Int J Legal Med (2012) 126:107–112
DOI 10.1007/s00414-011-0600-7

ORIGINAL ARTICLE

Chronological course of third molar eruption in a Portuguese population

Inês Morais Caldas · José Luís Carneiro · Alexandra Teixeira · Eduarda Matos · Américo Afonso · Teresa Magalhães

Received: 17 April 2011 / Accepted: 28 June 2011 / Published online: 14 July 2011

Abstract Forensic age determination has become increasingly important over the past few years. Dental age estimation is frequently used as a part of this process due to the technique simplicity and reliability. This process is done taking into account pre-established values that, often, concern the population of the undocumented person. In this manner, population parameters are needed. In this paper, the authors present data concerning the third molar eruption in a Portuguese population: The minimum age for alveolar emergence of third molars ranged from 6.6 to 11.3 in females and 7.4 to 8.3 in males, for gingival emergence was 11.1 to 15.1 for females and 8.3 to 14.4 in males and for complete emergence was 15.9 to 19.4 in females and 13.4 for males. Complete emergence was found to be a useful marker for diagnosing age inferior 16 years, both in males and females, with 99.2% and 99.3% of correct predictions, respectively. These findings point out that it is possible to estimate the age of investigated persons based on alveolar, gingival and complete emergence of the third molars in the occlusal plane.

Keywords Forensic age estimation · Dental age estimation · Third molar eruption

I. M. Caldas (✉) · A. Teixeira · A. Afonso
Faculty of Dental Medicine, Porto University,
Rua Dr. Manuel Pereira da Silva,
4200-393 Porto, Portugal
e-mail: icaldas@fmd.up.pt

J. L. Carneiro
Porto, Portugal

I. M. Caldas · A. Afonso · T. Magalhães
CENCIFOR—Centre of Forensic Sciences,
Coimbra, Portugal

E. Matos · T. Magalhães
"Abel Salazar" Biomedical Sciences Institute, Porto University,
Porto, Portugal

T. Magalhães
National Institute of Legal Medicine—North Branch,
Porto, Portugal

T. Magalhães
Faculty of Medicine, Porto University,
Porto, Portugal

Introduction

In recent years, forensic age estimation of living people has become increasingly important, particularly in what concerns age estimation of undocumented minors [1, 2]. The international interdisciplinary Study Group on Forensic Age Diagnostics (AGFAD) has proposed some orientations to guide forensic age estimation [3]. These guidelines include (a) a clinical examination, performing body measurements and assessment of sexual maturity signs; (b) assessment of an X-ray of the left hand and (c) a dental evaluation, with a clinical examination and analysis of an orthopantomogram (OPT). Additionally, if the skeletal development of the hand is completed, an X-ray examination of the clavicles needs to be performed. In fact, according with Kellinghaus et al. [4], the determination of the stage of ossification of the medial clavicular epiphysis is a crucial part of age estimation in criminal proceedings, when evaluating individuals with complete hand ossification. According with recent references studies [5], if a late stage 3 is attained (characterized by a fusion between the metaphysic and the epiphysis completing more than two thirds of the former epiphyseal gap), it is possible to substantiate that an individual has reached age 18.

Often, the information needed relates with the probability of an individual being older than 14, 16, 18 or 21 years old [3, 6, 7]; in these situations, third molars are the only teeth able to provide valuable information, since all the remaining teeth have finished their development process. Several new dental techniques have been recently proposed to prove with certainty that the age of 18 has been reached. Olze et al. [8] referred to the use of the periodontal ligament in the lower third molars as a potential age estimation criterion after completed formation of the root. The evaluation of the radiographic visibility of the root pulp [9] has also been purposed to be used to prove age over 18 years old and also to prove age over 21 years old.

One other criterion used to assess a subject's age is tooth eruption. Tooth eruption, unlike tooth mineralization, the visibility of the periodontal ligament or the visibility of the root pulp, can be studied in two ways—by clinical examination and/or evaluating dental X-rays [7]—and therefore can be used in forensic age estimation following the AGFAD recommendations. However, there are not many studies concerning third molar emergence. As a matter of fact, we found studies only concerning in German, South African, Japanese and Canadian populations [7, 10–12].

