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Contribution of third molar eruption to the estimation of the forensic age of living individuals

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Abstract

Forensic age estimation of a living individual is frequently performed in clinical forensic medicine. Medicolegal physicians are usually called upon by the authorities to estimate the age of a living person requesting asylum or to determine whether a suspected offender is subject to juvenile or adult criminal law. Dental age is one of the parameters studied to estimate biological age. Several methods are used, and among these, analysis of the eruption of the third molar (M3) on an orthopantomogram (OPG) is one of the common methods. The objective of the study was to analyse the contribution of M3 eruption to age estimation, in particular with regard to the threshold of 18 years of age, in a sample of individuals examined in a French university hospital. The stage of wisdom tooth eruption of all individuals aged between 15 and 24 years, who had an OPG performed between 1 January 2013 and 31 December 2015, was interpreted using a three-stage scoring system. In total, 557 OPGs (340 males and 217 females) were included. None of the stage scores allowed a distinction between minors and majors, for either sex. Overall, 85% of females and 98% of males with four M3s in stage 3 (complete emergence in the occlusal plane) were majors.

Keywords Clinical forensic medicine · Age estimation · Dental age · Third molar eruption

Introduction

In France, forensic age estimation of living individuals is frequently performed in the clinical practice of forensic medicine, particularly when the authorities suspect the chronological age of an individual to be wrong. This occurs primarily in the case of young asylum seekers who have arrived in France claiming to be minors; asylum seekers who are minors are eligible for complete financial support by social services as any minor in France [1]. Forensic age estimation can also be used in the determination of whether juvenile or adult jurisdiction applies to an individual, and what specific rules should be applied if the individual is retained in custody, when a criminal offence is suspected. Several age thresholds may be relevant for judicial and administrative proceedings, but the 18-year age threshold is the most important in France, because it is the age of majority.

According to the guidelines published by the International Study Group on Forensic Age Diagnostics, age estimation should consist of a physical examination, a radiograph of the left hand, a dental examination and, when necessary, radiography or computed tomography of the clavicles [2, 3]. Thus, dental age estimation based on direct examination of the oral cavity and an orthopantomogram (OPG) is one step in the process of biological age evaluation. The guidelines do not detail which reference method should be used to estimate dental age. A literature review on the topic highlights the most frequently used methods. These methods are either based on tooth development or on tooth eruption. The first can be studied radiographically, the latter radiographically or clinically. Mainly three staging techniques are used to study tooth development: (1) the Demirjian classification is based on eight stages regarding anatomical changes and relative proportions [4], (2) the Moorrees and Fanning classification is composed of 14 stages and is based on predicted crown and root lengths [5, 6] and (3) the Cameriere method is a metric method based on metric measurements and absolute proportion [7–9]. These staging techniques have been used in different age estimation methods [7, 10, 11]. However, none of these methods give a

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clear answer for the 18-year-old cutoff, despite the methods' complexity.

Based on this extensive literature, the most appealing criterion to distinguish between minors (younger than 18 years of age) and majors (18 years of age or older) seems to be the complete closing of apical ends of the roots of M3s [4–10]. However, we have noticed in our daily practice that visualisation of the apex was not always easy, especially for the maxillary M3. This development criterion seemed to be harder to visualise than the eruption of the M3s. The eruption criterion has already been analysed in several studies, based on clinical observation only [12] or OPG evaluation [13–16]. These studies mostly conclude that fully erupted M3s occur at a minimum age of 16 years.

The quickness (for legal reasons) in which the physicians must estimate the age of a young person does not often allow the medicolegal physicians to take specific odontological advice. This explains why medicolegal physicians have tried to develop a simple and reproducible method to assess dental age estimation. The methods based on the development/maturation are rather complex and focusing on the eruption phase might be easier to assess dental age [12–16]. Our objective was to study the value of M3 eruption on OPGs for forensic age estimation of French living individuals.

