

U. PORTO



**FACULDADE DE
MEDICINA DENTÁRIA
UNIVERSIDADE DO PORTO**

DISSERTAÇÃO DE INVESTIGAÇÃO

MESTRADO INTEGRADO EM MEDICINA DENTÁRIA

**FORENSIC AGE ESTIMATION USING THE ERUPTION OF THE SECOND PERMANENT
MANDIBULAR MOLAR**

Marta Rebelo Marques

Porto, 2013



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Acknowledgments

I would not have been able to write my thesis and done what I did all these years without the help and support of many people and therefore I have to thank them.

To my supervisor, Professor Inês Caldas, for the exchanged ideas, time spent on my thesis, the gracious help given, and above all for the amazing availability and knowledge reveled and transmitted.

To Justin Wong and Rosário Pinto, for helping me to see the mistakes that my eyes could not see.

To my brother, Alexandre Marques, my source of strength when in need, my best example and one of the best parts of myself.

To my Mom and Dad, Ana Marques and Manuel Marques, for all the support over these years, without your encouragement and your love and care none of this would be possible.

To my family for helping remind myself how important is to be surrounded by people that fight for your dreams with you.

To my friends, they know who they are, for the support along the past 5 years, long nights of study, conversations and moments that we shared.

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Figure 1 - Stages A to D of the second permanent molar (adapted from [9])8

Resumo

Introdução: O grupo internacional interdisciplinar *Study Group on Forensic Age Diagnostics* recomenda que para a identificação da idade forense de indivíduos vivos não identificados se combinem vários métodos de investigação, envolvendo um exame clínico, com o registo de dados antropométricos e sinais de maturação sexual, exame radiográfico da mão esquerda, exame oral com análise de uma ortopantomografia (OPT), e, eventualmente, análise do estadio de maturação da epífise medial da clavícula. Devido à sua reconhecida precisão para determinação da idade cronológica quando comparada com outros indicadores de idade, o estudo do desenvolvimento dentário é já largamente usado para a determinação da idade forense em indivíduos não identificados. Contudo, ainda persistem algumas dificuldades, designadamente no que concerne à escolha da metodologia mais adequada.

O principal objetivo deste estudo é contribuir para a o processo de estimativa forense da idade, percebendo qual a contribuição que o estudo dos estadios de erupção do segundo molar mandibular esquerdo pode ter.

Materiais e Métodos: Foram selecionadas 200 OPTs, de indivíduos de origem portuguesa, procedendo-se à classificação dos estadios de erupção do segundo molar mandibular inferior esquerdo, utilizando a metodologia proposta por Olze et al. Realizou-se análise descritiva da idade de atingimento dos estádios de erupção do segundo molar, correlacionando-se os diferentes estadios e a idade. O nível de significância estabelecido foi de 95%. Realizou-se ainda uma regressão linear usando a idade como variável preditiva e uma regressão logística para determinar a idade superior a 14 anos, utilizando a fase D como valor preditivo.

Resultados: A idade mínima da emergência alveolar variou entre os 7 e os 10 anos em ambos os sexos. A idade mínima da emergência gengival variou, em ambos os sexos, entre os 8 e os 13 anos, Também não existiu variação entre sexos na idade mínima da emergência completa com atingimento do plano oclusal (10 a 15 anos). A emergência completa revelou ser um marcador útil para o diagnóstico de idade superior a 14 anos, em ambos os sexos, com 87.5% e 86.5% de predições corretas, no sexo masculino e feminino, respetivamente.

Conclusão: Estes dados apontam para a possibilidade de ser possível estimar a idade de menores indocumentados tendo por base a emergência alveolar, gengival e completa do segundo molar mandibular.