We were unable to find data concerning the Portuguese population. Nevertheless, according with Olze et al. [13], population-specific reference data should be used when evaluating wisdom tooth eruption for the purpose of forensic age estimation, in a similar way as it is done for age assessment through third molar mineralization. In this study, the chronological course of third molar eruption is analysed using OPT from a Portuguese population, in order to determine the suitability of this methodology in forensic age assessment and provide reference data for this population.

Material and methods

A total of 521 OPT from 264 male and 257 female Portuguese subjects from ages 6 to 22 years were assessed. Subjects attended the residency dental clinic of the Faculty of Dental Medicine of University of Porto. The radiographs were taken for diagnostic purposes; dates of birth and exposure were proven, but unknown to the examiners. Date of X-ray exposure ranged between March 2005 and December 2010. The socioeconomic background of the subjects' sample can be described as middle to low; the general health status of the sample subjects was good, with no known systemic pathologies. The population affinity could not be verified but it can be assumed, since all subjects were born in Portugal, lived in Portugal and had Portuguese last names. Age and sex distribution of the studied population is shown in Table 1. The OPT used belong to the Faculty of Dental Medicine of Porto University.

Table 1 Sample age distribution according with sex

Age (in years)	Sex		Total (*n*)
	Male	Female	
6	12	14	26
7	18	34	52
8	31	29	60
9	28	27	55
10	22	35	57
11	13	17	30
12	20	18	38
13	23	21	44
14	19	9	28
15	13	6	19
16	11	11	22
17	12	2	14
18	5	3	8
19	13	13	26
20	15	10	25
21	8	8	16
22	1	0	1

The staging system used to classify third molar eruption was the one proposed by Olze et al. [7, 11, 12] and comprehends four stages as described (Fig. 1): (a) stage A: occlusal plane covered with alveolar bone, (b) stage B: alveolar emergence—complete resorption of alveolar bone over occlusal plane, (c) stage C: gingival emergence—penetration of gingival by at least one dental cusp and (d) stage D: complete emergence in occlusal plane.

Third molars with an unclear eruption direction and impacted teeth were excluded from this investigation. Impacted teeth were those which had their eruption detained by a physical barrier (another tooth, bone or soft tissues) or due to an anomalous position of the tooth itself [14].

All assessments were made by the same investigators (IMC and JLC), who are both dentists with over 12 years of professional practice. A training sample of 20 OPT was assessed prior to the study investigation, to analyse the methodology suitability.

Statistical analyses were performed using IBM SPSS Statistics 19.0 software. Descriptive analysis of mean age, standard deviation, standard error of the mean and minimal and maximal age (in years) for third molars, for stages A–C, was determined; for stage D, mean values were not calculated, and 50% probability values were calculated using logistic regression, following Garamendi et al. [15] recommendations. To cope with outliers and/or skew

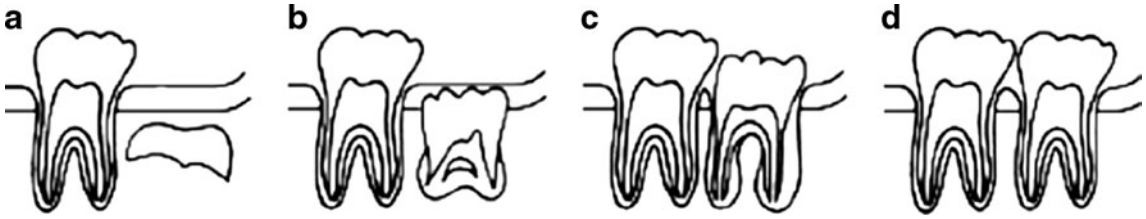

Fig. 1 Stages A to D of third molar eruption (adapted from [12])

distributions, differences between groups of interest were analysed using nonparametric tests (sign test for side and jaw differences, Kruskal–Wallis test for sex differences). Correlation between age and stage of eruption was evaluated using Spearman rank order correlation (rho). The level of significance was defined as $p<0.05$. Inter- and intra-observer agreement was determined on a sample of 30 OPT randomly selected, using the Wilcoxon signed ranks. A logistic regression analysis was also performed for age 16 years old, with teeth staging (C and D) as predictor variables.