Material and methods

Material

All OPGs from individuals aged between 15 and 24 years, performed between 1 January 2013 and 31 December 2015, were retrospectively selected from the Picture Archiving and Communication System (PACS; McKesson Medical Imaging Group, Richmond, BC, Canada) of a French university hospital. All OPGs were reviewed by two independent observers. OPGs showing tumours, surgical materials, mandibular or maxillary fractures or signs of infection in the M3 areas were excluded. OPGs which were of poor quality and did not allow a correct interpretation, individuals who previously had extraction of the M3, those with primary retained M3s, agenetic M3s and individuals who were addressed by the clinical forensic medicine department were also excluded.

Third molar eruption scoring system

Teeth were numbered following the World Dental Federation convention. As a reminder, right and left maxillary M3s are numbered 18 and 28, and right and left mandibular M3s are numbered 48 and 38, respectively. A three-stage scoring system was developed (Figs. 1, 2, and 3). In stage 1 (Fig. 1), the follicle is intact. In this stage, the cusps of the wisdom tooth are under the alveolar bone and the tooth is not erupted. In stage 2 (Fig. 2), the follicle is disrupted and the tooth has begun to emerge. Hence, this means that one or more cusps broke the cortical bone. In stage 3 (Fig. 3), the wisdom tooth has fully emerged and reached the occlusal plane (i.e., it is fully erupted). All the M3s visible on the selected OPG were staged with the three-stage scoring system when it was possible. When OPGs had four assessable M3, we defined four phases as follows: phase A: the four M3s are classified as stage 1; phase B: at least one M3 is classified as stage 2; phase C: at least one M3 is classified as stage 3 and phase D: the four M3s are classified as stage 3.

Image analysis

Each X-ray was anonymised and randomly selected for evaluation by the observer. The images were evaluated separately by two senior forensic pathologists (AG, CR), in order to evaluate inter-observer variability. The images were reviewed after a 2-month interval by the first observer (AG) to measure intra-observer variability. The results presented here correspond to the first evaluation of the first observer.

Statistical analysis

Statistical analysis was performed with the R.3.3.5 software (*R Core Team (2016). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria*). Firstly, intra- and inter-observer variabilities were calculated using Cohen's kappa test, which estimates the proportion of agreement after chance agreement is removed from consideration [17]. Secondly, descriptive statistics were calculated and graphically presented with box-plots. The probability of being at least 18 years of age if the lower left M3 was completely erupted was calculated for each sex. A Student's *t* test was used to compare age distributions per stage between left and right M3, upper and lower M3, males and females. Thirdly, transition analysis was performed, for each sex, to determine the age at transition distribution. Transition analysis is a method to represent the passage from a given state to the next higher state, in an ordered sequence. It is based on the fact that the developmental trajectory for a single trait can be separated into an invariant sequence of distinct and non-overlapping states and that morphological change is unidirectional with respect to those states [18]. Transition analysis was applied between phases A to D.

Results

In total, 960 OPGs were collected. Figure 4 represents the selection of OPGs from the database. Five hundred fifty-seven OPGs, consisting of 217 females and 340 males, met the inclusion criteria; 12.56% of the 557 individuals had

