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Third molar root development in relation to chronological age: a large sample sized retrospective study

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Abstract

The aim of the present investigation, which is a continuation and extension of a previous published pilot study [Forensic Sci. Int. 129 (2002) 110], was to calculate the chronological age of an individual based on the dental developmental stages of third molars (so-called wisdom teeth).

The evaluated material consisted of 2513 orthopantomograms (OPG's) of patients all of Belgian Caucasian origin between 15.7 and 23.3 years.

The sample of OPG's was scored by two observers who were calibrated for intra- and interobserver reliability by means of κ statistics.

The κ statistics revealed a strong agreement between the intra- and interobserver measurements.

Further statistical analysis was performed in order to obtain multiple regression formulae for dental age calculation with the chronological age as the independent variable and the third molar developmental stages as dependent variables.

Both for males and females a significant Pearson correlation coefficient was noticed for contralateral third molars, a smaller less significant one for the antimeres.

For the application of the regression formulae one has to take into consideration the gender, the location and number of wisdom teeth.

Probabilities for an individual to be older than 18 years were also calculated in case of fully developed wisdom teeth.

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

1. Introduction

The need for accurate age calculation techniques has never been greater. In the last decade the number of unidentified cadavers and human remains as well as the number of cases lacking age documentation and therefore requiring age determination has increased [1–3]. This requires age calculation, not only for differentiating the juvenile from the adult status in criminal law cases, but also for chronological age estimation in relation to school attendance, social benefits, employment and marriage [1–3].

Notwithstanding the fact that a broad range of age estimation methods exists, the determination of the chronological age within the age span of 15.7–23.3 years of age still remains a problem. Skeletal indicators such as epiphysial fusion, hand–wrist bones, amino acid racemisation, sternoclavicular bones, changes in the pubic symphysis, fusion of cranial sutures, or changes in secondary sex characteristics, all have their advantages and disadvantages and especially during these years are more or less indecisive [4–10]. Similarly, dental age can be assessed among young children with greater accuracy because many teeth are undergoing development and mineralisation simultaneously [10–14].

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In the age span of 15.7–23.3 years of age the wisdom teeth represent the only teeth still in development and are thereby very important for dental age calculation. However, the third molar is the most variable tooth in the dentition with respect to size, time of formation and time of eruption [3,15] and for this reason has been categorised as a non-ideal developmental marker. In addition, the use of wisdom teeth in age estimation has been questioned in the literature [3,15–20]. Before drawing this conclusion, one has to take into consideration multiple misleading factors such as small sample sized studies [3,16,17,19], case reports [10,21], improper statistics [3,18] and mixed samples of different ethnic origin [17,22,23]. Recently, Schmeling et al. published the most suitable procedures that are currently available for age estimation in criminal procedures, being physical examination with anthropometric measurements, radiographic examination of the left hand in case of dexterity and radiographic study of the dentition [24]. The present paper reports on one of these procedures and more exactly on the role of the third molars as age indicators.

The present study is actually a continuation and extension of a previously published pilot study [25]. More than double the original number of orthopantomograms (OPG's) (2513 compared to 1175) of Belgian Caucasian males and females were taken in the age span of 15.7–23.3 years and were evaluated with the purpose of trying to correlate the chronological age of an individual with the dental developmental stage of the third molars present, as well as reducing the standard deviation and optimising the fit of the multiple regression models.

2. Materials and methods

Orthopantomograms of 2513 Belgian Caucasian individuals (1055 males and 1458 females) with known age and gender were selected for the study. Both mother and father of all individuals selected were from Belgian Caucasian origin and had Belgian nationality. Patients age ranged between late 15.7 and 23.3 years (Table 1). The investigated radiographs were taken from patients' files of the School of Dentistry, Oral Pathology and Maxillo-Facial Surgery of the Katholieke Universiteit Leuven, Belgium, within a period starting in the early 1970s until early 2002.

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

	Age (year)									Total (*n*)
	15	16	17	18	19	20	21	22	23	
Male	20	125	103	146	159	174	219	106	3	1055
Female	33	159	162	191	212	250	308	134	9	1458
Total	53	284	265	337	371	424	527	240	12	2513

Table 2
Distribution of the number of orthopantomograms for males and females (*n*) showing respectively 1, 2, 3 and 4 third molars present, related to the total number of evaluated third molars present on all 2513 orthopantomograms

x	*n*	Total
Male		
1	34	34
2	133	266
3	141	423
4	747	2988
Female		
1	58	58
2	180	360
3	181	543
4	1039	4156
Total (*n*)		8828

x: Number of third molars present on each orthopantomogram; *n*: number of orthopantomograms; total: absolute number of third molars.