Results

Repeated scoring of 30 radiographs revealed no significant inter- and intra-observer differences ($p>0.05$), and agreement occurred in over 95%. Results were studied according to sex and age for every third molar. Tables 2 and 3 show the mean age, standard deviation, standard error of the mean and minimal and maximal age (in years) for third molars, for stages A–C; for stage D, mean values were not calculated. The probability of excluding age younger than 18 years old was calculated for every third molar, both for males and females (Table 4). Table 5 presents 50% probability values, for each tooth, for stage D.

The minimum age for alveolar emergence of third molars ranged from 6.6 to 11.3 in females and 7.4 to 8.3 in males. The minimum age of gingival emergence was 11.1 to 15.1 for females and 8.3 to 14.4 in males; the minimum age for complete emergence was 15.9 to 19.4 in females and 13.4 for males.

A correlation analysis with Spearman rank order correlation (rho) was used to assess the strength and direction of the linear relationship between tooth emergence and chronological age. There was a strong, positive correlation between the two variables for every tooth in both genders ($p<0.001$).

The Kruskal–Wallis test was used to check for differences in tooth emergence according with sex. It was found that, overall, there were no statistically significant differences for emergence in all third molars in males and

Table 2 Age distribution by stage, by tooth, in males

Tooth	Stage	*n*	Mean	Standard deviation	Standard error of the mean	Minimum	Maximum
18	A	88	11.62	2.52	0.27	7.79	20.04
	B	47	13.81	3.00	0.44	7.37	21.18
	C	36	18.08	2.37	0.39	13.53	21.64
	D	17	–	–	–	13.36	22.29
28	A	91	11.66	2.62	0.28	7.79	20.04
	B	47	14.22	2.99	0.44	7.37	21.18
	C	31	17.78	2.96	0.53	8.28	21.79
	D	19	–	–	–	13.36	21.53
38	A	110	11.08	2.34	0.22	6.89	20.04
	B	43	15.13	2.82	0.43	8.28	21.64
	C	22	18.00	2.11	0.45	14.43	21.05
	D	21	–	–	–	13.36	22.29
48	A	102	11.02	2.28	0.23	6.28	20.04
	B	47	14.91	2.69	0.39	8.28	21.64
	C	24	18.11	2.30	0.47	14.20	21.05
	D	21	–	–	–	13.36	22.29

Table 3 Age distribution by stage, by tooth, in females

Tooth	Stage	*n*	Mean	Standard deviation	Standard error of the mean	Minimum	Maximum
18	A	81	11.29	2.14	0.24	7.20	19.76
	B	27	13.72	3.64	0.70	6.63	21.47
	C	22	17.88	2.09	0.45	13.57	21.24
	D	17	–	–	–	19.43	21.59
28	A	78	11.19	2.29	0.26	6.63	19.76
	B	27	13.86	3.02	0.58	7.53	20.74
	C	27	18.13	2.73	0.53	11.14	21.47
	D	14	–	–	–	18.91	21.59
38	A	113	10.62	2.04	0.19	6.63	16.76
	B	24	14.50	2.59	0.53	11.28	19.90
	C	9	18.56	2.22	0.74	15.06	21.05
	D	21	–	–	–	15.89	21.59
48	A	113	10.28	2.09	0.20	6.63	16.76
	B	28	14.90	2.64	0.50	10.74	20.74
	C	12	18.26	2.34	0.68	13.72	18.45
	D	16	–	–	–	15.89	21.59

females ($p>0.05$). Differences in the eruption chronology between the upper and lower, left and right third molars were also evaluated, and significant differences were observed, for females, between the following pairs: 18–48 ($p=0.008$) and 28–48 ($p=0.003$); for males, no significant differences were found.

