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Dental age estimation and third molars: a preliminary study

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Abstract

The aim of the present investigation was to reconstruct the chronological age based on the dental developmental stages of third molars evaluated on orthopantomograms. A total of 1175 orthopantomograms were assembled from patients of Caucasian origin between 16 and 22 years of age. Each third molar present was scored by two observers according to a 10-stage developmental scale. The κ statistics measured the intra- and inter-observer reliability. The general statistical analysis was based on multiple regression analysis in order to obtain multiple regression formulas for dental age estimation based on the number of third molars present on the evaluated orthopantomogram. No regression models were statistically significant when there was only one-third molar present because of the relatively small number of orthopantomograms that fitted this criterion. A strong agreement was found between the intra- and inter-observer measurements. The statistical analysis revealed both for males and females high Pearson correlation coefficients between contralateral third molars and smaller coefficients between antimeres. The obtained multiple regression formulas are only applicable in certain specified conditions, for instance when four third molars are present the following formulas should be used in a Caucasian male "age = 10.2000 + 0.5122UL + 0.5273LL" (developmental stage of upper and lower left third molars) or in case of a female "age = 13.6206 + 0.1933UR + 0.5080LR" (developmental stage of upper and lower right third molars). This investigation revealed that the chronological age of a Caucasian individual may be estimated based on regression formulas with a S.D. of 1.52 or 1.56 years for males and females, respectively, when all four third molars are present.

Keywords: Forensic science; Forensic odontology; Dental age estimation; Third molar

1. Introduction

A number of reports in the field of forensic odontology have dealt with estimating chronological age in humans, living or dead. Typically, this research has been approached in two ways: age estimation in non-adults or in adults. Recently, both areas of research have been covered well by an extensive literature review in which the conclusion was reached that using modern techniques in adults, teeth are better suited for age estimations than bones [1,2].

However, few studies have addressed the transition zone between non-adults and adults. This is surprising since, in criminal law a need exists to separate the juvenile from adult status for individuals lacking age documentation. The principal methods available for age estimation in living subjects are skeletal radiology (hand-wrist [3], sternoclavicular joints [4], long bones [5], secondary sex characteristics and tooth development [6–9]). Specifically around 18 years of age, all permanent teeth have completed their root formation and show closed apices, except for the third molars. These teeth, if present, offer the only possibility for dental age estimation between 16 and 22 years of age. Contradiction is reported in the forensic literature on the usefulness of third molars for dental age estimation [10–14]. However, conclusions have to be drawn with care since some discrepancies may be

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accounted for by case reports [6] and small sample sized research projects [12,14,15].

The aim of this preliminary study was to correlate the developmental stages of third molar teeth with chronological age and to calculate multiple regression formulas with chronological age as the independent variable and the developmental stages of the third molars as the dependent variables evaluated on orthopantomograms taken from 16- to 22-year-old Caucasian males and females.

2. Materials and methods

In this retrospective study 1175 orthopantomograms, taken at a known chronological age between 16 and 22 years (498 males and 677 females), were assembled from the patients' files of the School of Dentistry, Oral Pathology and Maxillo-Facial Surgery of the Katholieke Universiteit Leuven, Belgium. Orthopantomograms were produced over a period starting in the early 1970s until late 2001. Table 1 shows the numbers of orthopantomograms included in this study distributed according to gender and age category. As can be seen from Table 1 a small amount of 15-year olds were included. When selecting the orthopantomograms, errors occurred in calculating the age of the individual at the time the orthopantomogram was taken but they all had a chronological age of more than 15.7 years and were therefore left in the study. Table 2 gives a frequency distribution of the number of third molars present on each of the 1175 evaluated orthopantomograms. It shows that this study was based on the evaluation of the developmental stage of 4155 third molars. The following abbreviations were used: upper right (UR), upper left (UL), lower right (LR) and lower left (LL) third molar.

The selection criteria for inclusion of the orthopantomogram in this study were: Belgian Caucasian origin, no medical history, no obvious dental pathology on the panoramic radiograph related to the third molars, at least one-third molar present, patients between the age of 16 and 22 years at the time the orthopantomogram was taken.

Dental age estimation was performed according to a modification of the method of Gleiser and Hunt [16] as was used previously by Kohler et al. [17]. Third molar development was subdivided into 10 developmental stages (Fig. 1 and Table 3). Each particular stage corresponds to a particular developmental score, ranging from 1 to 10, respectively. For each case, all third molars present on the orthopantomogram were given a particular score according to the developmental stage evaluated on the radiograph. In case of a third molar with multiple roots, the least developed root was scored.

