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ORIGINAL ARTICLE

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Evaluation of chronological age based on third molar development in the Spanish population

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Abstract A cross-sectional study was carried out to assess chronological age estimation based on the stages of third lower molar development, following the eight stages (A–H) method of Demirjian et al. The final sample consisted of 1,054 orthopantomograms from Spanish individuals of known chronological age (range 14–21 years) and gender (462 males and 592 females). Results showed a stronger correlation for males (r^2=0.54) than for females (r^2=0.45). Root formation occurred earlier in males than females, in stages 5, 6 and 7. The mean difference between chronological and estimated age was −0.10 years (±1.23 SD) for left third molar, and −0.07 years (±1.22 SD) for right third molar, with slight variations regarding sex. Comparative tables are provided regarding medicolegal questions concerning age 18 prediction in the Spanish population, showing that legal age is reached in stage 7 (G) by women and in stage 8 (H) by men. No differences have been observed between sides (p<0.0001). Differences were observed between Spaniards and other previously studied populations. Third molar maturity takes place earlier in the Spanish than French-Canadian, Scandinavian, American, German, Japanese and South African populations and is more similar to US Hispanics in root development.

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Introduction

Dental age can be assessed accurately in childhood, because many teeth are developing simultaneously.

Visual inspection of dental eruption was the first and most usual method for dental age assessment. However, although this method is fast, cheap and not very influenced by intra-observer and interobserver error, eruption is not a good age indicator when used alone, due to factors like interindividual variation or the elapsed time without changes in tooth emergence [20].

The dental development process correlates with different morphological stages of mineralization that can be observed with radiographic techniques, undergoes much more uniform and gradual changes than eruption and is less influenced by external factors like malnutrition, disease and mental stress than all other measurable criteria of maturity [3]. This is the reason why several methods of dental age estimation have been developed.

However, reliability in estimating age from dental development is not uniform from birth to adulthood. After the age of 14, as most of the teeth are already developed, age estimation becomes more difficult. The only teeth still growing at this age are the third molars and these are the most inconstant teeth of all [5]. However, evaluation of third molar maturity seems to be an adequate method for estimating the age of undocumented juvenile suspects or asylum seekers, when used in conjunction with skeletal maturity, as the skeletal development of hand and wrist or the ossification of the medial epiphysis of the clavicle [17].

Age estimation techniques attain special significance when it comes to the legal effects of calculating the age—adult or minor—of an udocumented young individual, whether delinquent or immigrant. In Spain the age of major ity is 18.

Use of wisdom teeth for age estimation has been questioned, but this is one of the few tools for age—assessing

undocumented juvenile suspects or asylum seekers, and no better dental indicators are yet available.

Like any anthropological analysis, the reference population characteristics are a significant element. Influence of genetic, nutritional, and geographical factors must be taken into account in benchmark development. Cross-applicability of standards for members of different ethnic groups has been the subject of much discussion. Up to now several studies have been undertaken in different populations to explore the usefulness of the third molar as a reliable age indicator [1–3, 6, 8, 10, 12, 18, 19, 21]. These studies show that dental development varies slightly between different populations, making population-specific studies necessary.

Our objective was to evaluate dental development in a sample of young Spanish people, and make a comparison with results of previous studies.

Materials and methods

A cross-sectional study was carried out to assess chronological age based on the stages of lower third molar development.

The total sample consisted of 1,306 digital orthopantomograms randomly collected over nine months from Spaniards of known age and gender. Exclusion selection left out the following:

- Third mandibular molars missing
- Image deformity affecting third molars
- Orthopantomogram showing obvious dental pathology

The final sample consisted of 1,054 individuals aged 14–21 years (mean age 16.8, SD 1.91), 44% males and 56% females (Table 1).

Dental development evaluation followed the method of Demirjian et al. [2], the system based on eight stages of tooth formation. The first four stages (A–D) show crown formation from the beginning of cusp calcification to completed crown, and the second four (E–H) root formation from initial radicular bifurcation to apical closing.

To score third molar development radiographic records were compared with the representative diagram shown in Fig. 1.

Of the total radiographs 10% were evaluated twice at different times, in order to obtain the intraobserver error, which came out at 0.8%.

