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Estimation of legal age using calcification stages of third molars in living individuals

Philipp Streckbein [a,*], Isabelle Reichert [a], Marcel A. Verhoff [b], Rolf-Hasso Bödeker [c], Christopher Kähling [a], Jan-Falco Wilbrand [a], Heidrun Schaaf [a], Hans-Peter Howaldt [a], Andreas May [a]

[a] Dept. of Cranio-Maxillo-Facial Surgery, Justus-Liebig-University Giessen, Klinikstrasse 33, 35385 Giessen, Germany
[b] Dept. of Forensic Medicine, Justus-Liebig-University Giessen, Frankfurter Strasse 58, 35392 Giessen, Germany
[c] Institute of Medical Statistics, Justus-Liebig-University Giessen, Heinrich-Buff-Ring 44, 35392 Giessen, Germany

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ABSTRACT

The increased number of adolescents and young adults with unknown or inaccurately given date of birth is a current issue in justice and legal medicine. The objective of this study was to determine the extent to which third molar calcification stages assessed on panoramic X-rays could be useful as additional criteria for forensic age estimation in living individuals, focusing on the legally important ages 17 and 18.
In a retrospective multi-center study, the developmental stage of each individual's third molar was analyzed using Demirjian's scale in 2360 cases. Additionally, sex, age and ancestry were assessed.
Individuals with the lowest calcification stage of all present molars in stage H were ≥18 years with a likelihood of ≥99.05% in the female ($n = 388$), and ≥99.24% in the male ($n = 482$) population.
The lowest calcification stage of all present third molars proved to be useful as an additional reliable criterion for the determination of an age ≥18 years.

1. Introduction

Forensic age estimations are used to establish criminal responsibility and the applicability of juvenile or adult criminal law for suspected persons. The increased number of adolescents and young adults with unknown or inaccurately given date of birth is a current issue in justice and legal medicine. Furthermore, the proportion of young adults who have committed criminal offenses has increased considerably in the past years [1–7].

In Germany, legally important age limits are 14, 18, and 21 years [8]. Persons who have not completed their 14th year are criminally incapable [9]. Between 14 and 18 years of age, an accused person is subject to juvenile criminal law. If the accused is ≥18 but <21 years old, he or she is defined as a young offender [10]. Young offenders are generally regarded as criminally responsible and subject to adult criminal law with limitations. Adult criminal law applies to ≥21 year old individuals [9].

To ensure the quality of age estimation in legal medicine, the study group on Forensic Age Diagnostics (AGFAD) was founded in 2000 in Berlin, Germany. Recommendations for the preparation of expert opinions in forensic age estimation of accused young adults with unknown birthdates have been developed. Three independent opinions have to be prepared by experts with forensic experience in their respective areas of specialization. These include physical examination to collect anthropometric measurements, signs of sexual maturity, and possible developmental disorders relevant to age. Furthermore, a clinical and radiographic dental examination and an X-ray examination of the left hand have to be provided [5,11,12].

To assess whether an individual is ≥21 years of age, an additional X-ray examination of the clavicles is recommended if the hand ossification is completed [13].

Dental development is one of the most useful biomarkers for age estimation in children [14–16]. With increasing age, this biomarker becomes less accurate [17]. Skeletal examination is currently the most precise method of age estimation in young adults [18,19]. Due to a relatively late completion of maturation the clavicle, the skeleton of the hand and the apophysis of the iliac crest provide a good age estimation of young adults [20]. Nevertheless, an additional radiological assessment of third molar calcification could be useful for age determination [21].

The objective of the present study was to analyze the correlation between third molar calcification stages and age, focusing on the legally important ages 17 and 18.

* Corresponding author. Tel.: +49 641 985 46271; fax: +49 641 985 46279.
E-mail address: philipp.streckbein@uniklinikum-giessen.de (P. Streckbein).

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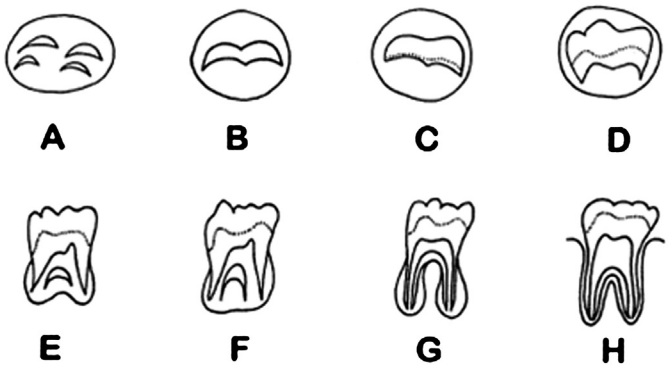

Fig. 1. Diagrammatic representation of the third molar formation stages A–H described by Demirjian et al.

2. Material and methods

Conventionally and digitally panoramic X-rays from the Justus-Liebig-University (Giessen, Germany) and the OPI-Implant Center (Darmstadt, Germany) were evaluated between 1998 and 2009 ($n = 2{,}360$). Sex, date of birth, ancestry and the acquisition date of the panoramic X-ray were recorded for each individual. The age of the individuals at the time of X-ray was calculated. Caucasian individuals aged 15–22 years at the time of the X-ray were included in the study.