At the beginning of the study, two observers made repeated measurements of 50 orthopantomograms with an interval of 2 weeks in order to evaluate intra- and inter-observer reliability. The κ measure was used to measure the strength of agreement between the two measurements of one observer and also to measure the agreement between the measurements of the two observers. Because κ statistics are only calculated for tables where the number of rows are the same as the number of columns, for some combinations, we

Table 2
Frequency distribution for males and females of the number of third molars (n) present on all 1175 orthopantomograms evaluated

n	Frequency	Total
Males		
1	14	14
2	64	128
3	66	198
4	354	1416
Females		
1	29	29
2	70	140
3	82	246
4	496	1984
Total (n)		4155

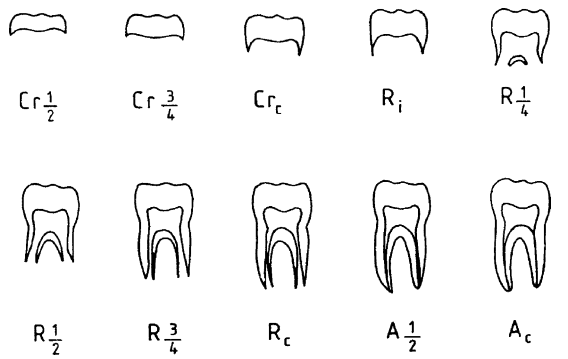

Fig. 1. Developmental stages according to a modification of the technique by Gleiser and Hunt [16], Kohler et al. [17].

Table 1
Absolute number of orthopantomograms in each age category for males and females

	15 Years	16 Years	17 Years	18 Years	19 Years	20 Years	21 Years	22 Years	Absolute (n)
Males	17	55	52	66	69	84	91	64	498
Females	25	67	86	94	105	107	125	68	677
Total (n)	42	122	138	160	174	191	216	132	1175

Table 3
Dental developmental stages of third molars describing crown and root formation [17]

Stage	Score	Description
Crown formation		
1	1	Crown 1/2 calcified
2	2	Crown 3/4 calcified
3	3	Crown completely calcified
Root formation		
4	4	Beginning of root formation
5	5	Root 1/4 calcified
6	6	Root 1/2 calcified
7	7	Root 3/4 calcified
8	8	Nearly completed root formation, root canals terminally divergent
9	9	Completed root formation, root canals terminally parallel
10	10	Completed root formation, root canals terminally convergent

were not able to measure the agreement. Besides the κ value itself, we also have considered the 95% confidence interval. The general statistical analysis was based on multiple regression analysis in order to obtain multiple regression formulas for dental age estimation based on one or more third molars.

3. Results

The κ statistics revealed no significant intra- or inter-observer effects. Both observers were in agreement in scoring the developmental stages of all four third molars.

For males, statistical analysis revealed a high Pearson correlation coefficient of 0.96 between the developmental

Table 4
Pearson correlation coefficients between upper and lower third molars for males and females

	UR	UL	LR	LL
Males				
UR	1.00	0.96	0.65	0.73
UL	0.96	1.00	0.69	0.76
LR	0.65	0.69	1.00	0.89
LL	0.73	0.76	0.89	1.00
Females				
UR	1.00	0.96	0.79	0.78
UL	0.96	1.00	0.80	0.78
LR	0.79	0.80	1.00	0.94
LL	0.78	0.78	0.94	1.00

UR: upper right; UL: upper left; LR: lower right; LL: lower left.

Table 5
Absolute number of individuals <18 years of age showing at least one-third molar with complete root formation (stage 10)

	15 Years	16 Years	17 Years	Absolute (n)
Males	0	5	12	17
Females	1	9	14	24
Total (n)	1	14	26	41

Table 6
Absolute number of individuals <18 years of age showing third molars with complete root formation (stage 10), subdivided per third molar

	15 Years	16 Years	17 Years	Absolute (n)
Males				
UR	0	4	10	14
UL	0	5	8	13
LR	0	1	3	4
LL	0	2	4	6
Subtotal	0	12	25	37
Females				
UR	1	6	11	18
UL	1	8	12	21
LR	1	3	3	7
LL	1	2	3	6
Subtotal	4	19	29	52
Total (n)	4	31	54	89

UR: upper right; UL: upper left; LR: lower right; LL: lower left.