Fig. 1 Stage 1 of tooth 28 and 38 (**a**), and of tooth 48 (**b**)
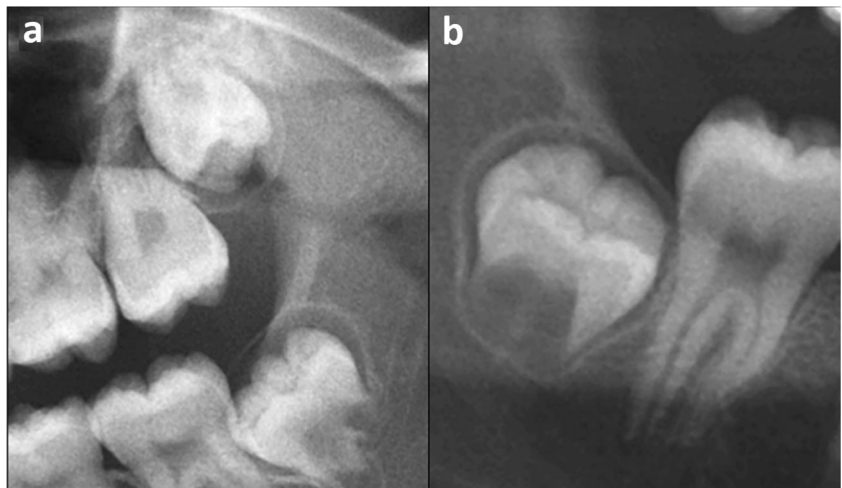
between one and three impacted M3. The mean age of the sample was 19.69 years and the median age was 19.64 years. Table 1 shows the distribution of the sample by age and sex. Cohen's kappa test between the two observers was 0.96, with a 95% CI of 0.94–0.99. Intra-observer variability was 0.96, with a 95% CI of 0.94–0.99. Figures 5 and 6 show the age distribution for both sexes and for each stage.

The probability of being at least 18 years of age if M3 (38) was stage 3 was 0.801 for males and 0.849 for females.

Descriptive statistics were summarised in Table 2. Among males, for each tooth, the mean age of each stage was significantly different from one another (comparison between stages 1 and 2, stages 2 and 3 and stages 1 and 3; $p < 0.001$). Among females, the mean age of stages 1 and 2 and the mean age of stages 1 and 3 were significantly different from one another ($p < 0.001$). When comparing stages 2 and 3, the mean age was different for tooth 18, 28 and 38 ($p < 0.05$). No statistically significant difference was noted for tooth 48. For any given tooth, there was no significant difference between males and females, for each stage. Furthermore, for each sex, there was no statistically significant difference in the mean age of each

stage between the maxillary and the mandibular M3s, nor between the left and the right M3s. Table 3 shows the age at transition distribution, based on the joint stages of all four third molars, as classified in phases.

Discussion

Probability of being at least 18 years old

Root formation of the second molar is completed at around 14 years of age and M3s are the only teeth that continue to form in late adolescence [5]. Thus, M3 are the only teeth suitable for dental forensic age estimation [9]. The beginning of M3 eruption on OPG has been demonstrated in the literature as occurring between 16 and 21 years of age [19–21], and it has been stated that all four M3s are fully erupted after 18 years of age [14]. In a similar study to ours, the authors analysed 666 OPGs from German subjects and demonstrated that the minimum age for complete emergence of the four wisdom teeth in the occlusal plane was 17.4 years in females

