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Assessment of legal adult age of 18 by measurement of open apices of the third molars: Study on the Albanian sample

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ABSTRACT

The third molar tooth is one of the few anatomical structures in development available for estimating the age of individuals in the late adolescence. This study tests the accuracy of Cameriere's cut-off value of the third molar index (I_{3M}) in assessing legal adult age of 18 years in an Albanian sample. For this purpose, a sample of orthopantomograms (OPTs) of 286 living subjects (152 female and 134 male) aged between 15 and 22 years was analyzed.

Intra-rater and inter-raters agreement of I_{3M} were 0.998 and 0.998, respectively and Cohen Kappa for intra-rater and inter-rater agreement in decision on adult or minor was 1.0 and 1.0, respectively. Age distribution gradually decreases as I_{3M} increases in both males and females. The mean age of females is higher than that of males when I_{3M} is between 0.04 and 0.08. Sensitivity test for males was 94.1%, with a 95% confidence interval (95% CI) 85.6–98.4%, and specificity was 90.9% (95%CI 81.3–96.6%). The proportion of correctly classified individuals was 92.5%, with a 95%CI of (86.7%, 96.4%). For females, the sensitivity test was 75.4%, with a 95%CI of (63.1%, 85.2%) and specificity was 96.6%, with a 95%CI of (90.3%, 99.3%). The proportion of correctly classified individuals was 87.5%, with a 95%CI of (81.2%, 92.3%). The results indicate that Cameriere's cut-off value of the third molar index (I_{3M} = 0.08) is useful in discriminating between Albanian adults and juveniles, and encourage us to test its suitability for determining the adult age in individuals from other populations.

1. Introduction

Age estimation of individuals in the forensic context is necessary for both the dead and the living. For the dead person, it is mainly used to aid in the identification and creation of the biological profile which can then be compared with those of missing persons. For the living person, the aim of age estimation is to solve some medico-legal, civil or social problems concerning, for example, the real age of minors in cases of child adoption, properly treating unaccompanied minors who do not know their age or when there is a suspicion that the did not give their real age. Other reasons include asylum seeking procedures, assessment of the capability of being imputable, prosecuting pedophilia, child pornography and, for adults, different civil matters such as pensionable age and similar questions for individuals without valid documents of identification [1–4].

In particular, the assessment of biological age of a living subject around the legal cut off age for adulthood became a serious challenge for medical or dental forensic experts in Italy, mostly because of implications of criminal liability of the subject in proceedings, and also for other purposes, as noted above.

In the European Union (EU), the need for accurate age estimation techniques has never been greater than in the last two decades. This is partly due to armed conflicts within the subjects' native countries, resulting in an increased number of immigrants and asylum-seekers in EU. In cases such as these, a refugee's birth might never have been registered, and identity documents are often never even issued [1]. One of the criteria for having asylum granted is often being a minor [5].

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Age estimation is also required during the procedure for adoption of children from countries where there is no legal procedure for the registration of birth [6–8]. In immature individuals, still in development, age can be estimated relatively accurately with various morphological or radiological methods. However, toward the end of skeletal growth and development, only a few age-dependent features remain for the age estimation by the morphological methods. These methods include an evaluation of the development of the bones of the hand and wrist, clavicles, knee, ribs, iliac crest, and third molar teeth [9–16]. When authorities, different institutions or courts are in doubt about the age of the specific person, particularly if the individual is suspected of criminal activity, age estimation is often requested from official forensic experts in order to determine whether individual will be treated as, child, juvenile or adult [7].

In Italy, the age of criminal and legal responsibility is the 14 years. If person between age 14 and 18 would be charged with a crime, subject would be tried in the juvenile court. If a juvenile is convicted, he or she faces the possibility of serving time in a detention center designated for non-adults. At the age of 18 years, a person is considered to be an adult, and would therefore be judged according to general criminal laws [17].