Palavras-chave: Estimativa da idade forense; Estimativa da idade dentária; Erupção dentária; Segundo molar

Abstract

Introduction: The international and interdisciplinary Study Group on Forensic Age Diagnostics recommends using combine investigation methods to perform forensic age estimation of undocumented living individuals. The methodology recommended includes a physical exam, including registering of body weight and height and assessment of sexual maturity signs, an X-ray analysis of the left hand, dental examn with an orthopantogram (OPT) analysis and, eventually, the analyses of the medial clavicular epiphyses. Because of its greater accuracy when compared with other age indicators in the body, dental age estimation has been widely performed in human identification. However, accurate age estimation in children still challenging, mainly when it comes to decide the most suitable methodology to apply.

The main goal of this study is to contribute to the forensic age estimation process, trying to understand which is the contribute that the stages of eruption of the second permanent mandibular molar can give.

Materials and methods: Two hundred OPTs of individuals between 3 and 15 years old, from a Portuguese population were selected. The stage of eruption of the second left permanent mandibular molar for each OPT was classified according with Olze et al. method. A descriptive analysis of the age of attainment of the stages of eruption of the second molar was performed and different stages and age were correlated. The significance level was set at 95%. A simple linear regression was also performed using age as a predictor variable and a logistic regression to determine the age older than 14 years using the phase D as predictive value was also done

Results: The minimum age for alveolar emergence ranged between 7 and 10 years in both sexes. The minimum age for gingival emergence varied, in both sexes, between 8 and 13 years. There was also no variation between sexes in the minimum age for the complete emergency with attainment of the occlusal plane (10-15 years). Complete emergency was a useful marker for the diagnosis of older than 14 years in both sexes, with 87.5% and 86.5% correct predictions, in males and females, respectively.

Conclusions: These data point to the possibility of estimate the age of undocumented minors based on the alveolar, gingival and emergence of the second permanent mandibular molar.

Key Words: Forensic age estimation; Dental age estimation; Tooth eruption; Second molar

Introduction

In the past years, Forensic Sciences and Dental Medicine have gained more relevance, mainly due to globalization. In fact, we have seen an increasing number of individuals, usually illegal immigrants, without valid identification documents. Forensic Dentistry has presented simple and easy methods to at least estimate the forensic age of these individuals. This is important since most countries prosecute minors and adults using different rules. In addition, age estimation can be relevant in other contexts such as parental kidnapping, obtaining refugee status or asylum, in child abuse cases, and for obtaining state financial support [1]. As a result of these growing problems, the Study Group on Forensic Age Diagnostics (AGFAD) has proposed some guidelines for forensic age estimation in undocumented persons submitted to criminal procedures. [1] These guidelines include: a clinical exam, with collection of body measurements and assessment of sexual maturity signs, left hand radiograph analysis, and an oral clinical exam followed by an orthopantomogram (OPT). In case of doubt an X-ray or CAT-scan of the medial epiphysis of the clavicle should also be done.

In age estimation in living individuals, dental age estimation assumes particular relevance because if we consider each methodology alone, dental techniques are the most reliable. 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 the physical development [1] [2], being much more influenced by ethnicity and sex, which are of course, factors we can have better control.

Thus, dental development has been referred to as a suitable method to determine the most likely age in living individuals. [3] Several other methods have been proposed, namely methods based on the observation of the periodontal ligament [4], the complete formation of the teeth roots [5], or the stages of eruption and mineralization of one or a group of teeth [6]. Teeth eruption has been widely studied [7] [8] [9] [10] [11]. These studies concern mainly the third molar, and to the best of the authors' knowledge, there are not any studies regarding the second molar eruption in the Portuguese population. However, these data can be important, since they can be quite informative of the age in individuals younger than 15 years old.

The aim of this study is to verify if the different eruption stages of the second permanent mandibular molar can give reliable information concerning the age of an unidentified child in the Portuguese population, providing reference values for the studied population.

Material and Methods

Materials

A total of 200 OPT from 96 male and 104 female Portuguese subjects from ages 3 to 15 years (mean age 9.07 ± 3.55) belonging to patients attending the residency clinic of the Faculty of Dental Medicine of Porto University were assessed. 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. Age and sex distribution can be observed in Table I.