A logistic regression analysis was also performed for age 16 years old, with teeth staging (C and D) as predictor variables. Analysis was done dividing the sample according to gender. A total of 351 cases were analysed: 178 cases for females and 173 cases for males (Table 6). Stage D was found to be a useful marker for diagnosing age inferior 16 years, both in males and females, with 99.2% and 99.3% of correct predictions, respectively.

Criteria validity was also assessed, evaluating this method's specificity (the percentage of non-occurrences correctly predicted) and sensitivity (the percentage of occurrences correctly predicted) (Table 7). The results pointed out that excluding age 16 or over (true negatives) is a more secure prediction for every stage. Equations for age estimation, for each sex according with tooth emergence stage, were also developed (Table 8).

Discussion

Forensic age estimation based on dental development has been used for a long time [16, 17]; in this context, dental examination is conducted in order to relate teeth development with chronological age, and two major factors can be studied: teeth emergence and teeth mineralization. Teeth emergence is a discontinuous process that can be assessed either using visual inspection or X-ray analysis; teeth mineralization is a continuous process that can only be evaluated using X-ray images [18]. Hence, each technique has advantages and disadvantages. In fact, if teeth mineralization can be a more informative process, teeth emergence is easier to assess, not requiring radiographic techniques (although more information is obtained if X-ray analysis is done). The simplicity of this methodology is

Table 4 Probability of excluding age younger than 18 years if stage D is attained

Tooth	Male	Female
18	99.3	99.9
28	98.6	99.9
38	98.6	98.0
48	98.6	98.7

Table 5 Fifty percent probability values for stage D, according to sex

Tooth	Male	Female
18	21.4	19.8
28	20.8	20.2
38	21.0	19.0
48	21.6	19.2

Table 6 Binary logistic regression results, by sex, according with tooth staging

Stage	Sex	Model significancy			Variance explained (%)	Correct predictions (%)		
		Omnibus χ^2	*DF*	χ^2		<16	≥16	Total
C	Male	39.562	4	<0.001	20.4–29.9	95.3	48.9	83.2
	Female	47.983	4	<0.001	23.6–36.3	96.4	46.2	85.4
D	Male	43.219	4	<0.001	22.1–32.4	99.2	40.0	83.8
	Female	67.504	4	<0.001	31.6–48.5	99.3	51.3	88.8

DF degrees of freedom

illustrated in the present study by the nearly inexistence of inter- and intra-observer differences.

The third molars, in particular, are often used as dental age indicators [6, 19–24]; in fact, although there are contradicting reports on the usefulness of third molars for dental age estimation [25], they remain the only useful dental age indicator after certain age, (approximately 15 years old) [26]. However, this usefulness has resulted in a great number of studies concerning third molar mineralization and very few concerning third molar emergence. In fact, Olze et al. [7, 11, 12] stated that studies on the chronology of wisdom tooth eruption are scarce; this can pose as a problem in those cases where X-rays are available, and there are third molars emerging.

In this investigation, we noticed an almost linear relationship between age and third molar emergence, which means that third molar emergence can be used as a dental age indicator. Overall, there were no statistically significant differences for emergence in all third molars in males and females. These data agree with those from other investigations [7, 11]. Gingival emergence was found to be a useful marker for diagnosing age equal or superior to 16 years, both in males and females, with 95.3% and 96.4% of correct predictions, respectively, meaning that, in the absence of X-ray, a fairly secure prediction of age over 16 can be made. If we compare these results with those observed in a study concerning third molar mineralization study in a Portuguese population [6], the accuracy of predicting age 16 was similar, suggesting that third molar emergence can be safely used as a criterion for age estimation.