Additional selection criteria were no medical history, no obvious dental pathology on the orthopantomograms and at least one-third molar present. The frequency distribution of the number of third molars present on each of the 2513 evaluated orthopantomograms shows that the study was based on the evaluation of the developmental stage of 8828 third molars (Table 2). Radiographs meeting these selection criteria were evaluated using a 10 stage developmental scoring method as was proposed by Köhler et al. [26]. Each of the 10 stages relates to a particular developmental phase as is illustrated by Fig. 1. All of the third molars present on the radiograph were given a score corresponding

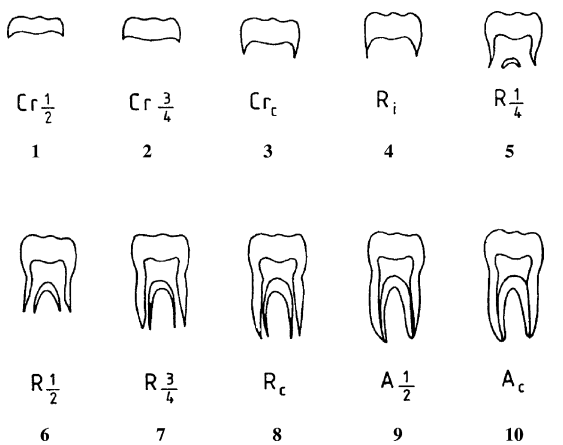

Fig. 1. Developmental stages according to a modification of the technique by Gleiser and Hunt [28]. Each developmental phase of the third molar evaluated has a score ranging from 1 to 10. When calculating the chronological age, this score must be used for the corresponding third molar in the selected regression formula.

to the stage of root development. In the case of a different developmental stage of the multiple roots of one-third molar, the least developed root was evaluated and scored.

The sample consisted of 2513 orthopantomograms scored by two observers who were trained beforehand. Both observers scored 50 OPG's twice with an interval of 2 weeks. κ Statistics were used to evaluate the intra- and interobserver reliability.

Pearson correlation coefficients between contralateral third molars and between antimeres were calculated.

Multiple regression analysis was performed in order to obtain multiple regression formulae for dental age calculation with the chronological age as the independent variable and the third molar developmental stages as dependent variables. In case of multiple wisdom teeth present, there is often a problem of multicollinearity especially between upper left and right or lower left and right third molars. Therefore, the third molar with the lowest statistical contribution (R^2) to that particular regression model is omitted. Additionally, sometimes in case of several wisdom teeth present, a specific third molar displays no significant contribution to the statistical model and is therefore omitted.

3. Results

The κ statistics revealed no significant intra- or interobserver effects. The intraobsever analysis revealed a simple κ coefficient of 0.127 with −0.214 to 0.468 95% confidence bounds, while the interobserver analysis revealed a simple κ coefficient of 0.141 with 95% confidence bounds between −0.186 and 0.468.

Significant Pearson correlation coefficients revealed a strong correlation between the different variables (Table 3). The greatest correlation coefficient was found between the developmental stage of upper right (UR) and upper left (UL) third molars, namely 0.97 for males and females. Similar correlation coefficients were noticed between lower right (LR) and lower left (LL) third molars (0.93 for males and 0.95 for females). When both upper or both lower third molars were present, one was omitted from the model for reasons of multicollinearity. The lower correlation coefficients between antimeres such as UR and LR or UL and LL did not result in a statistically significant multicolinearity and therefore both antimere were used in the same model.

Table 3
Pearson correlation coefficients between upper and lower third molars for males and females

	UR	UL	LR	LL
Male				
UR	1.00	0.97	0.79	0.75
UL	0.97	1.00	0.81	0.77
LR	0.79	0.81	1.00	0.93
LL	0.75	0.77	0.93	1.00
Female				
UR	1.00	0.97	0.81	0.80
UL	0.97	1.00	0.82	0.81
LR	0.81	0.82	1.00	0.95
LL	0.80	0.81	0.95	1.00

UR: upper right third molar (TM); UL: upper left TM, LR: lower right TM; LL: lower left TM.

The multiple regression analysis delivered several formulae with chronological age as the independent variable and third molar root development as the dependent variables (Table 4). These regression formulae are subdivided based on categories such as gender, the number and location of wisdom teeth present. Depending on the available number of wisdom teeth in an individual, R^2 varied for males from 0.36 to 0.62; for females from 0.27 to 0.61. In the case of all four third molars being present the standard deviation for males and females was 1.49 and 1.50 years, respectively. The 95% confidence interval of the difference between the estimated and true chronological age was rather low, about ±2.92 years in males and ±2.94 years in females.