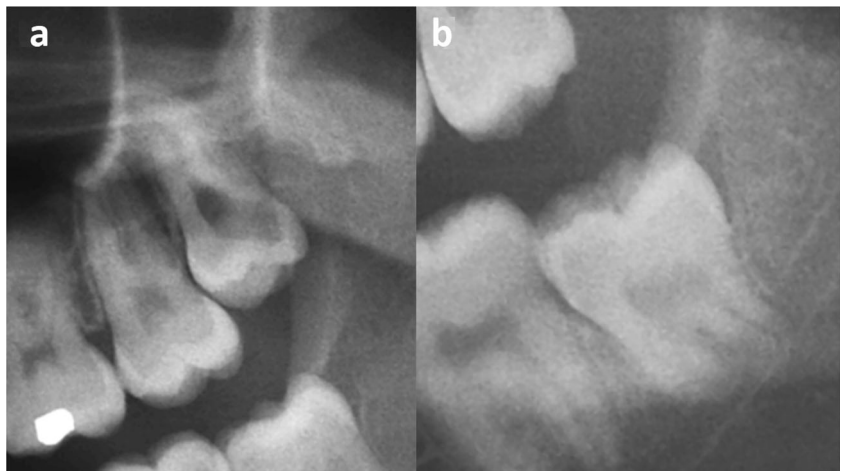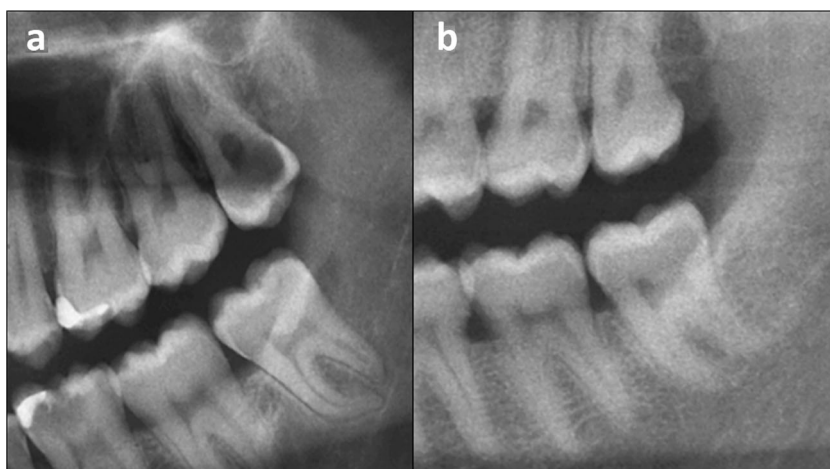**Fig. 2** Stage 2 of tooth 28 (**a**), and of tooth 38 (**b**)

Fig. 3 Stage 3 of tooth 28 and 38 (**a**), and of tooth 28 and 38 (**b**)

and 19 years in males [16]. With regard to the threshold of 18 years of age, Liversidge et al. tested several methods of estimation of dental age [11]. Using the stages of development of M3s on 1663 OPGs from individuals aged 9 to 25 years, the authors found that the probability of being aged 18 years or more was 0.945, if the M3 had finished its maturation (stage H of the classification of Demirjian [4]; stage Ac of the classification of Moorees and Fanning [5, 6]). Other probabilities of published studies related to development of M3s are presented in Table 4 and compared to ours [7, 10, 22–24]; however, such probabilities were not reported in other studies on eruption [13–16]. In our study, the probability of being at least 18 years of age if M3 (tooth 38) is stage 3 was 0.801 for males and 0.849 for females. The youngest male to have four M3s in the occlusal plane was 17.75 years old; he was the only minor in this situation. Five women younger than 18 years old had four totally erupted M3s. Thus, this criterion alone cannot be used for the 18 years of age threshold.

