as juveniles. Legal consequences differ for adult detainees versus juvenile detainees. The stages of tooth mineralization based on radiologic, distinguishable stages of tooth formation can be used to estimate chronological age in young persons. Mincer et al. (3) scored the radiologic, mean ages of third molar developmental stages in a Caucasian population according to the developmental stages of tooth formation as proposed by Demirjian et al. (8). The purpose of this study was to evaluate the chronology of third molar development in Hispanics following the stages at formation as described by Demirjian et al. (8).

Material and Methods

Panoramic radiographs from 679 Hispanic individuals with known age and gender were selected for the study. There were 395 females and 284 males. Panoramic radiographs were available for 95% of the sample; for the remaining 5%, periapical films were used.

The identification of ethnicity was made according to the patient family name, and/or demographic information present in the patient charts that could confirm Hispanic ethnicity (i.e., parent's name). Radiographs with major variations in tooth eruption or tooth morphology were not selected. The population ranged in age from 14 and 25 years. The mean ages for males and females were 17.3 years and 17.7 years, respectively.

One hundred radiographs were assigned for each observer. Radiographs were coded to ensure that the observers were blind to gender, name and age of the patients.

The observers scored the stage of third molar development using the eight-grade scheme developed by Demirjian and coworkers (8,9). This was done by following the descriptive written criteria for each stage and by comparing the radiographs with representative sketches of each stage (Fig. 1).

Difficulties may be greater when estimating with precision, stages "F" or "G". In order to achieve higher accuracy in defining the stages of development towards apexification, two stages were added, F1 and G1, making ten stages of crown and root formation.

For every patient, four measurements were scored. This made it possible to also evaluate intra and inter-arch synchrony. The results and analyses were tabulated separately for each gender. If the third molar was not present, it was scored as letter code "N". This was done to estimate the frequency of missing third molar development. When the third molar had atypical anatomy, it was scored as "U". Whenever there was a disparity in the same tooth rated by two or more observers, the earliest formation stage was chosen.

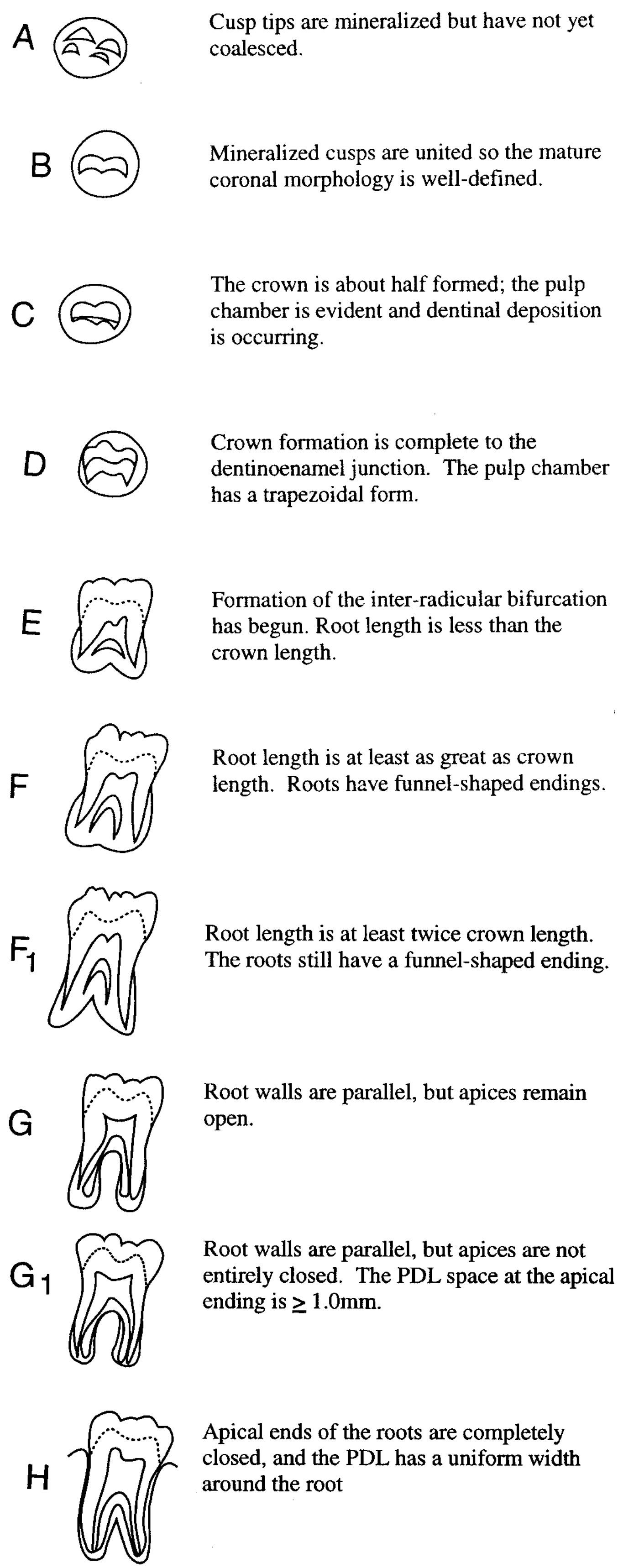

FIG. 1—*Schematic drawings and definitions of the ten stages of crown and root formation used to score third molar development (modified from Demirjian et al.* (10)).

