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Forensic age estimation using the eruption of the second permanent mandibular molar: determining age over 14 years-old

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Little is known about the role of the second molar eruption in forensic age estimation; however, in countries where the legal age is 14-years-old, it can provide important information. This study aims to analyse whether the eruption stages of the second mandibular molar can be used for forensic age estimation purposes. The eruption stage of the second left mandibular molar was assessed and correlation between age and stage of eruption was evaluated using Spearman rank order correlation. A Chi-square test was used to assess the correlation between age equal or superior to 14 and stage C or D attainment. The level of significance was defined as $p<0.05$. Stage C and D attainment and age 14 were significantly related in both sexes ($p<0.001$). Still, stage 3 was attained by 37% and 44.4% of the males and females younger than 14 years, respectively; stage 4 was attained by 14.8% and 25.6% of the males and females younger than 14 years, respectively. Second molar emergence, particularly stage D, can be used as a dental age indicator. When stage D is attained, particularly in males, there is strong suggestion of age over 14 years. However, other markers should also be used.

Keywords: forensic age estimation; dental age estimation; second molar eruption; tooth eruption; living individuals

Introduction

The International Interdisciplinary Study Group on Forensic Age Diagnostics (AGFAD) has proposed guidelines for forensic age determination in undocumented persons submitted to criminal procedures[1]. These guidelines include a clinical examination, a left hand radiograph analysis, and a dental examination followed by an orthopantomogram (OPT) analysis. In case of doubt, or if it is needed to know if the individual is between 18 and 21, an X-ray or CAT-scan of the medial epiphysis of the clavicle should also be performed.

A lot has been written about dental age estimation in the forensic context[2–6]. In living individuals, dental age estimation is particularly relevant due to its high reliability. In fact, dental development has proved to be a very useful method because it is not as influenced by genetic, nutritional, climatic and environmental factors as are the physical development markers[1,7]; instead, dental age seems to be much more influenced by ethnicity and sex, which are normally known and, thus, easily taken into account.

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Several other methods have also been proposed, namely the assessment of the visibility of the periodontal ligament in lower third molars[8], the visualisation of dental pulp in the third lower molar[9], root development[3], or the assessment of the stages of eruption of one or a group of teeth[10]. Regarding this technique, teeth eruption has been widely studied[11–16]. In fact, although not being as informative as root development methods, dental eruption methodologies are often preferred, since they can provide results without using X-ray exams. However, most studies performed concern mainly the third molar eruption process[11,12,14,15] and little is known about the forensic usefulness of the second molar eruption process. This happens because third molar development can help to figure out if a person is over 16 or 18 years-old, those being the more frequent law-relevant ages; still, sometimes it can be useful to determine earlier age-frames. In cases of suspected child pornography or other type of children sexual abuse, the age of the victim can represent a crucial factor for legal prosecution.

This study aims to analyse if the eruption stages of the second mandibular molar can be used in forensic age estimation.

Material and methods

A total of 200 OPT from 96 male and 104 female Portuguese subjects with ages ranging 3 to 15 years (mean age 9.07 ± 3.55) were assessed. The OPTs belonged to patients attending the residency clinic of the Faculty of Dental Medicine of Porto University. The date of X-ray exposure ranged between November 2009 and March 2013. 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 staging system used to classify second molar eruption was the one proposed by Olze et al.[11,12] and considers four stages as described (Figure 1): (a) stage A: occlusal plane covered with alveolar bone; (b) stage B: alveolar emergence; complete resorption

Table 1. Sample age distribution according to sex.

	Sex		
Age (in years)	Male	Female	Total (*n*)
3	4	5	9
4	8	10	18
5	8	10	18
6	5	5	10
7	10	7	17
8	11	7	18
9	7	7	14
10	8	10	18
11	7	14	21
12	4	10	14
13	9	5	14
14	11	9	20
15	4	5	9
Total (*n*)	96	104	200