Table 7
Absolute number of individuals <18 years of age showing all four third molars third molars with complete root formation (stage 10)

	15 Years	16 Years	17 Years	Absolute (n)
Males	0	1	2	3
Females	1	2	2	5
Total (n)	1	3	4	8

Table 8
Absolute number of 18- and 21-year-old individuals showing all four third molars third molars with complete root formation (stage 10)

	18 Years	21 Years
Males	9	39
Females	3	51
Total (n)	12	90

Table 9
Multiple regression formulas for males based on developmental scores of the third molars that are present on the orthopantomogram

n	TM present	R^2	Regression formulas	S.D.
Males				
1	UR/UL/LR/LL		Too few numbers of observations	
2	UR[a]–UL[b]	0.59	$y = 13.4694 + 0.7524UL$	1.45
	UR–LL/UR–LR		Too few numbers of observations	
	UL–LL[c]	0.59	$y = 13.4694 + 0.7524UL$	1.45
	UL–LR		Too few numbers of observations	
	LR[b]–LL[a]	0.31	$y = 15.9933 + 0.4494LR$	1.13
3	UR[a]–UL[b,c]–LL	0.65	$y = 13.0664 + 0.8006LL$	1.14
	R[b,c]–UL[a]–LL	0.65	$y = 13.0664 + 0.8006LL$	1.14
	R[c]–LR[a]–LL[b]	0.65	$y = 13.0664 + 0.8006LL$	1.14
	L[c]–LR[a]–LL[b]	0.65	$y = 13.0664 + 0.8006LL$	1.14
	UR[a]–UL[b]–LR	0.69	$y = 13.0189 + 0.4613UL + 0.3785LR$	1.01
	UL–LR[b]–LL[a]	0.69	$y = 13.0189 + 0.4613UL + 0.3785LR$	
4	UR[a]–UL[b]–LR[a]–LL[b]	0.48	$y = 10.2000 + 0.5122UL + 0.5276LL$	1.52

(UR: upper right; UL: upper left; LR: lower right; LL: lower left) plotted with the absolute number (*n*) and the specific location of the third molar(s) (TM) present. R^2 and S.D. are given for each regression formula.
[a] These teeth may not be used in the same model because of multicollinearity and therefore this tooth is omitted from the present model.
[b] These teeth may not be used in the same model because of multicollinearity.
[c] No significant contribution to regression model and thus omitted.

stage of UR and UL and a similar correlation coefficient of 0.89 was found between LR and LL. For females, correlation coefficients of 0.96 and 0.94, respectively, were found. Smaller correlation coefficients ranging from 0.65 to 0.80 were found between upper and lower third molar combinations both for males and females (Table 4).

In total 41 individuals, younger than 18 years of age, 17 males and 24 females, showed that, in at least one-third molar, root formation had reached stage 10, corresponding to complete root formation (Table 5). Table 6 shows in more detail the total number of 89 third molars that had reached stage 10 before the chronological age of 18 years.

Table 10
Multiple regression formulas for females based on developmental scores of the third molars that are present on the orthopantomogram

n	TM present	R^2	Regression formulas	S.D.
Females				
1	UR	0.42	$y = 15.5810 + 0.6057UR$ (only 11 observations)	
	UL/LR/LL		Too few numbers of observations	
2	UR[a]–UL[b]	0.49	$y = 13.9157 + 0.6986UL$	1.73
	UR–LL/UR–LR		Too few numbers of observations	
	UL–LL/UL–LR		Too few numbers of observations	
	LR[b]–LL[a]	0.34	$y = 15.2038 + 0.5507LR$	1.41
3	UR[a]–UL[b,c]–LL	0.28	$y = 15.3523 + 0.5452LL$	1.63
	UR[b,c]–UL[a]–LL	0.28	$y = 15.3523 + 0.5452LL$	1.63
	UR[a]–UL[b,c]–LR	0.40	$y = 14.1709 + 0.6688LR$	1.61
	UR[c]–LR[b]–LL[a]	0.40	$y = 14.1709 + 0.6688LR$	1.61
	UL[c]–LR[b]–LL[a]	0.40	$y = 14.1709 + 0.6688LR$	1.61
	UL[c]–LR[a]–LL[b]	0.28	$y = 15.3523 + 0.5452LL$	1.63
4	UR[b]–UL[a]–LR[b]–LL[a]	0.37	$y = 13.6206 + 0.1933UR + 0.5080LR$	1.56

(UR: upper right; UL: upper left; LR: lower right; LL: lower left) plotted with the absolute number (*n*) and the specific location of the third molar(s) (TM) present. R^2 and S.D. are given for each regression formula.
[a] These teeth may not be used in the same model because of multicollinearity and therefore this tooth is omitted from the present model.
[b] These teeth may not be used in the same model because of multicollinearity.
[c] No significant contribution to regression model and thus omitted.