The criteria for age estimation of the living individuals in criminal proceeding were presented and published by the Study Group on Forensic Age Diagnostics of the German Society of Legal Medicine (AGFAD), with special attention to sensitive legal and ethical implications. The AGFAD proposed guidelines for age estimation in the living, with procedures which include a physical examination with determination of anthropometric measures, inspection of sexual maturation and identification of any relevant developmental disorder. Examination of skeletal development include hand and wrist and if their maturation is completed, additional clavicles examination. Dental examinations include evaluation of dental status and additional X-ray analysis of the teeth, mostly using orthopantomograms (OPT) [18,19]. Different dental age estimation methods were published and tested, and they are differentiated according the age range of the evaluated individuals, using developmental or regressive changes on the teeth [2]. Most used method, based on the evaluation of the mineralization of selected number of teeth, is Demirjian staging system (DSS) that uses eight developmental stages (A–H) [20,21]. Age estimation is very effective by evaluation of mineralization of permanent teeth until the age of 12–14, when mineralization of the second molars finishes [22–26]. The assessment of development of the third molars is possible for individuals from 14 years up to 23 years of age, when their mineralization is completed in most healthy individuals [27].

The assessment of whether a person is an adult or not, is a constant challenge for forensic science, and every improvement of available or introductions of new, reliable methods is welcome. According to literature, Mincer et al. [28] was the first to study the third molars in determining whether an individual was an adult or minor by using DSS. Cameriere et al. [29] published a method for the discrimination between adults or minor, based on the correlation between the age and the normalized measures of the open apices and height of the third molar or the third molar maturity index (I_{3M}). The method was based on Italian sample and was particularly developed to more accurately classify minors. Other study by De Luca et al. [30] showed on different Italian sample of 397 adolescent and adults between 13 and 24 from Milan region, high performance of the accurately classification of the individuals when I_{3M} value of 0.08 was used.

According to the 2013 annual report of the changes in migrations and related polices in the Organization for Economic Cooperation and Development (OECD) countries, permanent immigration in Italy still remains at high level and foreign residents increased to 9% of the entire registered Italian population in 2011 [31]. Italy is specially affected in 2011 when landing of illegal immigrants increased drastically from under four and half thousands in 2010 up to over sixty thousand in 2011, as a result of political conflicts and changes in some African countries, particularly in Libya and Tunisia [32]. According to the OECD report from 2012, stocks of foreign population by nationality in specific countries shows that immigrants from Albania represent second largest group with population of 483,000, between Romanian (969,000) and Moroccan (452,000) citizens at the end of 2010 [32]. Furthermore, about one third of Albanian population was estimated to be living abroad, mainly in Greece and Italy, and to a smaller degree in other EU countries (mainly in the UK and Germany) as well as USA, Canada and Australia [33]. The correlation between age and the development of wisdom teeth in Albanians has not been assessed before, although Albanian immigrants and their families in Italy and EU are an important group to which the dental records, including OPT, can be reached for study. Therefore, the objective of the study was to test the applicability of the Cameriere's third molar index value of 0.08 for discriminating adult or minor age in Albanian sample of young adults.

2. Materials and methods

2.1. Subjects and materials

This is cross-sectional study based on the evaluation of 298 OPTs collected from four Albanian private dental clinics during 2012 and 2013 years. The study was conducted in accordance to the ethical standards laid down by the Declaration of Helsinki [34]. Selection criteria included the following: Albanian origin; age between 15 and 22 years; all teeth in the right lower jaw present; no obvious dental pathology on panoramic radiology related to the right lower jaw. Exclusion criteria included the following: subjects of unknown dates of birth; OPTs showing no lower right third molar; image deformity affecting third molars. A total of 12 (4.2%) OPTs were excluded from the considered sample, leaving OPTs of 286 Albanian individuals (134 boys and 152 girls) in this study. Age distribution is shown in Table 1.

All OPTs were recorded as computer files in JPG format in the resolution of 300 dpi. The digital images were examined by using the software package (Adobe Photoshop® CS4, Adobe Systems Inc., San Jose, CA). The right lower third molars were evaluated. The I_{3M} index of each evaluated third molar was performed according to the Cameriere et al. [29] method. Briefly, if the apices of the third molar are complete in maturation, i.e., the apical ends of the roots are completely closed, then $I_{3M} = 0$. Otherwise, I_{3M} is the result of proportion of the sum of the digital projections on OPTs of the width of the root in single-rooted or of the inner margins of both the open apices in multi-rooted teeth, and tooth length. Usage and determination of I_{3M} allows the use of a single predicting variable that is obtained by normalizing the measured values of the width

Table 1
Sample of panoramic radiographs from Albania according to sex and age categories.