The ease of assessing eruption compared to development

Analysis of the development of M3s and their eruption stage are two different perspectives of the dental age assessment problem. This study focused on eruption of M3. The simplicity of this method is its main asset, such as it has been stated in previous studies related to eruption of M3s [25, 26]. To discuss the use of this approach, it can be compared with studies focusing on development. From a strictly methodological perspective, it is easier to learn to assess the three stages of this study than the eight stages of the Demirjian et al. or the 14 stages of the Moorees and Fanning classification [4–6]. Mohd Yusof et al. tried to mix the developmental and the eruption approaches in a combined mathematical model [27]. The cost of this original perspective was a complex methodology, which seemed to be hard to use in everyday practice when you take into account how quickly medicolegal physicians must provide an answer for legal reasons. Our method may be useful for medicolegal physicians who are not experts in odontology.
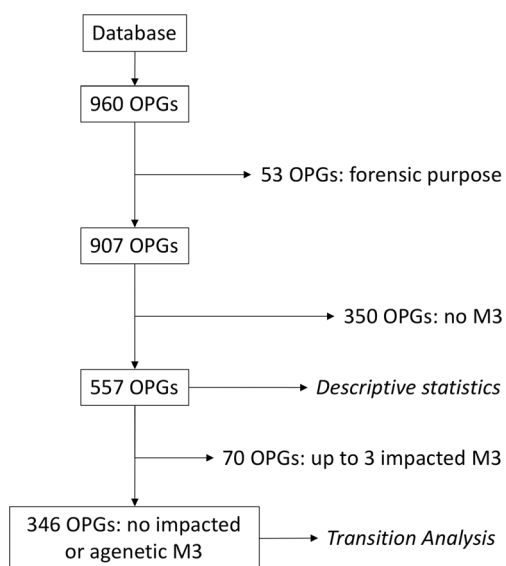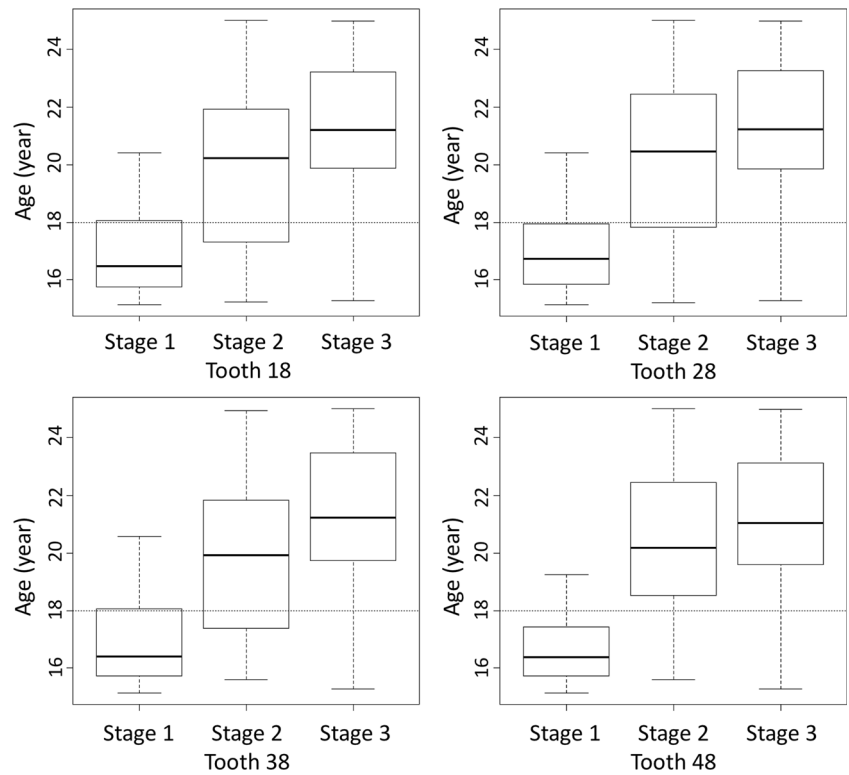

Fig. 4 Flow diagram of OPGs selection

Table 1 Distribution of individuals by age and sex

Age (years)	Female	Male	Total
15	22	17	39
16	25	39	64
17	22	22	44
18	14	25	39
19	25	39	64
20	28	48	76
21	24	40	64
22	16	32	48
23	18	39	57
24	23	39	62
Total	217	340	557

Fig. 5 Age distribution for each
M3, for males

Use of clinical eruption in age estimation

Multiple studies show that the apical closure of the M3 root is the main criterion for the threshold of 18 years of age in a forensic context [7, 10, 22–24]. However, the tooth apex is sometimes difficult to identify on an OPG, especially the maxillary M3. Moreover, radiation exposure should be limited to a minimum in the context of non-therapeutic procedures [28].