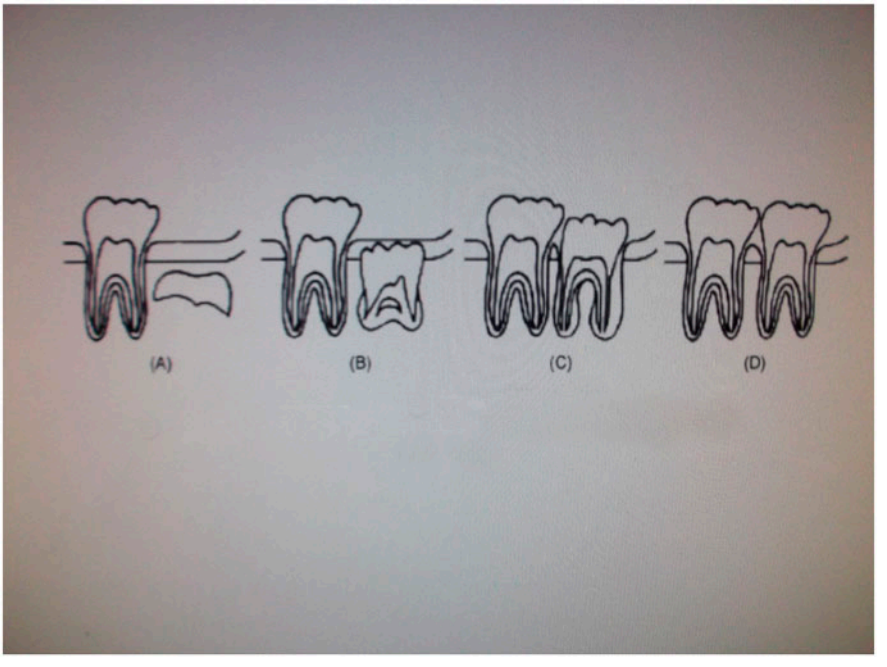

Figure 1. Stages A to D of third molar eruption (adapted from Ref. 14).

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.

OPTs with second molars with caries that reached the pulp chamber, endodontic treatments, with the absence of 37 and 47 simultaneously, or with clear pathological signs able to influence teeth development (namely, agenesis, supernumeraries, and tumours) were excluded from this investigation.

Statistical analyses were performed using IBM SPSS Statistics 22.0 software. Descriptive analyses of mean age, standard deviation, mean and minimal and maximal age (in years) for second molars eruption, for stages A–D, were performed. To cope with outliers and/or skew, differences between groups of interest were analysed using nonparametric tests (Mann-Whitney U test). Correlation between age and stage of eruption was evaluated using Spearman rank order correlation (rho). A Chi-square test was used to assess the association between age as equal or superior to 14 and stage 3 or 4 attainment. The level of significance was defined as $p<0.05$. Inter and intra-observer agreement was determined using a sample of 20 OPT randomly selected, with Wilcoxon signed ranks. To do this, the main investigator classified 20 OPT randomly selected twice, within a week interval, and a second investigator also classified 20 OPT previously analysed by the main author.

Results

Repeated scoring of 20 radiographs revealed no significant inter and intra-observer differences ($p>0.05$), and agreement occurred in over 95% of cases.

In Tables 2 and 3, the mean age, standard deviation, and minimal and maximal age (in years) for stages A–D are given, for males and females, respectively. The minimum age for alveolar emergence (stage B) was 7 years old in both groups; for gingival emergence (stage C) the minimum age was 8 years old for both females and males; and the minimum age for complete emergence (stage D) was 10 years, also in both sexes. Maximum age for each stage was also the same for males and females: in stage A, the maximum age was 8 years, in stage B 10, in stage C 13 and in stage D 15. The mean age of the first 50% reaching stage D was 11.32 years for girls and 12.38 for boys.

Spearman rank order (rho) correlation analysis 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 sexes ($p<0.001$).

The Mann-Whitney U test was used to check for differences in tooth emergence according to sex, as seen on Table 4. It was found that, overall, there were no statistically significant differences for emergence in the second lower left molars in males and females ($p>0.05$). Still, if a 10% level of significance were to be considered, complete emergence attainment (stage D) would be significantly different in males and females ($p=0.06$).

Stage C and D attainment and age 14 were significantly related in both sexes ($p<0.001$). Still, stage 3 was attained by 37% and 44.4% of the males and females

Table 2. Age distribution by stage, in males.

Stage	*n*	Mean	Standard deviation	Minimum	Maximum
A	36	5.42	1.574	3	8
B	15	8.33	0.976	7	10
C	18	10.56	1.338	8	13
D	27	13.37	1.305	10	15

Table 3. Age distribution by stage, in females.