Age (years)	Females	Males	Total
15	21	14	35
16	33	26	59
17	33	26	59
18	16	10	26
19	15	13	28
20	10	17	27
21	17	18	35
22	7	10	17
Total	152	134	286

of the apices and height of the teeth [21]. This is important because the available sample of OPTs was obtained from various sources and various radiologic devices were used.

2.2. Data management and statistical analysis

Patients' identification number, gender, date of birth, date of X-rays and I_{3M}were recorded in a Microsoft Excel® file. The age of each individual was calculated as the difference between the date of birth provided in the dental record and the date on which the radiograph was taken, which was indicated by lead markers on the panoramic radiographs.

Based on the results of Cameriere et al. [29] and De Luca et al. [30], the same cut-off value of 0.08 for I_{3M} for both genders was evaluated, so that an individual is considered to be 18 years of age or older if I_{3M} is lower than 0.08. The third molar index can help to discriminate between individuals who are 18 and over and those under 18 by the post-test probability, or p, of being 18 years of age or older (i.e., the proportion of individuals with I_{3M} <0.08 who are older than or equal to 18 years). The sensitivity of the test, p_1 (i.e., the proportion of subjects older than or 18 years of age who have I_{3M} <0.08), together with specificity p_2 (i.e., the proportion of individuals younger than 18 who have $I_{3M} \geq 0.08$) were evaluated.

According to Bayes' theorem, post-test probability may be written as:

$$p = \frac{p_1 p_0}{p_1 p_0 + (1 - p_2)(1 - p_0)} \quad (1)$$

where p is post-test probability and p_0 is the probability that the subject in question is 18 years old or older, given that he or she is aged between 15 and 22 years, which represent the target population. Probability p_0 was calculated as the proportion of Albanians between 18 and 22 years of age who live in the Republic of Albania and those between 15 and 22 years which was evaluated from data from the National Institute of Statistics of Albania (INSTAT) [35] and considered to be 62.0% for males and 61.6% for females.

Intra-class correlation coefficient (ICC) of I_{3M} was used for intra-observer and inter-observer agreement between two different observers.

Cohen Kappa was used for intra-observer and inter-observer agreement between two different observers for agreement in selection on adult ($I_{3M} < 0.08$) or minor ($I_{3M} \geq 0.08$). Fifty randomly selected OPTs were reexamined one month after examination by the first and two other observers.

Statistical analysis of data and related graphs were carried out by the R statistical program, version 3.02 [36].

3. Results

Distribution of real age gradually decreased as I_{3M} increased, in both males and females (Fig. 1). The mean ages for both groups in each I_{3M} class varied between genders (Table 2) but the differences were statistically significant only for the second group. The mean age of females was higher than that of males when I_{3M} was between 0.04 and 0.08 ($p = 0.02$). Consequently, the performance of the cut-off value of $I_{3M} = 0.08$, reported in Cameriere et al. [29] and the validity of I_{3M} on the actual Albanian sample used for training purposes was analyzed for males and females separately. ICC for intra-rater and inter-raters agreement of I_{3M} was 0.998 (95% CI 0.988–0.999) and 0.998 (95% CI 0.988–0.999), respectively. Cohen Kappa for intra-rater and inter-rater agreement was 1.0. The results of the analysis of the effectiveness of I_{3M} are presented in two 2×2 contingency tables (Tables 3 and 4), which list the numbers of individuals who have $I_{3M} \geq 0.08$ and are younger than 18, those with $I_{3M} \geq 0.08$ who are over 18, those with I_{3M} <0.08 who are under 18, and those with I_{3M} <0.08 who are over 18.