Table I – Sample age distribution according to sex

Age (in years)	Sex		Total (n)
	Male	Female	
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

Our exclusion criteria were:

- Other nationality than Portuguese;
- Deep caries reaching the pulp chamber, endodontic treatments or absence of 37 and 47 simultaneously;
- OPTs with clear signs of pathological diseases able to influence tooth development (agenesis, supernumeraries, odontogenic tumors, etc.)

Methods

Second left mandibular molar was the evaluated tooth, or when that was not possible 47 was used instead. The eruption stages were classified according to the classification proposed by Olze *et al* [8] [9] [10] and comprehend four stages as depicted in **Figure 1**.

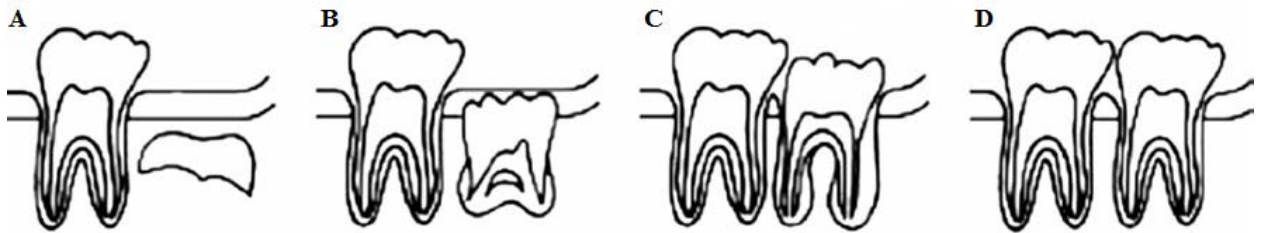


Figure 1 - Stages A to D of the second permanent molar (adapted from [9])

Each stage was defined as following:

- a) Stage A – occlusal plane covered by alveolar bone;
- b) Stage B – alveolar emergence (complete resorption of the bone above the occlusal plane);
- c) Stage C – gingival emergence (penetration of the gingiva by at least one cusp);
- d) Stage D – complete emergence in the occlusal plane.

All assessments were made by the main investigator. A training sample of 20 OPT were assessed prior to the study investigation, to analyze the methodology suitability.

Statistical analyses were performed using IBM SPSS Statistics 20.0 software. Descriptive analyses of mean age, standard deviation, mean, minimal and maximal age (in years) for second molars eruption, for stages A–D was determined. Because the mean age at stage D reflects the upper limit of the sample age, mean age of the first 50% to reach stage D, in each sex, was also determined.

To cope with outliers and/or skew differences between groups of interest were analyzed using nonparametric tests (Mann-Whitney U test). Correlation between age and stage of eruption was evaluated using Spearman rank order correlation (ρ). 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 so, the main investigator classified 20 OPT randomly selected twice; within a week interval, and a second investigator classified 20 OPT previously analyzed by the main author as well. A logistic regression analysis was also performed for each sex, for reaching the 14 years of age threshold, with reaching stage D as predictor variable. Finally, a simple linear regression analysis was also performed for age determination as predictor variables.

Results

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

The eruption of the second left mandibular molar was studied according with sex and age. Table II and Table III show the mean age, standard deviation, and minimal and maximal age (in years) for second molars for stages A–D.

Table II – Age distribution (in years) by stage, in males

Stage	<i>n</i>	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 III – Age distribution (in years) by stage, in females

Stage	<i>n</i>	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

The minimum age for alveolar emergence (stage B) of second molars 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.

The maximum age for each stage was the same for males and females in every stage. In stage A, the maximum age was 8 years, in stage B 10, in stage C 13 and in stage D 15. . Because the mean age at stage D reflects the upper limit of the sample age, mean age of the first 50% to reach stage D, in each sex, was also determined and is depicted in Table IV.

Table IV – Age (in years) of the first 50% to attain stage D

	n	Minimum	Maximum	Mean	Standard deviation
Male	12	10	13	12.25	1.138
Female	20	10	13	11.40	0.753

A Spearman 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 in both sexes ($p < 0.001$).