Stage	*n*	Mean	Standard deviation	Minimum	Maximum
A	37	5.05	1.471	3	8
B	13	8.62	1.121	7	10
C	17	10.35	1.367	8	13
D	37	12.65	1.549	10	15

Table 4. Differences in tooth emergence according with sex.

Stage	*p*
A	0.325
B	0.444
C	0.695
D	0.060

Table 5. Age and stages C and D attainment, for males and females), *n*(%); (0 – non-attainment, 1 – attainment).

Sex	Age	Stage 3		Stage 4		*p*
		0	1	0	1	
♀	<14	50(55.6)	40(44.4)	67(74.27)	23(25.6)	<0.001
	≥14	0	14(100)	0	14(100)	
♂	<14	51(63.3)	30(37.0)	69(85.2)	12 (14.8)	
	≥14	0	15(100)	0	15(100)	

younger than 14 years, respectively; stage 4 was attained by 14.8% and 25.6% of the males and females younger than 14 years, respectively (Table 5).

Discussion

In dental eruption, unlike other methodologies such as dental mineralization, the visibility of periodontal ligament or the visibility of the root pulp can be studied in two ways – clinical examination and/or evaluation of dental X-rays[12,15]. Furthermore, it is a methodology that requires little training and it is simple and reliable[15,16], as shown by our high reliability values (over 95%).

Teeth mineralization analyses are considered to be a more reliable method for age estimation, because while eruption is a discontinuous and variable measurement, affected by several factors – such as malnutrition, premature loss of primary teeth, crowding and dental decay – tooth formation is seen as a more robust measure with high heritability, low coefficient of variation and resistance to environmental effects[17]. Thus, techniques based on the mineralization process of teeth are, perhaps, the most used; nevertheless, tooth eruption maybe of the utmost importance since, as previously stated, unlike tooth mineralization, it can be studied in two distinct ways: by clinical examination and/or evaluating dental X-rays[12,15]. Thus, dental eruption assessment can be particularly important in those situations where no X-rays are available. Additionally, the third molar, the tooth that is normally studied in forensic age assessment, is also the tooth with a greater percentage of agenesis in the European population[18]. Therefore, the use of other teeth, such as the second molars, can be very useful, particularly in counties such as Portugal, where if sexual abuse occurs, sentences will be different depending on the age of the victim (younger or older than 14). In these cases, second molar development process, in particular dental eruption, can be very informative.

The Demirjian method is also frequently used in this context, but this methodology can be difficult to apply since it depends on the integrity of the seven lower left mandibular teeth[19]; moreover, it has a tendency to age overestimation[10] and, finally, may not be suitable for dental age estimation since it was initially developed to study dental maturation and not to estimate dental age, being adapted later for that propose[17].

Our data showed no statistically significant differences for emergence in the second mandibular molar in males and females. Still, stage D exhibited a trend towards the existence of significant differences. This may be explained with the peak of growth that occurs in girls at this age[20].

Moreover, we found a strong correlation between eruption stage and chronological age. These data agree with those from Lee et al.[21] who also describe this relationship.

Stage 3 was reached by 37% and 44.4% of the males and females younger than 14 years, respectively; stage 4 was attained by 14.8% and 25.6% of males and females younger than 14 years, respectively. Thus, although 100% of the participants older than 14-years of age had attained stages 3 and 4, there were a large number of participants younger that had also reached those stages. So, considering stage 4, we have found that more than a quarter of the girls younger than 14 attained stage 4; in boys, this number was not as high, but was relevant (almost 15%). Therefore, the possibility of ethical unacceptable errors occurring[22], i.e. stating that people are older that they really are, is considerable, and in these scenarios (stage C or stage D attainment), this methodology should not be used alone for age estimation of the 14-year attainment threshold. On the other hand, if stages C or D are not reached, one can say for sure that the person is younger than 14.

Conclusion

Forensic age estimation using the eruption of the second mandibular molar is possible, however with some important limitations. If stages C or D are not reached, one can say for sure that the person is younger than 14. On the other hand, if there is stage C or D attainment, other methodologies should be applied to avoid ethical unacceptable errors.

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