Results

The data were divided into separate genders, and then further subdivided into subgroups for the maxilla and the mandible. Table 1 displays the mean ages of maxillary and mandibular third molar crown-root formation for the ten stages of tooth development. The sample sizes for stages B and C were too small to consider. Consequently, the analyses began at stage D where crown formation is complete. In Hispanics, the mean ages at each developmental stage were lower for males than for females. This is true for both maxilla and mandible. Maxillary arch mean stage developmental ages were less than the mandibular arch mean ages in both genders. Consequently there is a trend for third molar development to be more advanced in the maxilla than in the mandible.

Tables 2 and 3 demonstrate the percentile distribution at each developmental stage for both genders and both jaws. This illustrates the variation of each stage in the age span. The distribution of ages throughout the 15th, 25th, 50th, 75th, and 90th percentile follows a logical distribution pattern horizontally and vertically.

Table 4 expresses the probability of an individual being less than 18 years of age based on third molar developmental stages. The probabilities vary according to the tooth being examined. In female stages F1, G and G1, the probability of the chronological age being less than 18 is smaller than in males. Males reach each of the formative stages at an earlier age than females for all developmental stages.

Table 5 displays a cross tabulation of maxillary intra-arch synchrony for males and for females. In the maxilla, males exhibited the same grade of crown-root formation, i.e., concordance 83% of the time. For females, the concordance was 84%. Table 6 displays a cross tabulation of mandibular intra-arch synchrony for males and for females. In the mandible, males had an overall concordance of 78% and females 87%.

The accuracy of estimated age was computed by subtracting the mean age (obtained from the evaluation of the stages of teeth development), from the chronological age (true age). The results are displayed in Table 7 with teeth pooled under gender. The mean absolute difference is 3.0 years for females and 2.6 years for males. The smaller the mean absolute difference, the greater the accuracy.

Discussion

Estimating chronological age from third molar formation stages is suggested because of the absence of other reliable biological markers during late adolescence (3). All permanent teeth, except the third molars, have completed their formation (10). When estimating chronological age from tooth development, greater accuracy and precision is attained when many teeth are under development (1,3). The Demirjian stages of tooth development (8) used in this study were designed for permanent molars with no adaptation for third molars. Third molars are by far the most variable teeth in the dentition when considering anatomy (11), agenesis (12,13), and age of eruption (12,14).

Third molar development occurs earlier in males than in females in Hispanics. Males being ahead of females in tooth development is a unique aspect of third molars. This finding confirms the trend reported by Mincer et al. (3), Kullman et al. (15,16) and Levesque et al. (14). Results of the present study agree with a previous one (17), suggesting that Latinos develop earlier than a population sample of Canadian Caucasians (8).

The criteria used to identify a Hispanic subject for this study was the name and demographic information supplied in the patient chart. When completing a demographic questionnaire, voluntary

TABLE 1—*Mean ages of third molar crown-root formation at given stages of tooth development.*

Stages	D	E	F	F1	G	G1	H
Mandible							
Males							
Mean	15.5 (34)	15.8 (62)	16.3 (38)	16.7 (5)	17.1 (15)	18.4 (32)	20.6 (52)
SD	1.5	1.2	1.3	0.77	1.7	2.2	2.3
Females							
Mean	15.6 (72)	16.1 (62)	17.3 (57)	18.0 (13)	18.5 (34)	19.3 (46)	21.7 (51)
SD	1.4	1.4	2.6	1.4	2.1	2	1.8
Maxilla							
Males							
Mean	15.3 (54)	16.0 (46)	16.1 (35)	16.6 (8)	16.7 (17)	18.0 (26)	20.1 (62)
SD	1.4	1.4	1.5	1.4	1.4	1.9	2.6
Females							
Mean	15.7 (94)	16.2 (41)	16.7 (44)	17.6 (18)	18.4 (19)	18.6 (33)	20.8 (85)
SD	1.4	1.7	1.8	1.9	2.2	2.2	2.2

* (*N*)-total number of teeth in each sub-sample.