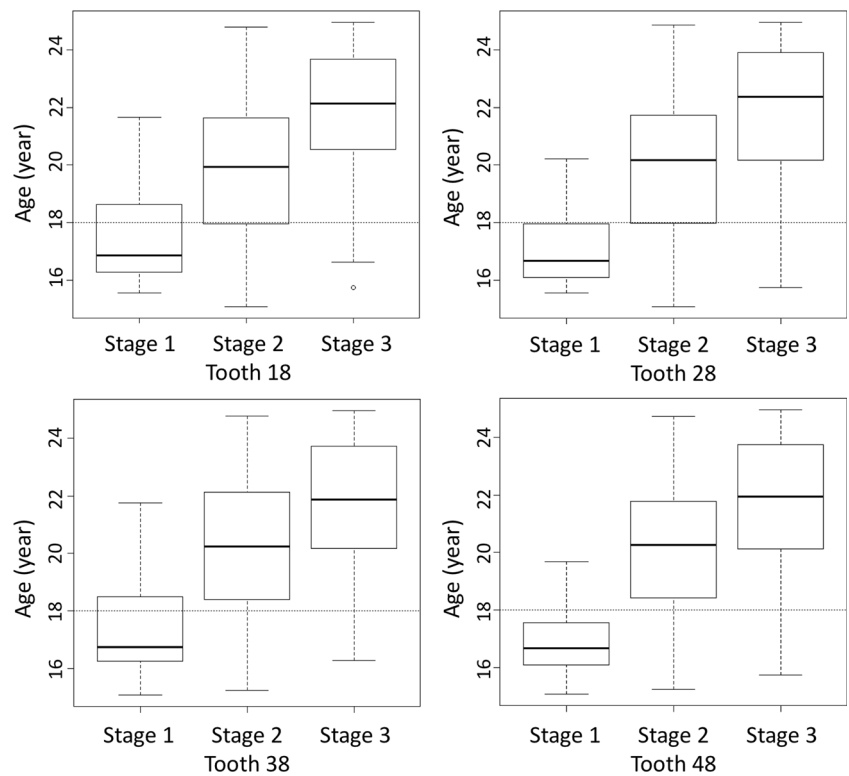**Fig. 6** Age distribution for each
M3, for females

Table 2 Descriptive statistics for each phase by sex

Phase	Male				Female			
	n	Mean	Min	Max	n	Mean	Min	Max
A	20	16.26	15.54	21.56	16	16.26	15.15	18.4
B	66	18.97	15.09	24.55	51	19	15.22	24.62
C	79	20.27	15.66	24.86	39	20.69	15.9	24.99
D	64	21.17	15.11	24.95	48	21.13	15.28	24.98

Age is expressed in years. Phase A: the four M3s are classified as stage 1; phase B: at least one M3 is classified as stage 2; phase C: at least one M3 is classified as stage 3 and phase D: the four M3s are classified as stage 3

Thus, one may wonder if a clinical examination of the dental status regarding the presence of one or several M3 erupted in the occlusal plane could be an appealing criterion for forensic age estimation. Stage 3 would correspond to the total emergence of the M3, which could be seen in the oral cavity by the physician. Our results show that this criterion could be used for males, as 98.08% of the males in our sample with four fully emerged M3s were at least 18 years old; on the other hand, the results were not as compelling among females, with 85.11% of the females with four erupted M3s being aged 18 years or older. Unfortunately, other studies on M3 eruption did not report these statistics [13–16]. As one of the recommendations in forensic age estimation is to use several reference methods together to increase age estimation accuracy, observation of the eruption of M3s in the oral cavity may be an interesting criterion that could be used as a supplementary method. When the four M3s are totally erupted, it could be decided not to perform an OPG, especially in males. However, clinical intraoral examination was not assessed in this study. It was not possible to have a direct access to the individuals, because the study was retrospective. We made the hypothesis that the examination of eruption of the M3 on OPGs could be applied directly to the oral cavity, but studies are needed on this subject to verify such a hypothesis.