Mann-Whitney U test was used to check for differences in tooth emergence according to sex, as showed on Table V.

Table V– Differences in tooth emergence according to sex

Stage	P
A	0.325
B	0.444
C	0.695
D	0.060

It was found that, overall, there were no statistically significant differences for emergence in the second lower left molars in males and females ($p > 0.05$).

A simple linear regression analysis was also performed for age estimation, with stage eruption as predictor variable. Sex was not considered since we have found no statistically significant differences for emergence in the second lower left molars in males and females. Assumptions underlying this analysis were verified, namely the existence of a linear relationship between the variables and the independence of the observations. Moreover, the residuals were normally distributed and had the same variability for all fitted values of variable age.

The equation of the estimated regression line is:

$$Age = 2,817 + 2,552 \times Stage\ of\ eruption$$

In which stage A was classified with 1, stage B with 2, stage C with 3, stage D with 4.

A logistic regression analysis was also performed for each sex, for reaching the 14 years old threshold, with reaching stage D as predictor variable. In fact, despite there were not any statistically significant differences for the emergence in the second lower left molars in males and females, stage D showed a tendency to be different. Actually, if the level of statistical significance was set at 10%, stage D age of attainment would be different in males and females. Therefore, the analysis was done by dividing the sample according with sex. Stage D was found to be a useful marker for diagnosing age inferior to 14 years, both in males and females, with 87.5% and 86.5% of correct predictions, respectively.

Discussion

In this study, we have chosen to use tooth eruption to perform age estimation. Unlike tooth mineralization, visibility of periodontal ligament or visibility of the root pulp, tooth eruption can be studied by clinical examination alone. It can also be used in forensic age estimation following the AGFAD guidelines [7]. Furthermore, it requires little training and it is a simple and reliable methodology [7] [11], as shown by our high reliability values (over 95%).

However, tooth mineralization is considered to be a more reliable method for age estimation; while eruption is a discontinuous and variable measurement affected by several factors like 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 [12]. Thus, techniques based on the mineralization process of teeth often preferred; nevertheless, tooth eruption maybe of the utmost importance since, unlike tooth mineralization, it can be studied in two distinct ways: clinical exam and dental X-rays analysis [13]. Therefore, the assessment of tooth eruption can be particularly important in those situations where there are no X-rays available. At any rate, several authors have advocated the use teeth eruption as a suitable methodology for forensic age estimation [7] [11] [14] [15] [16] [17]. Still, these authors address mainly the third molar eruption. In fact, to the best of our knowledge, this is the first study on the subject of forensic age estimation using the second molar eruption.

Nevertheless, studying the second molar can be an advantage, since this tooth is a more stable one, less subject to variations than the third molar, which is related with more percentage of agenesis in the European population than any other tooth [18]. Thus, the second molar presents itself as a more reliable indicator.

The eruption of the third molar is a well-known and well-studied process, mainly because this tooth is the only indicator of tooth maturation beyond age 15. Still, there are other age thresholds of legal relevancy. In Portugal, the age of 14 years is particularly important in child abuse cases. In fact, when guilty of this crime, there are different sentences if the victim is a child younger or older than 14 years of age [19]. Our study has shown that second molar eruption stage can be of great value in this issue, since the logistic regression analysis performed revealed that stage D attainment was a useful marker for diagnosing age inferior to 14 years, both in males and females, with 87.5% and 86.5% of correct predictions, respectively.

This age threshold can also be determined using the method developed by Demirjian et al. [20] Still, this methodology is more elaborate and more time-consuming, because it evaluates 7

different teeth in 8 different stages [21]. Furthermore, a tendency to overestimate the chronological age when using the original French-Canadian standards has been reported [22], requiring the use of population-specific data, which are not always available. Finally, using the methodology developed by Demirjian to estimate age is methodologically inadequate, since this method was initially developed to study tooth maturation and not to determine dental age [20].