Additionally, eight individuals were found to present complete root formation of all four third molars present before their 18th birthday (Table 7). Table 8 gives the number of individuals with complete root formation of all four third molars at the age of 18 and 21. Respectively, 12 and 90 orthopantomograms showed all four third molars to have completed root formation.

For dental age estimation based on third molar development in Caucasian males statistical analysis revealed several multiple regression formulas which should be used in the specified conditions. Based on gender and on the absolute number and the location of the third molar(s) present on the orthopantomogram, a specific regression formula with corresponding R^2 and S.D. must be used (Tables 9 and 10). R^2 varies from 0.31 to 0.69 for males and from 0.28 to 0.49 for females depending of the multiple regression model used. S.D. for males and females range from 1.01 to 1.52 and from 1.41 to 1.73 years, respectively.

The maxillary third molar formation was slightly advanced over the mandibular third molar formation and completion of third molar formation occurred earlier in males than females.

4. Discussion

The specific nature and methodology of the few studies reported involving third molars for dental age estimation has contributed to the controversy which nowadays exists on this matter. In addition, third molar development is probably not the ideal developmental marker [11–13]. The frequent absence of these teeth due to extraction or congenitally lack, the aberrant position, size, structure, formation and eruption time, all contribute to the great variability [12,13]. Studies that report on the use of third molars as age predictors range from single case reports [6] to only two studies that involved an adequate sample size. One study reported on the use of 823 orthopantomograms of which 658 were Caucasian males and females between 14 and 24.9 years of age [13]. Nevertheless, this study reported adequate probabilities of an individual being at least 18 years of age based on the level of third molar formation. It also confirmed our findings with respect to the earlier development of third molars in males compared to females and showed the same trend of an earlier third molar development in the maxilla compared to the mandible.

The latter findings were also confirmed by the second more recent report published in 2001 [18]. In this study 1202 orthopantomograms were evaluated, of which 28% were of non-European origin. In addition, the age ranged between 15 and 24 years of age. They reported mean ages with 95% confidence intervals according to the different developmental stages used for evaluation.

In the study by Willershausen et al. [18] root development was evaluated based on seven stages of root development of third molars (Fig. 1 and Table 3) as has already been reported in the literature [17]. No significant inter- and intra-observer effects were found, in contrast to some reported studies [19]. Although Kullman [19] evaluated 880 orthopantomograms it was not clear in view of the previously reported study [18] whether all of the assembled orthopantomograms belonged to patients of the same Caucasian origin. The R^2 of 0.48 and 0.37 found for males and females, respectively, when all four third molars are present are quite promising results and illustrate that at least third molars might be as good as the hand-wrist bones, or even better as claimed in literature [1,2]. Other researchers reported an R^2 of 0.48 for skeletal age which seems to be a very comparable value [19].

In the present study an attempt was made to narrow down the spread of the results as much as possible. This was done by implementing only two well calibrated observers who made all of the 1175 evaluations. Also, all 1175 samples were of Caucasian origin and the measurements carried out on 1175 orthopantomograms were all used for multiple regression analysis, in contrast to other studies as mentioned above where of the total reported sample size only part was of the same racial origin. Thirdly, the age range was reduced and set at 16–22 years of age in stead of the 15–24 years of age reported. Thereby a larger number of orthopantomograms was evaluated over a smaller age span which resulted in a larger absolute number of orthopantomograms per age category of 1 year (Table 1).

Ideally one should be able to gather a larger set of material in a prospective study over a period of 6 months and not retrospectively as was done in this study over a period of some 30 years. In addition, this prospective material should be grouped according to its racial and geographical origin. According to a recent study [20] the rate of ossification would be primarily affected by socio-economic development of the population. Skeletal maturation was reported to take place in identical defined stages and was unaffected by ethnicity.

Finally, it is important to note that even before the age of 18 some or all third molars might have reached complete root development (Tables 5–7). This indicates that linking the completion of root development of one or more third molars to an age above 18 years is unsatisfactory.

5. Conclusion

This investigation has revealed that the chronological age of a Caucasian individual may be estimated based on regression formulas with a S.D. of 1.52 or 1.56 years for males and females, respectively, in cases where all four third molars are present. Further continuation of this research is needed to acquire an even larger sample size in order to try and reduce S.D. of the findings and in order to try and optimise the R^2 of the multiple regression formulas. Bearing in mind the limitations of this chronological age predictor, it remains a practical and useful tool for forensic purposes [14].

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