Table 1 Age distribution by gender

	Age (Years)		
	Total	Females	Males
Mean	16.81	16.80	16.86
Std. dev.	1.915	1.80	1.86
Std. error	0.053	0.070	0.081
Count	1,054	592	462
Minimum	14.000	14.000	14.000
Maximum	20.910	20.910	20.910

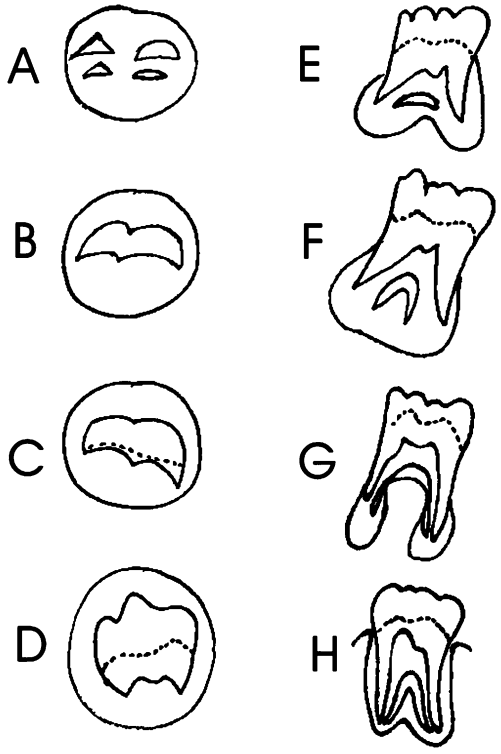

Fig. 1 Stages of dental maturity (modified from Demirjian)

Correlation coefficients between contralateral third molars were calculated, and regression analysis used for dental age calculation and comparison with the other populations.

Results

Data was subgrouped by sex and age for both left and right mandibular hemiarches.

Tables 2 and 3 show mean age and standard deviation for stages C–H in left and right third mandibular molars, respectively for males and females. At no time did we observe stages below C.

As can be seen, the mean ages at D stage were very similar for both genders, with a 0.04% difference between males and females, while in stages E, F and G there was significant sex dimorphism, with males reaching maturity indicators earlier than females. Therefore, mean ages for the same stages were around seven months younger for males than for females, with differences of 0.8 years in stage E, 0.4 years in stage F and 0.5 years in stage G. At stage H results by sex once again converge, showing a difference of 0.08 years. Results were uniform for both hemiarches.

This faster rate of formation is evident when the data distribution is expressed by percentiles for each stage of development by sex on each hemiarch as shown in Tables 4 and 5. As can be seen, data is distributed in a logical, progressive way from lower to higher percentiles (10–90). Legal age (18 years) is reached in stage G by women and in stage H by men for percentile 50, with no difference between right and left sides.

Table 2 Age distribution by stage and gender (M3 left)

M3 left						
	Mean	Std. dev.	Std. error	Count	Minimum	Maximum
Total	16.81	1.92	0.05	1,054	14	20.91
Stage C, females	14.99	1.33	0.40	11	14	17.5
Stage C, males	14.96	0.69	0.28	6	14	15.66
Stage D, females	15.11	1.00	0.11	85	14	19.33
Stage D, males	15.08	1.04	0.16	43	14	18.58
Stage E, females	16.00	1.43	0.12	137	14	20.91
Stage E, males	15.22	1.03	0.10	114	14	19.83
Stage F, females	16.83	1.56	0.10	238	14.08	20.83
Stage F, males	16.42	1.34	0.10	177	14.25	20.75
Stage G, females	18.41	1.44	0.16	86	15.16	20.75
Stage G, males	17.92	1.50	0.17	76	14.58	20.75
Stage H, females	19.66	0.98	0.16	35	17.5	20.91
Stage H, males	19.74	1.09	0.16	46	17.08	20.91

Table 3 Age distribution by stage and gender (M3 right)