There were no statistically significant differences for emergence in the second mandibular molar in males and females. Still, stage D revealed a tendency for statistically significant differences ($p=0.06$). One possible explanation for this may be the different age of puberty between boys and girls, with girls having earlier teeth maturation in ages more susceptible to pre-pubertal or pubertal growth changes.

Our study revealed a strong correlation between the eruption stage of the second mandibular molar and chronological age. This data agrees with those from Lee et al. [23]. On that study they reported the same strong correlation between both variables ($r^2=0.93$ in males; $r^2=0.94$ in females). This same tendency was observed in other studies concerning other teeth eruption process [7] [11] [14] [15] [16] [17]. In what concerns the need of specific-population standards, we were not able to determine whether these are necessary or not, since we did not find any study to compare our data with. However, taking into account data from other teeth, namely the third molar [7] [19] [23], we believe that this might also be the case for the second molar, since the same factors that act in third molar eruption (socioeconomic factors, for example) may act in second molar eruption, as well. In the future, this can be analysed using the equation developed in this study for age estimation in other populations.

Conclusion

After this study we can make some conclusions about tooth eruption and in particular the contribution of the second mandibular molar concerning forensic age determination:

- Tooth eruption is a reliable method for forensic age determination, whose methodology requires little training and is simple to apply, and follows AGFAD guidelines.
- The second molar eruption stage can be of great value for forensic age determination, which is an advantage, since this tooth is more stable and less subject to variations than the third molar.
- Our study revealed a strong correlation between the eruption stage of the second mandibular molar and chronological age, which shows that is possible to determine the forensic age with reliability from the stages of eruption of this tooth.
- Our study revealed a strong correlation between the eruption stage of the second mandibular molar and chronological age, which shows that is possible to determine the forensic age with reliability from the stages of eruption of this tooth.
- Complete eruption of the second mandibular molar can be very useful marker for diagnosing age inferior 14 years, both in males and females, with 87.5% and 86.5% of correct predictions, respectively.

As Alexandre Lacassagne said *The social environment is the culture broth of crime, the microbe is the criminal element which has no importance until the day he finds the fermented broth.*” It is our part to solve this crime and to make society a more livable place and therefore we can make sure that Forensic Medicine plays not only a legal role, but a moral and ethical one too.

The 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 second mandibular molars into the occlusal plane and to allow an estimation of the minimum and most probable age of such individuals and the likelihood of persons being younger than 14 years age. This can be a huge help when it is necessary to identify the age of an undocumented person undergoing criminal procedures.

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Attachments

Exma. Senhora
Estudante Marta Rebelo Marques
Curso de Mestrado Integrado em
Medicina Dentária da
Faculdade de Medicina Dentária da U. Porto

8 20 3 10

15 MAR 2013

Assunto: Avaliação pela Comissão de Ética da Faculdade de Medicina Dentária da Universidade do Porto do Plano de Atividades a realizar no âmbito da unidade curricular “Monografia de Investigação/Relatório de Atividade Clínica” do Mestrado Integrado em Medicina Dentária e cujo título é: “Estimativa forense da idade utilizando a erupção do segundo molar mandibular permanente”.

Informo V. Exa. que o projeto supra citado foi:

- **Aprovado** na reunião da Comissão de Ética do dia 06 de março de 2013.

Com os melhores cumprimentos,

O Presidente da Comissão de Ética



António Felino
(Professor Catedrático)

DECLARAÇÃO

Monografia de Investigação/Relatório de Atividade Clínica

Declaro que o presente trabalho, no âmbito da Monografia de Investigação/Relatório de Atividade Clínica, integrado no MIMD, da FMDUP, é da minha autoria e todas as fontes foram devidamente referenciadas.

____/____/____

O / A investigador(a)

PARECER
(Entrega do trabalho final de Monografia)



Informo que o Trabalho de Monografia desenvolvido pelo(a)
Estudante _____
com o título: _____,
está de acordo com as regras estipuladas na FMDUP, foi por mim conferido e
encontra-se em condições de ser apresentado em provas públicas.

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O(A) Orientador(a)