2.1. Determination of calcification stage

The calcification stage of each third molar was determined using the classification of Demirjian et al. [22] (Fig. 1). The lowest calcification stage of all present third molars was determined and recorded.

2.2. Statistical analyses

The statistical analysis was performed by the Institute for Medical Statistics (University of Giessen, University of Giessen, Germany) using SAS software (V9.2; SAS Institute, Cary, NC, USA). The distribution of continuous variables was described by the minimum and maximum, first and third quartiles, and the median. The absolute and relative numbers of the stage of all present third molars in dependency of age were determined using the rank correlation coefficient. The probability estimator for a subject with stage H (Demirjian's method) being ≥18 years, as well as the corresponding $(1 - \alpha)$-confidence interval (CI), was calculated.

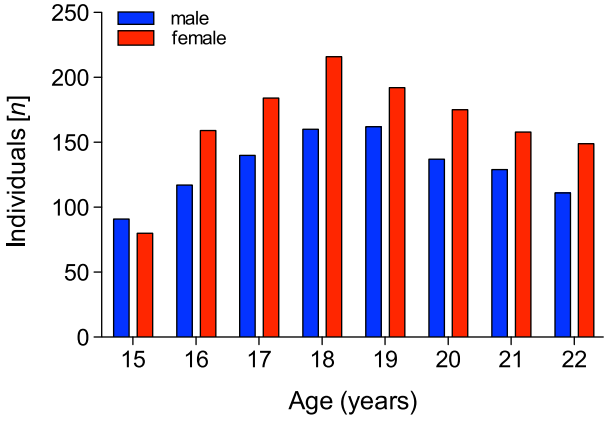

Fig. 2. Number of evaluated panoramic X-rays divided by sex.

Table 1
Lowest calcification stage of all present molars divided by age (female).

Age (female)	Lowest calcification stage of all present third molars						
Frequency Col Pct	C	D	E	F	G	H	Total
15	1	33	22	19	5	0	80
	14.29	22.45	16.18	8.48	1.22	0.00	6.09
16	4	46	33	48	28	0	159
	57.14	31.29	24.26	21.43	6.81	0.00	12.11
17	1	26	34	53	70	0	184
	14.29	17.69	25.00	23.66	17.03	0.00	14.01
18	1	29	28	40	93	25	216
	14.29	19.73	20.59	17.86	22.63	6.44	16.45
19	0	13	12	29	85	53	192
	0.00	8.84	8.82	12.95	20.68	13.66	14.62
20	0	0	1	22	61	91	175
	0.00	0.00	0.74	9.82	14.84	23.45	13.33
21	0	0	6	12	42	98	158
	0.00	0.00	4.41	5.36	10.22	25.26	12.03
22	0	0	0	1	27	121	149
	0.00	0.00	0.00	0.45	6.57	31.19	11.35
Total	7	147	136	224	411	388	1313

3. Results

2360 individuals aged 15–22 years were included in analysis. The gender distribution female to male was 1.25:1 (female: $n = 1{,}313$; male: $n = 1{,}047$). The distribution of age separated by sex is shown in Fig. 2. In the sample of females, 423 were ≤17 years and 890 were ≥18 years. In the sample of males, 348 were ≤17 years and 699 were ≥18 years.

A significant correlation between third molar calcification stage and age could be identified (female: $p < 0.001$, $r = 0.697$; male: $p < 0.001$, $r = 0.766$).

All individuals with the lowest calcification stage H of all present molars were ≥18 years. The relative frequency (f) as the estimator of the probability of the event of interest, and the corresponding confidence interval (CI = 1.00–0.05) were: $f = 1.00$;0.95-CI = (0.0024;1.000).

Tables 1 and 2 represent the evaluation of the lowest calcification stage, classified by sex and age. The statistical age distribution of the calcification stage of all present molars separated by sex is displayed in Tables 3 and 4. Fig. 3 represents the distribution of stage H classified third molars within the population of 18-year-old individuals divided by sex.

Table 2
Lowest calcification stage of all present molars divided by age (male).

Age (male)	Lowest calcification stage of all present third molars						
Frequency Col Pct	C	D	E	F	G	H	Total
15	4	30	30	21	6	0	91
	50.00	40.00	38.96	17.50	2.11	0.00	8.69
16	2	26	19	33	37	0.00	117
	25.00	34.67	24.68	27.50	12.98	0.00	11.17
17	2	11	15	35	77	0	140
	25.00	14.67	19.48	29.17	27.02	0.00	13.37
18	0	7	5	17	70	61	160
	0.00	9.33	6.49	14.17	24.56	12.66	15.28
19	0	1	6	13	50	92	162
	0.00	1.33	7.79	10.83	17.57	19.09	15.47
20	0	0	1	0	18	118	137
	0.00	0.00	1.30	0.00	6.32	24.48	13.09
21	0	0	1	1	20	107	129
	0.00	0.00	1.30	0.83	7.02	22.20	12.32
22	0	0	0	0	7	104	111
	0.00	0.00	0.00	0.00	2.46	21.58	10.60
TOTAL	8	75	77	120	285	482	1047