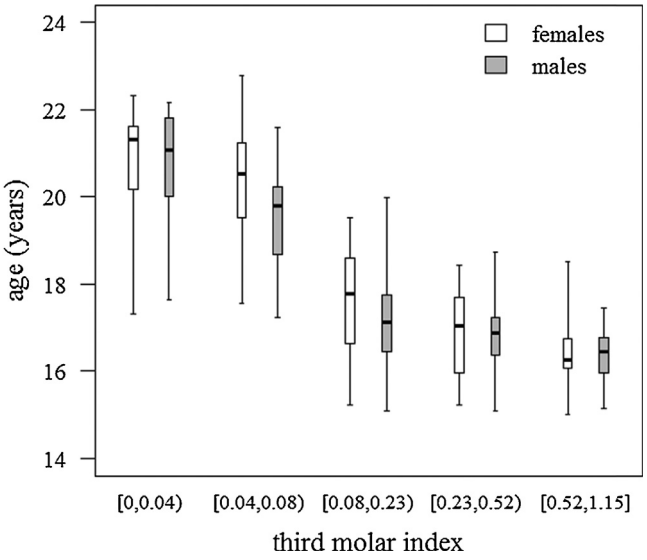

Fig. 1. Boxplot of relationship between age and Cameriere's third molar maturity index of open apices of the mandibular right third molar in Albanian females and males. Boxplot shows median and inter-quartile ranges while whiskers are lines extending from box to maximum and minimum ages, excluding outliers.

Table 3 shows the close association between adult age and the positivity of the test (i.e., $I_{3M} < 0.08$) in males. In fact, 124 out of 134 individuals were accurately classified. These results show that the sensitivity of the test for males (the proportion of individuals being 18 years of age or older whose test was positive) was 94.1% (95% CI 87.6–97.8%) and the specificity of the test (the proportion of individuals younger than 18 years whose test was negative) was 90.9% (95% CI 84.2–94.7%). The proportion of correctly classified individuals was 92.5% (95% CI 85.9–96.2%). The probability that a subject positive on the test (i.e., $I_{3M} < 0.08$) was 18 years of age or older (estimated post-test probability p) was 94.4% (95% CI 88.7–97.3%).

Similar to Table 3, Table 4 shows the close association between adult age and the positivity of the test (i.e., $I_{3M} < 0.08$) in the female group. Of 152 individuals, 131 were accurately classified. These results show that the sensitivity of the test for females was 75.4% (95% CI 68.1–78.8%) and the specificity (the proportion of individuals younger than 18 whose test was negative) was 96.6% (95% CI 91.1–99.1%). The proportion of correctly classified individuals was 87.5% (95% CI 81.2–90.4%). Estimated post-test probability p in females was 97.2% (95% CI 91.9–99.1%).

Table 2
Summary statistics of chronological age according to gender and third molar maturity index (I_{3M}): number of individuals (n), mean, standard deviation (SD), minimum value (min), 1st quartile (Q_1), median, 3rd quartile (Q_3) and maximum value of age distribution for each I_{3M} class.

I_{3M}	n	Mean	SD	Min	Q_1	Median	Q_3	Max
Females								
[0,0.04)	20	20.6	1.5	17.3	20.2	21.3	21.6	22.3
[0.04,0.08)	32	20.5	1.3	17.6	19.6	20.5	21.2	22.8
[0.08,0.23)	38	17.6	1.2	15.2	16.7	17.8	18.6	19.5
[0.23,0.52)	31	16.8	0.9	15.2	16.0	17.1	17.7	18.4
[0.52,1.15]	31	16.4	0.7	15.0	16.1	16.3	16.8	18.5
Males								
[0,0.04)	48	20.7	1.3	17.6	20.0	21.1	21.7	22.2
[0.04,0.08)	21	19.6	1.1	17.2	18.7	19.8	20.2	21.6
[0.08,0.23)	27	17.1	1.2	15.1	16.4	17.1	17.8	20.0
[0.23,0.52)	22	16.8	1.0	15.1	16.4	16.9	17.2	18.7
[0.52,1.15]	16	16.3	0.6	15.1	16.0	16.4	16.8	17.4

Table 3
Contingency table describing discrimination performance of the test for males.

Test	Age		Total
	<18	≥18	
$I_{3M} \geq 0.08$	60	4	64
$I_{3M} < 0.08$	6	64	70
Total	64	70	134

Table 4
Contingency table describing discrimination performance of the test for females.

Test	Age		Total
	<18	≥18	
$I_{3M} \geq 0.08$	84	16	100
$I_{3M} < 0.08$	3	49	52
Total	87	65	152

4. Discussion

Our study demonstrated the similar maturation of third molars in males when compared with females. Only the *r* mean chronological age in the second I_{3M} group in males was statistically significantly lower compared to females. Results of repeated measuring of values of I_{3M} and discrimination performance of the test, using 0.08 value of I_{3M} for cut-off value, for both intra-rater and inter-rater, were almost perfect [37]. Males were better classified (92.5%) than females (87.5%) into adults or minors. Specificity was better for females (96.6%) compared to males (90.9%) while sensitivity was better for males (94.1%) compared to females (75.4%). Both results were good in estimating post-test probability, 94.4% in males was and 97.2% in females.