In this population of Belgian Caucasian origin, the mean age at each developmental stage was lower for males than for females, indicating a slightly earlier development in males compared to females. There is also a trend for earlier third molar development in the maxilla than in the mandible.

Taking into account the location and the number of fully developed wisdom teeth, the probability for an individual being older than 18 years is expressed in Table 5. In case of the presence of four fully developed wisdom teeth, this chance is 96.3% for males and 95.1% for females.

The absolute and total number of individuals less than 18 years of age showing at least one-third molar with complete root formation is shown in Tables 6 and 7 details the subdivision per third molar.

Completion of formation of all wisdom teeth before the age of 18 years occurred in eight persons (Table 8). The end of root formation was established in 29 and 192 persons at the age of 18 and 21 years, respectively (Table 9).

4. Discussion

Age estimation by means of tooth development has been used over a long period of time, after all tooth development is an accurate measure of chronological age that seems to be independent of exogenic factors like malnutrition or disease [10,17,27]. However, age estimation based on dental methods has shortcomings, especially during adolescence when the third molar is the only variable dental indicator left. Indeed a great variation in position, morphology and time of formation exists. The differences between populations, the different methodology and the dissimilarity between observers are other important shortcomings.

In this study, in order to overcome some of these shortcomings, all selected subjects were of Belgian Caucasian

Table 4
Regression formulae for males and females based on the number of present wisdom tooth (n) and their location

n	TM present	R^2	Regression formulae	S.D.
Male				
1	UR/UL/LR/LL		Too few numbers of observations	
2	UR*–UL(*)	0.41	13.9911 + 0.6895 UR	1.48
	UR(*)–UL	0.40	14.2486 + 0.6595 UL	1.50
	UR–LL/UR–LR/UL–LR		Too few numbers of observations	
	UL(*)–LL*	0.49	12.2999 + 0.8765 LL	1.22
	LL**–LR	0.41	14.8622 + 0.5823 LR	1.34
3	UR(*)–UL*–LL**	0.37	13.3882 + 0.7466 UL	1.40
	UR*–UL(*)–LL**	0.36	13.5689 + 0.7201 UR	1.41
	UR*–UL(*)–LR	0.56	12.2212 + 0.6032 UR + 0.3132 LR	1.26
	UR**–LR(*)–LL*	0.62	12.2915 + 0.8849 LL	1.37
	UR**–LL(*)–LR*	0.61	12.3395 + 0.8791 LR	1.39
	UL*–LL(*)–LR**	0.61	13.0453 + 0.7832 UL	1.16
	UL*–LL**–LR(*)	0.61	13.0453 + 0.7832 UL	1.16
4	UR(*)–UL*–LR**–LL*	0.45	11.5886 + 0.4493 UL + 0.4525 LL	1.49
	UR*–UL(*)–LR**–LL*	0.45	11.5419 + 0.4426 UR + 0.4651 LR	1.49
Female				
1	UR	0.27	16.0204 + 0.4957 UR	1.97
	UL	0.43	15.5403 + 0.5640 UL	1.37
	LL	0.61	15.0536 + 0.6494 LL	1.19
	LR		Too few numbers of observations	
2	UR(*)–UL*	0.53	13.9365 + 0.7031 UL	1.46
	UR*–UL(*)	0.48	13.9392 + 0.6979 UR	1.54
	UR–LL/UR–LR		Too few numbers of observations	
	UL–LR/UL–LL		Too few numbers of observations	
	LL(*)–LR*	0.37	15.4518 + 0.5451 LR	1.31
	LL*–LR(*)	0.36	15.3779 + 0.5529 LL	1.32
3	UR*–UL(*)–LL**	0.29	15.9468 + 0.4912 UR	1.33
	UR(*)–UL*–LL**	0.28	16.0947 + 0.4732 UL	1.34
	UR(*)–UL**–LR*	0.31	16.0558 + 0.5026 LR	1.61
	UR**–UL(*)–LR*	0.31	16.0558 + 0.5026 LR	1.61
	UR**–LL(*)–LR*	0.33	13.7186 + 0.7335 LR	1.64
	UR–LL**–LR*	0.29	13.8418 + 0.7086 UR	1.68
	UL**–LR(*)–LL*	0.42	13.8227 + 0.6928 LL	1.33
	UL**–LR*–LL(*)	0.34	14.2609 + 0.6314 LR	1.42
4	UR(*)–UL*–LL**–LR	0.42	13.0484 + 0.3056 UL + 0.4736 LR	1.51
	UR*–UL(*)–LR–LL**	0.42	13.0725 + 0.4773 LR + 0.3010 UR	1.50

TM present: third molar present; R^2: root square; S.D.: standard deviation. *: These teeth may not be used in the same model because of multicollinearity. (*): These teeth may not be used in the same model because of multicollinearity and therefore this tooth is omitted. **: No significant contribution to the regression model and thus omitted.

origin. All 2513 orthopantomograms were evaluated by two well trained observers using a 10 stage developmental scale according to the modified method of Gleiser and Hunt [28] (Fig. 1). This method was previously used by Köhler et al. [26] and is subdivided into three stages for crown formation and seven for root formation. A similar technique was also used by Kullman with seven stages of root formation [16].