TABLE 2A—*Percentiles at given developmental stages of mandibular third molar crown-root formation for females.*

	Percentiles				
Stages	10	25	50	75	90
D	14.11	14.62	15.33	16.62	17.74
E	14.47	14.98	15.70	17.23	18.45
F	14.64	15.48	16.50	18.53	21.41
F1	15.94	16.74	18.20	19.24	20.16
G	16.65	17.13	17.99	19.96	21.83
G1	16.77	17.77	19.24	21.06	21.92
H	19.02	20.42	21.80	23.00	24.20

N = 670 molars.

TABLE 2B—*Percentiles at given developmental stages of mandibular third molars crown-root formation for males.*

	Percentiles				
Stages	10	25	50	75	90
D	14.17	14.50	15.07	16.17	17.54
E	14.25	14.96	15.72	16.38	17.63
F	14.71	15.40	16.01	17.05	17.84
F1	15.99	16.05	16.76	17.47	
G	14.76	15.72	17.55	18.25	20.14
G1	16.11	16.62	18.00	19.42	22.83
H	17.51	18.78	20.26	22.39	24.09

N = 476 molars.

TABLE 3A—*Percentiles at given developmental stages of maxillary third molar crown-root formation for females.*

	Percentiles				
Stages	10	25	50	75	90
D	14.27	14.65	15.40	16.45	17.67
E	14.34	15.08	15.70	17.08	18.38
F	14.60	15.28	16.18	18.05	19.83
F1	14.92	16.06	17.77	18.70	20.39
G	15.81	16.78	18.02	19.99	21.66
G1	16.21	17.11	18.55	20.02	21.53
H	17.42	19.16	21.12	22.52	23.95

N = 618 molars.

TABLE 3B—*Percentiles at given developmental stages of maxillary third molar crown-root formation for males.*

	Percentiles				
Stages	10	25	50	75	90
D	14.18	14.44	15.00	15.88	17.08
E	14.22	15.16	15.78	16.82	17.77
F	14.37	15.06	15.99	16.52	18.44
F1	14.65	15.65	16.32	17.99	
G	15.38	15.82	16.16	17.29	19.79
G1	15.43	17.03	17.93	18.49	21.15
H	16.56	18.10	19.95	22.18	23.89

N = 496 molars.

TABLE 4—*Probability of an individual being under 18 years of age based on third molars developmental stages.*

Stages	D	E	F	F1	G	G1	H
Tooth #1							
Females (*N*)	95% (95)	88% (41)	75% (44)	53% (15)	45% (20)	44% (25)	16% (86)
Males (*N*)	92% (51)	93% (44)	88% (34)	78% (9)	82% (17)	60% (25)	25% (61)
Tooth #16							
Females	95% (83)	90% (42)	79% (47)	70% (14)	47% (15)	37% (30)	21% (95)
Males (*N*)	95% (55)	94% (47)	90% (29)	85% (13)	81% (16)	63% (19)	24% (66)
Tooth #17							
Females (*N*)	94% (64)	94% (65)	73% (55)	54% (11)	46% (28)	30% (44)	9% (58)
Males (*N*)	90% (31)	95% (65)	94% (36)	100% (7)	73% (15)	53% (30)	11% (53)
Tooth #32							
Females (*N*)	92% (76)	87% (70)	69% (32)	55% (20)	60% (30)	31% (42)	8% (60)
Males (*N*)	91% (35)	95% (62)	94% (35)	83% (6)	77% (13)	55% (31)	15% (53)

(*N*) number of teeth in each sub-sample.

TABLE 5—*Cross tabulation of stages of tooth development between teeth #1 and 16 (maxillary) showing the intra arch variability for males and females, respectively.*

	Tooth #16							
Tooth #1	D	E	F	F1	G	G1	H	Total
D	**77**	9	2					88
E	3	**29**	5			1	2	40
F		2	**39**					41
F1			1	**11**	1	1		14
G				2	**13**	5		21
G1						**15**	10	25
H						7	**77**	84
Total	82	40	46	13	14	29	89	**313**

NOTE: Numbers are raw count of cases: total sample is 626 for maxillary comparisons in males. Numbers in bold correspond to the number of teeth that are in concordance with its counterpart.

Tooth #1	D	E	F	F1	G	G1	H	Total
D	**48**	2						50
E	4	**40**						44
F		1	**28**	5				34
F1			1	**8**				9
G					**16**			16
G1		1				**17**	6	24
H						2	**57**	59
Total	52	44	29	13	16	19	63	**236**

NOTE: Numbers are raw count of cases: total sample is 626 for maxillary comparisons in females. Numbers in bold correspond to the number of teeth that are in concordance with its counterpart.