Regarding sex differences in third molar emergence, it was found that females reach stage A earlier than males; stage B and C are first reached by males; 50% probability values for stage D point out that females reach complete emergence in occlusal plane first. This type of sequence is not verified in other investigations; results from Olze et al. [11], in a Japanese population, do not show these differences, and only a very little difference is noted between stages, being that in same teeth, females reach the stage first, and in others, the inverse is noticed. In Germans [7], female reach all stages first; in a black African population [12], an earlier stage attainment was described for males, for every stage and every teeth, exception being for stage A in the first upper right molar. In what concerns eventual population differences, in Japanese, 50% probability values for stage D are higher than those verified in this investigation, except for males' lower third molars, whereas in the black African population they are lower, for every teeth. In a German population-based study, no 50% probability values were given; however, mean values of stage attainment were higher in all stages, in both genders. These findings point out the need for population-based third molar emergence data, as it is defended by some authors for third molar mineralization [6, 27].

Conclusions

Our findings point out that it is possible, in a Portuguese population, to estimate the age of investigated persons based on alveolar, gingival and complete emergence of the third molars in the occlusal plane and to allow an estimation of the minimum and most probable age of such individuals and the likelihood of being older than 16 and 18 years.

Table 7 Criterion validity (chronological age ≥16) according with tooth staging for male (n=173) and female (n=178)

Stage	Sex	TP	TN	FP	FN	Sensitivity (CI 95%)	Specificity (CI 95%)
C	Male	22	122	6	23	41.5	85.3
	Female	18	134	5	21	46.2	96.4
D	Male	18	127	1	27	40.0	99.2
	Female	20	138	1	19	51.28	99.3

Table 8 Equations for age estimation, for each sex according with tooth emergence stage (y = age in years, x = tooth stage—1=a, 2=b, 3=c, 4=d)

Tooth	Males		Females	
	Equation	Determination coefficient (r^2)	Equation	Determination coefficient (r^2)
18	$Y = 9.727 + 2.469X$	0.50	$Y = 8.804 + 2.805X$	0.70
28	$Y = 9.165 + 1.972X$	0.46	$Y = 8.866 + 2.807X$	0.70
38	$Y = 9.909 + 2.390X$	0.42	$Y = 8.849 + 2.695X$	0.60
48	$Y = 9.233 + 1.936X$	0.41	$Y = 8.660 + 2.762X$	0.58