In the literature studies dealing with age estimation by using third molars as age predictors are scarce. They vary from single case reports [10,21] to only a few studies in which a rather large sample was screened. In one study 679 orthopantomograms from subjects all of Hispanic origin were evaluated [11], but in most of the studies subjects from different racial origin were screened [15,22]. In the study of Mincer et al. 658 of the 823 individuals were of the same ethnic origin [15]; in the study of Willershausen et al. the division was 865 Caucasians to 1202 subjects of mixed origin [22]. The origin of the investigated material of 938 patients in the study of Köhler et al. was not clearly defined [26].

Table 5
Probability for an individual to be older than 18 years in case of full third molar development

Chance > 18 years (%)	Male	Female
UR = 10	82	87.3
UL = 10	82.6	87.2
LL = 10	94.8	94.5
LR = 10	96.4	93.1
UR + UL = 10	82.7	88.2
LR + LL = 10	96.6	94.0
UR + UL + LL + LR = 10	96.3	95.1

Table 6
Absolute and total number of individuals less than 18 years of age showing at least one-third molar with complete root formation (stage 10)

	Age (year)			Total (*n*)
	15	16	17	
Male	0	13	24	37
Female	0	12	22	34
Total (*n*)	0	25	46	71

By setting the age range at 16–22 years, the absolute number of individuals around the age group of 1 year is augmented, compared to previously published studies where an age span of 10 years was evaluated [11,15,22,26]. In previous studies results were reported by means of 95% confidence intervals [22], or probabilities [11,14]. In the present evaluation multiple regression analysis led to clear formulae easily applicable in well defined situations.

Table 7
Absolute and total number of individuals less than 18 years of age showing third molars with complete root formation (stage 10), subdivided per third molar

	Age (year)			Total (*n*)
	1	16	17	
Male				
UR	0	11	20	31
UL	0	12	18	30
LR	0	2	4	6
LL	0	1	5	6
Total (*n*)	0	26	47	73
Female				
UR	0	9	19	28
UL	0	9	20	29
LR	0	2	5	7
LL	0	3	5	8
Total (*n*)	0	23	49	72
Sum of total (*n*)	0	49	96	145

Table 8
Absolute and total number of individuals less than 18 years of age showing all four third molars with complete root formation (stage 10)

	Age (year)			Total (*n*)
	15	16	17	
Male	0	1	2	3
Female	0	1	4	5
Total (*n*)	0	2	6	8

Table 9
Absolute and total number of 18- and 21-year-old individuals showing all four third molars with complete root formation (stage 10)

	Age (year)	
	18	21
Male	21	88
Female	8	104
Total (*n*)	29	192

The left–right symmetry in third molar development expressed by the Pearson correlation coefficient was found to be higher in the maxilla than in the mandible. The Pearson correlation coefficient of UR and UL was 0.97 for males and females, of LR and LL was 0.93 for males and 0.95 for females. This trend was confirmed by other studies [11,15,22,26].

The influence of gender on formation expressed a trend for earlier development in males than females and did not differ from results of previous studies [3,15–17,22,26,29–31]. This is a unique finding for third molars, since for the other permanent teeth the root development rate is faster in females.

The probability for an individual being older than 18 years, and thus the answer to the question whether a person is already considered as an adult, was measured for several possible combinations of fully developed wisdom teeth (as seen in Table 7). These percentages indicate the degree of confidence whether an individual has reached the age of 18 years or not.

5. Conclusion

From this investigation it can be concluded that in the case where all four third molars are present:

1. the chronological age of a Belgian Caucasian individual may be estimated based on regression formulae with a standard deviation of 1.49 or 1.50 years for males and females, respectively;

2. the chance for a Caucasian individual to be older than 18 years is 96.3 or 95.1% for males and females, respectively in the case were tooth development is completed.

These results indicate the appropriateness of using third molars as a developmental marker, especially when comparing the obtained standard deviation with other skeletal age calculation techniques based on, e.g. hand–wrist or long bones [32].

Future research should aim at investigating the effect of race and culture, preferably following a prospective protocol with gathering of data over a period of 6–12 months.

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