Influencing factors

Various factors may influence the speed of biological maturation; sex is one of them. It is widely accepted that skeletal maturation occurs earlier in females than in males. As for dental maturation, a review of the literature suggests that M3

Table 3 Mean age at transition (in years) and standard deviation for stages 1, 2 and 3, for each sex for individuals with four M3s

Phase	Female	Male
Phase A => B	12.70 (1.15)	11.20 (1.34)
Phase B => C	19.10 (0.53)	17.90 (0.56)
Phase C => D	22.6 (0.64)	23.80 (0.72)

maturation occurs earlier in males than females [10, 13, 22, 23], but females precede males for the development of other teeth between 6 and 14 years of age [15, 22, 29]. Other studies, such as ours, did not find a statistically significant difference between males and females [30, 31]. Different information can be found in the literature concerning the difference in maturation between maxillary and mandibular M3s [32–34]. Some authors argue that maxillary M3s mature before mandibular M3s, while others conclude that there is no significant difference. In the same manner, no difference between right (18 and 48) and left (28 and 38) M3s has been clearly highlighted in the current literature [29, 30]. Another important factor in the process of maturation is the socioeconomic status (SES) of the individual [33]. However, we could not take SES into account in our study, as this information was not available in the data we accessed. It is recognised that the estimation of dental age is less dependent on environmental factors than skeletal age [35]. On the one hand, some authors suggest that the dimensions of the osseous palate influence dental maturation and that these dimensions depend on an individual's origin [29]: when the palate is narrower, the M3 has a greater risk of remaining impacted. This is the reason why several studies have found that individuals of African origin, who are assumed to have a wider palate, had earlier dental development. On the other hand, no correlation between dental development, age and clinical emergence in the mouth was identified in two studies from different geographical origins [12, 36].

Limitations

Our study presented several limitations. One of them concerned the age range of our sample, since the lower and upper limits of the range affect the mean ages and age ranges per stage and per phase. Forensic age estimation studies usually choose approximatively the same age distribution and thus meet the same limitations. However, a sufficient number of individuals was included around the age of 18 years, which is important for the analysis of the results, as 18 years is the main threshold that interest the judicial authorities in France.

The problem of impacted M3 is also a limitation because this incidence is variable but can be high in adult populations. For example, 72% of a Swedish population and 68.8% of a Chinese population of young adults had at least one impacted wisdom tooth [37, 38]. On the other hand, this prevalence is estimated at under 20% in Eritrean, Jordanian and Saudi Arabian populations [39–41]. In our study, at least one impacted M3 was identified in 12.5% of the studied OPGs. These statistics must be cautiously interpreted because the age distribution was not strictly the same in each article. Impacted wisdom teeth could not be included, because our scoring system was based on eruption, which is disturbed by impaction.

Table 4 Probability of being at least 18 years of age if M3 (38) is stage H of Demirjian classification, stage Ac of Moorrees classification or stage 3 of our classification

First author	Publication year	Criterion	Probability for male	Probability for female
Mincer	1993	Development	0.901	0.922
Solari	2003	Development	0.887	0.914
Gunst	2003	Development	0.963	0.951
Garamendi	2005	Development	0.714	
Cameriere	2008	Development	0.96	0.98
Liversidge	2010	Development	0.945	
Gambier	2017	Eruption	0.801	0.849

Unfortunately, impaction was rather common in our study population, which limited the use of our approach.

Conclusion

Assessment of the eruption of M3s alone is not sufficient for the determination of whether or not an individual is aged 18 years or older. However, the results of our study suggest that when the four M3s are present in the oral cavity and have reached the occlusal plane, the probability of being over 18 years of age is very high, for both males and females. The method presented here is easy to use in a daily clinical context, even for a non-specialist in forensic odontology. Therefore, it could be used as a tool for dental age estimation, which is only one part of the forensic age estimation process, as emphasised in the recommendations of the Study Group on Forensic Age Diagnostics from the German Society of Legal Medicine [42].

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving retrospective anonym data of human beings were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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