M3 right						
	Mean	Std. dev.	Std. error	Count	Minimum	Maximum
Total	16.81	1.92	0.05	1,054	14	20.91
Stage C, females	14.92	1.19	0.32	14	14	17.5
Stage C, males	14.78	0.63	0.26	6	14	15.66
Stage D, females	15.12	0.97	0.10	87	14	18.5
Stage D, males	15.05	0.94	0.13	54	14	18.58
Stage E, females	15.86	1.17	0.11	138	14	20.41
Stage E, males	15.17	0.91	0.09	105	14	18.66
Stage F, females	16.82	1.53	0.10	225	14.08	20.75
Stage F, males	16.44	1.33	0.10	182	14.08	20.25
Stage G, females	18.48	1.37	0.15	84	15.41	20.58
Stage G, males	17.67	1.48	0.18	70	14.58	20.75
Stage H, females	19.60	1.15	0.18	41	16.33	20.91
Stage H, males	19.72	1.07	0.16	48	17.08	20.91

Table 4 Age distribution in percentiles by stage and sex (M3 left)

M3 left					
	Percentiles				
Stage, gender	10.00	25.00	50.00	75.00	90.00
Total	14.41	15.16	16.33	17.91	19.58
D, females	14.07	14.33	14.83	15.50	16.33
D, males	14.08	14.25	14.87	15.33	16.30
E, females	14.33	14.91	15.79	16.58	17.42
E, males	14.16	14.50	15.00	15.66	16.53
F, females	14.97	15.58	16.58	17.87	18.75
F, males	14.82	15.41	16.25	17.08	18.10
G, females	16.51	17.41	18.46	19.66	20.25
G, males	15.85	16.83	17.91	19.00	20.08
H, females	18.00	18.85	20.00	20.41	20.66
H, males	18.01	18.75	20.25	20.58	20.82

Table 5 Age distribution in percentiles by stage and sex (M3 right)

M3 right					
	Percentiles				
Stage, gender	10.00	25.00	50.00	75.00	90.00
Total	14.41	15.16	16.33	17.91	19.58
C, females	14.41	14.54	14.66	14.72	14.91
D, females	14.00	14.25	14.83	15.62	16.33
D, males	14.08	14.33	14.83	15.27	15.96
E, females	14.33	14.93	15.75	16.50	17.16
E, males	14.16	14.50	14.91	15.68	16.41
F, females	14.92	15.58	16.58	17.79	18.74
F, males	14.75	15.41	16.29	17.25	18.21
G, females	16.59	17.25	18.54	19.54	20.25
G, males	15.73	16.58	17.83	18.56	19.61
H, females	17.91	18.79	20.00	20.41	20.66
H, males	18.00	18.73	20.16	20.60	20.83

Table 6 Frequency distribution for age by stage and gender (M3 left)

	Age from (≥) to (<)							
	14.000–14.987	14.987–15.974	15.974–16.961	16.961–17.949	17.949–18.936	18.936–19.923	19.923–20.910	Total
C, female	72.727	0.000	18.182	9.091	0.000	0.000	0.000	100.000
C, male	33.333	66.667	0.000	0.000	0.000	0.000	0.000	100.000
D, female	54.118	28.235	12.941	3.529	0.000	1.176	0.000	100.000
D, male	55.814	27.907	6.9776	6.977	2.326	0.000	0.000	100.000
E, female	24.818	29.927	25.547	10.949	2.920	3.650	2.190	100.000
E, male	49.123	30.702	13.156	4.386	1.754	0.877	0.000	100.000
F, female	9.664	23.109	25.630	15.548	15.126	6.303	4.622	100.000
F, male	14.124	25.424	31.638	13.559	9.605	3.955	1.695	100.000
G, female	0.000	4.651	13.953	23.256	19.767	18.605	19.767	100.000
G, male	3.947	6.579	17.105	25.000	21.053	14.474	11.842	100.000
H, female	0.000	0.000	0.000	8.571	20.000	17.143	54.286	100.000
H, male	0.000	0.000	0.000	8.696	17.391	17.391	56.522	100.000

Table 7 Frequency distribution for age by stage and gender (M3 right)