TABLE 6—*Cross tabulation of stages of tooth development between teeth #17 and #32 showing the intra arch variability for males and females, respectively.*

	Tooth #32							
Tooth #17	D	E	F	F1	G	G1	H	Total
D	**57**	5						62
E	7	**56**	2					65
F	5	7	**28**	8	3			51
F1				**10**			1	11
G			1		**20**	6	1	28
G1				2	4	**28**	10	44
H						8	**47**	55
Total	69	68	31	20	27	42	59	**316**

NOTE: Numbers are raw count of cases: total sample is 632 for mandibular comparisons for males. Numbers in bold correspond to the number of teeth that are in concordance with its counterpart.

Tooth #17	D	E	F	F1	G	G1	H	Total
D	**25**	3						28
E	7	**55**	2	1				65
F		3	**31**	1		1		35
F1			2	**3**	1		1	7
G	1				**11**	2		13
G1				1	1	**25**	2	29
H						2	**49**	51
Total	33	61	35	6	13	30	52	**230**

NOTE: Numbers are raw count of cases: total sample is 460 for mandibular comparisons in females. Numbers in bold correspond to the number of teeth that are in concordance with its counterpart.

self-classified ethnicity is an acceptable marker of individual ethnicity (18). Based on the demographics in the Houston area, the majority of this study population is probably Mexican-American originating from northern Mexico and areas of the southern United States. These areas were originally colonized by Spanish conquistadors in the 18th century. The contemporary Mexican-American ethnic group is a combination of descendents of Mexican-settlers and American Indians (30 to 40%) and the European Spanish population (60 to 70%) (19). They are a complex, heterogeneous group identified by various criteria such as the father's surname, mother's maiden name, place of birth, and self-assessed ethnic identity (20).

No investigation was done to determine if any of the Hispanic individuals were from other Latin countries. The term Hispanic may be too broad to identify sources of variation within this ethnicity such as genetic influences, diet, socioeconomic status and language.

Ethnic variation within the chronology of tooth formation is well established and reference data should be adjusted to suit different groups. Further studies investigating the chronology of third molar development for Negro and Oriental populations may be warranted in the event that this analysis is useful for legal age determination of subjects of different ethnic/racial background.

When analyzing the probability of an individual being under 18 years of age based on the stages of third molar formation (Table 4), the accuracy is higher in the earlier stages (D, E, F). Subsequent to stage F1, there is a sharp decline in the proportion of times that chronological age is estimated to be less than 18 years of age.

The presence of stages F1 and G1 in this study improve the evaluation of third molar development. Thorson and Hagg (1) reported the presence of a stage called "late G" when investigating the accuracy and precision of the third molar development in a Swedish adolescent population. Stages F1 and G1 were not described by Demirjian et al. (8) as permanent molar developmental stages. The addition of two more stages is of particular value when evaluating third molar developmental stages because of their variability when compared to other permanent molars. The two additional stages may improve accuracy when the crown-root development of third molars is used to calculate the probability of an individual being under age 18. The mean age difference between the stages F, F1, G, and G1 is shown in Table 1 and is higher between stages G and G1 than for stages F and F1.

TABLE 7—*Mean age of the absolute value of the accuracy (estimated age minus true age).*

Gender	(*N*)	Mean	Std. Deviation
F	365	1.5	1.2
M	265	1.3	1.2

During the study, the observers found that apices of the maxillary third molars are hard to judge on panoramic films due to the superimposition of anatomic structures. This situation was improved when periapical films were used instead of panoramic films. It was difficult to find adequate third molar periapical projections in younger individuals less than 17 years old. Full mouth surveys using periapical films are used to routinely examine the dentition. However at this age, third molars have usually not erupted and are difficult to image on standard molar periapical radiographs. Special techniques may be required but they are technically difficult and uncomfortable for the patient. Panoramic radiographs, for their convenience, speed and quality of information of structures are often the radiographic technique of choice. The evaluation of the developmental stages of third molars using panoramic radiographs is more readily available and therefore used despite the panoramic image superimposition in the maxilla.

Age estimation from tooth development is not possible after tooth development has reached stage H and the apices are closed. In the present study, the mean age for stage H was 20.5 years (Table 1). However the mean could be lower if the population sample age range was limited to a younger age than 24 years. Consequently, we recommend that the maximum age limit for population samples in future studies be no greater than 22 years.

Summary

Even though there is a large inter-arch variability and race plays an important factor in tooth formation, third molar development is a valuable tool for age estimation in late adolescence and early adulthood as there are no other indicators available for age estimation.

Three questions remain to be addressed: (a) whether the accuracy can be improved using fewer raters; (b) whether a narrower age range can be formed for the stages considered "borderline" (F1, G, and G1), and (c) whether the use of periapical radiographs will improve accuracy especially when evaluating maxillary third molars.

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