References

1. Schmeling A, Reisinger W, Geserick G, Olze A (2006) Age estimation of unaccompanied minors: part I. General considerations. Forensic Sci Int 159(Suppl 1):S61–S64
2. Schmeling A, Olze A, Reisinger W, Rösing FW, Geserick G (2003) Forensic age diagnostics of living individuals in criminal proceedings. Homo 54(2):162–169
3. Schmeling A, Grundmann C, Fuhrmann A, Kaatsch HJ, Knell B, Ramsthaler F, Reisinger W, Riepert T, Ritz-Timme S, Rösing FW, Rötzscher K, Geserick G (2008) Criteria for age estimation in living individuals. Int J Legal Med 122(6):457–460
4. Kellinghaus M, Schulz R, Vieth V, Schmidt S, Schmeling A (2010) Forensic age estimation in living subjects based on the ossification status of the medial clavicular epiphysis as revealed by thin-slice multidetector computed tomography. Int J Legal Med 124:149–154
5. Kellinghaus M, Schulz R, Vieth V, Schmidt S, Pfeifer H, Schmeling A (2010) Enhanced possibilities to make statements on the ossification status of the medial clavicular epiphysis using an amplified staging scheme in evaluating thin-slices CT scans. Int J Legal Med 124:321–325
6. Caldas IM, Júlio P, Simões RJ, Matos E, Afonso A, Magalhães T (2011) Chronological age estimation based on third molar development in a Portuguese population. Int J Legal Med 125 (2):235–243
7. Olze A, Peschke C, Schulz R, Schmeling A (2008) Studies of the chronological course of wisdom tooth eruption in a German population. J Forensic Leg Med 15:426–429
8. Olze A, Solheim T, Schulz R, Kupfer M, Pfeifer H, Schmeling A (2010) Assessment of the radiographic visibility of the periodontal ligament in the lower third molars for the purpose of forensic age estimation in living individuals. Int J Legal Med 124:445–448
9. Olze A, Solheim T, Schulz R, Kupfer M, Schmeling A (2010) Evaluation of the radiographic visibility of the root pulp in the lower third molars for the purpose of forensic age estimation in living individuals. Int J Legal Med 124:183–186
10. Schmeling A, Heinecke A, Pfeiffer H, Schulz R, Kraul V, Olze A, Pynn BR (2010) Dental age estimation based on third molar eruption in First Nation people of Canada. J Forensic Odontostomatol 28(1):E32–E38
11. Olze A, Ishikawa T, Zhu BL, Schulz R, Heinecke A, Maeda H, Schmeling A (2008) Studies of the chronological course of wisdom tooth eruption in a Japanese population. Forensic Sci Int 174(2–3):203–206
12. Olze A, van Niekerk P, Schulz R, Schmeling A (2007) Studies of the chronological course of wisdom tooth eruption in a Black African population. J Forensic Sci 52(5):1161–1163
13. Olze A, van Niekerk P, Ishikawa T, Zhu BL, Schulz R, Maeda H, Schmeling A (2007) Comparative study on the effect of ethnicity on wisdom tooth eruption. Int J Legal Med 121(6):45–448
14. Gay Escoda C, Rosa Gay C (1999) Dientes incluidos e impactados. Possibilidades terapéuticas ante una inclusión dentaria. In: Gay Escoda C, Berini Aytés L (eds) Cirugía bucal. ERGON, Madrid, pp 353–354
15. Garamendi PM, Landa MI, Ballesteros J, Solano MA (2005) Reliability of the methods applied to assess age minority in living subjects around 18 years old. A survey on a Moroccan origin population. Forensic Sci Int 154(1):3–12
16. Calonius PE, Lunin M, Stout F (1970) Histologic criteria for age estimation of the developing human dentition. Oral Surg Oral Med Oral Pathol 29(6):869–876
17. Ashley KF (1970) Identification of children in a mass disaster by estimation of dental age. Br Dent J 129(4):167–169
18. Liversidge HM, Chaillet N, Mörnstad H, Nyström M, Rowlings K, Taylor J, Willems G (2006) Timing of Demirjian's tooth formation stages. Ann Hum Biol 33(4):457–470
19. Bassed RB, Briggs C, Drummer OH (2011) Age estimation and the developing third molar tooth: an analysis of an Australian population using computed tomography. J Forensic Sci doi:10.1111/j.1556-4029.2011.01769.x
20. Martin-de las Heras S, García-Fortea P, Ortega A, Zodocovich S, Valenzuela A (2008) Third molar development according to chronological age in populations from Spanish and Magrebian origin. Forensic Sci Int 174(1):47–53
21. Prieto JL, Barbería E, Ortega R, Magaña C (2005) Evaluation of chronological age based on third molar development in the Spanish population. Int J Legal Med 119(6):349–354
22. Orhan K, Ozer L, Orhan AI, Dogan S, Paksoy CS (2007) Radiographic evaluation of third molar development in relation to chronological age among Turkish children and youth. Forensic Sci Int 165(1):46–51
23. Sisman Y, Uysal T, Yagmur F, Ramoglu SI (2007) Third-molar development in relation to chronologic age in Turkish children and young adults. Angle Orthod 77(6):1040–1045
24. Solari AC, Abramovitch K (2002) The accuracy and precision of third molar development as an indicator of chronological age in Hispanics. J Forensic Sci 47(3):531–535
25. Mesotten K, Gunst K, Carbonez A, Willems G (2002) Dental age estimation and third molars: a preliminary study. Forensic Sci Int 129(2):110–115
26. Woelfel JB (1997) Dental anatomy. Its relevance to dentistry. Williams and Wilkins, Baltimore
27. Thevissen PW, Alqerban A, Asaumi J, Kahveci F, Kaur J, Kim YK, Pittayapat P, Van Vlierberghe M, Zhang Y, Fieuws S, Willems G (2010) Human dental age estimation using third molar developmental stages: accuracy of age predictions not using country-specific information. Forensic Sci Int 201(1–3):106–111