	Age from (≥) to (<)							
	14.000–14.987	14.987–15.974	15.974–16.961	16.961–17.949	17.949–18.936	18.936–19.923	19.923–20.910	Total
C, female	70.571	0.000	14.200	7.143	0.000	0.000	0.000	100.000
C, male	50.000	50.000	0.000	0.000	0.000	0.000	0.000	100.000
D, female	52.847	28.736	13.793	3.448	1.149	0.000	0.000	100.000
D, male	55.556	31.481	7.407	3.704	1.852	0.000	0.000	100.000
E, female	23.385	29.927	29.927	12.409	2.920	0.730	0.730	100.000
E, male	51.429	27.619	16.190	3.810	0.952	0.000	0.000	100.000
F, female	9.524	22.511	27.273	15.584	14.719	6.494	3.896	100.000
F, male	13.167	26.374	26.571	16.484	10.440	4.396	0.549	100.000
G, female	0.000	3.571	14.286	20.238	20.238	21.429	20.238	100.000
G, male	4.286	8.571	22.857	21.429	21.429	15.714	5.714	100.000
H, female	0.000	0.000	2.439	12.159	12.159	19.512	53.659	100.000
H, male	0.000	0.000	0.000	8.333	18.750	14.583	58.333	100.000

Table 8 Probability of an individual being less or at least 18 years old by stage and sex

	M3 right				M3 left				
	Males		Females		Males		Females		
Stage D	99.04		98.85		97.67		98.82		<18
		0.95		1.15		2.23		1.18	≥18
Stage E	98.14		95.62		97.37		91.24		<18
		1.85		4.38		2.63		8.76	≥18
Stage F	84.62		74.91		84.74		73.95		<18
		15.38		25.09		15.26		26.05	≥18
Stage G	57.14		38.09		52.63		41.86		<18
		42.86		61.91		47.37		58.14	≥18
Stage H	8.33		14.63		8.69		8.57		<18
		91.67		85.36		91.31		91.43	≥18

Table 9 Correlation between chronological age–dental age

	Correlation	Count	*Z*-value	*P* value	95% Lower	95% Upper
M3 left	−0.728	1,022	−29.495	<0.0001	−0.755	−0.698
M3 right	−0.738	956	−29.214	<0.0001	−0.765	−0.707

Differences between third lower molars for both sides were tested (paired *t*-test) and no significative differences were found for both genders (p=0.0276).

The frequency distribution by stages and sex for each of the age groups shown in Tables 6 and 7 are also logical, following a logical pattern. From this we could obtain the probability of an individual being less than 18, since for medicolegal purposes, 18 is the crucial age. Stages D–E and stage H are the only ones with sufficient probability to support a diagnosis of overage or underage (Table 8).

The accuracy of estimated or dental age, computed by subtracting the mean age (from tooth development stage evaluation) from the chronological or true age, is displayed in Table 9. The mean absolute difference between dental age and chronological age in males was similar for both molars (−0.106/−0.074). Multiple regression coefficients are provided. Statistical analysis shows a stronger correlation for males (r^2=0.54) than for females (r^2=0.45), without significant differences regarding side.

Discussion

Third molar calcification stage is one of the few tools we can use to assess the age when development is nearing completion [8] and its use is advised, according to the recommendations of the Arbeitsgemeinschaft für Forensische Altersdiagnostik (study group for forensic age diagnostics) [15], in combination with the general physical examination, and X-ray examination of the hand and clavicle, ensuring that each part is performed by forensically trained and experienced experts of the relevant disciplines [16]. For this purpose third molar examination represents one acceptable alternative, although it is the most variable tooth with regard to time of formation [7] and the age of eruption [4].

Different methods for evaluating dental maturity have been defined, based on the observation of distinctive formation stages [2, 4, 6, 9, 11]. We have chosen Demirjian's method because it is more simple (only four stages of root formation on third lower molars) and objective (only changes in shape or proportions and no metric estimations are defined). Moreover, recent studies verify that Demirjian et al.'s classification system performed best not only for observer agreement but also for the correlation between estimated and true age [13].

The results agree, in general terms, with those reported by previous studies which have observed third molar development with regard to side, gender and ethnicity.

Testing differences between third lower molars for both sides found similar correlation coefficients for both genders, in accordance with previously published papers.

Results show faster development in males than in females, that is, third molar maturity is earlier in males than females, ranging from six to nine months. The slight differences in the

Table 10 Mean age (±SD) in years in different populations, based on Demirjian's method

Stage/ gender	French-Canadian (Demirjian et al.)	American (Mincer et al.)	Hispanics from USA (Solari et al.)	German (Olze et al.)	Japanese (Olze et al.)	South African (Olze et al.)	Spanish (Prieto et al.)
E/females	15.40 −0.50[a]	16.9 (1.7) 1.0[a]	16.1 (1.4) −0.3[a]	21.2 (2.4) 1.21[a]	18.2 (2.3) 2.21[a]	15.9 (2.3) –	15.99 (1.42)
E/males	15.4 0.2[a]	17.3 (2.5) 2.1[a]	15.8 (1.2) 0.7[a]	16.7 (2.1) 1.48[a]	18.6 (2.9) 3.38[a]	15.2 (2.4) –	15.22 (1.03)
F/females	17.30 0.50[a]	17.7 (1.8) 0.9[a]	17.3 (2.6) −0.5[a]	19.0 (2.5) 2.17[a]	20.3 (1.9) 3.47[a]	21.3 (2.5) 0.47[a]	16.83 (1.56)
F/males	16.95 0.55[a]	17.5 (2.1) 1.0[a]	16.3 (1.3) −0.1[a]	18.2 (2.1) 1.77[a]	19.8 (2.2) 3.37[a]	18.7 (2.3) 2.27[a]	16.43 (1.34)
G/females	19.50 1.1[a]	19.1 (2.1) 0.7[a]	18.5 (2.1) −0.1[a]	21.6 (2.1) 3.19[a]	21.5 (1.8) 3.09[a]	19.8 (2.3) 1.39[a]	18.41 (1.43)
G/males	18.40 0.5[a]	18.3 (1.9) 1.3[a]	17.1 (1.7) −0.8[a]	21.2 (1.9) 3.28[a]	21.8 (2.1) 3.88[a]	20.8 (2.2) 2.88[a]	17.92 (1.50)
H/females	20.70 1.00[a]	20.9 (2.0) 1.3[a]	21.7 (1.8) 2.1[a]	22.9 (1.7) 3.24[a]	22.1 (1.8) 2.44[a]	22.4 (1.9) 2.74[a]	19.66 (0.97)
H/Males	19.20 −0.34[a]	20.5 (1.9) 0.8[a]	20.6 (2.3) 0.9[a]	22.5 (1.7) 2.76[a]	22.5 (1.8) 2.76[a]	22.6 (1.9) 2.86[a]	19.74 (1.08)

[a]Difference (in years) with regard to Spanish population

final stage could be due to the two sexes tending to come into line on maturity.

In accordance with previous studies suggesting that third molar maturity takes place earlier in Latinos than Canadian Caucasians [14], results show a development rate of the Spanish population faster than Americans [8], French-Canadians [7], and Germans [12]. Also with regard to Japanese and South African populations [12] (Table 10). Results are closer to US Hispanics [18]; however, the majority of the Hispanic population in the Solari and Abramovitch study seems to be the Mexican-American from northern Mexico and areas of southern USA, nowadays made up of Mexicans, American Indians and Spanish conquerors (60–70%).

Bolaños et al. [1] in a previous paper evaluated the third molar development of a sample of 786 young Spaniards, aged between 4 and 20 years, finding no significantly gender influence, with similar ages values and distributions. However, their results regarding the mean ages at final stage of root completion were very similar to ours on both lower hemiarches (around 19.5 years). In spite of this, there are several reasons to avoid a comparison of the results in the two studies, namely: (1) the main goal of Bolaños work is to establish, from a clinical point of view, the variability of third molar agenesis; (2) the method used to evaluate dental development was Nolla's method, which cannot be superimposed in its last four developmental stages (7–10) on Demirjian's method (E–H); (3) the age ranges are very different in both studies (4–20 in Bolaños and 14–21 in ours) and (4) the differences in sample size for the different stages and standard deviation.

Results about the probability of an individual being less than 18 years old (stages D and E) or major (stage H) are completely in line with those published by the quoted authors [7, 8, 11, 18]. The mean absolute difference between dental age and chronological age, showed the high precision but only moderate accuracy of the method, as previous studies have illustrated [18, 19]. Statistical analysis shows a stronger correlation for males (r^2=0.54) than for females (r^2=0.45), without significant differences regarding side. These results also agree with studies on other populations, highlighting the low reliability of this type of examination when used in isolation.

In any case, medical diagnosis should only be seen as one more complementary method of age determination, signalling clearly the limitations of the different techniques used and evaluating the overall harmony or discrepancies of the elements of judgement in play. In any event, the judge has the last word in deciding age after evaluating all the evidence presented.

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