The value of the results obtained in this study should be viewed from different standpoints. Firstly, the literature so far does not address the age estimation in the target population of Albanians by procedures on the teeth, especially using third molars. Secondly, Albanians are the second largest group of legal immigrants in Italy and therefore could be involved in the procedures for assessing their age for different purposes. Thirdly, so far the I_{3M} cut-off value has not tested on people who are not of Italian descent [29,30]. This raised the question whether there were significant differences in dental development of third molars between Italian and Albanian samples which could contradict the application of previously evaluated and tested method or age standards on the members of an ethnic group other than the reference population [4].

All the positions of the ethnic specificity are complex to evaluate and may change the cut-off value of I_{3M} at any time if necessary. All elements should be examined carefully before any decision to change the cut-off value. In particular, ethnicity must be studied judiciously, to establish what relevance to assign to the growth of the third molar. Several articles have discussed the influence of the ethnicity and geographical position on the third molar development, with mixed results [38–40]. Thevissen et al. [38,39] found no important difference in third molar development, while Liversidge et al. [40] showed that the third molars in South African Black children earlier maturate when compared to sample of Caucasian and Bangladeshi children from London. The question of biological and geographical effects on third molars should not be confused with the possible effect of other factors, which may vary, from local-intraoral factors, diet, socio-economic factors, climate and malnutrition [41–43]. Some recent publications emphasize that malnutrition may not have effect on the timing of maturation and development of the teeth [42,43]. Sample size and composition is of great importance when evaluating specific age estimation method or answering the specific question in new population and for individuals in specific proceedings [18,44]. The homogeneity of the sample, sufficient number of individuals, clear-cut sample definition, and defined reasons for including or excluding the subject are necessary requirements which will provide more reliable results [18]. Variations among several ethnic groups in tested sample can be clarified if significant differences exist and specific mathematical model or new calculation formula can be established on the total sample [45–48].

As a result of the rise of an immigration and cross-border migration in recent years, many European countries have seen an increased number of foreigners who cannot provide documentary evidence for their date of birth [1,31,32]. According to the 2012 OECD report, illegal migration increased almost fourteen-fold by August 2012 in Italy, compared to 2010 [32]. This had led to an increased need of forensic experts to use all available methods for age estimation for different purposes, especially forensic and medico-legal. Several age limits are applied for penal and criminal responsibility, where 18 years of age is the most common. Among the specific anatomical regions which are studied to evaluate whether a particular subject is around the age of 18 or cut-off of adult or not, the methods on the third molar were most frequently used [27,28,49–55].

Most studies have used Demirjian staging system (DSS) where dental development of the tooth was divided in eight specific stages of mineralization [56]. Mincer et al. [28] showed the low accuracy of DSS approach. They pointed that a small number of the developmental stages, which cover a specific age range of target population, are not distributed uniformly. Thevissen et al. [27] showed that increased numbers of stages of the third molar development in specific age span, may influence the age prediction when compared to DSS. Cameriere et al. [29] showed that small numbers of mineralization stages of DSS considerably effect on the sensitivity and specificity of the test to discriminate subjects between adults or minor. The same study showed that specific cut-off value 0.08 for I_{3M} for both genders better discriminated subjects between adult and minor when compared to DSS approach. Study by De Luca et al. [30] on another Italian sample of 397 subjects, aged between 13 and 22, from Milano region, showed usefulness of I_{3M} method. The obtained results of the sensitivity (86.6%) and specificity of the test (95.7%), correctly classified subject (91.4%) and post-test probability (95.6%) are comparable with finding on Albanian sample.

Up to date, insufficient knowledge has been obtained about how and does really ethnic origin can influence on tooth mineralization [57,58]. However, this constitutes a limitation on the reliability of the age estimation method on third molars and hence on the value of the specific information of estimated age stated by a forensic expert. This could be important to legal or criminal proceeding on specific person. For these reasons, the authors emphasize the importance of extending the study of age estimation to different reliable methods and inclusion of other and larger ethnic populations to test possible variability [4,44].

It may be concluded that population-specific standards would enhance the accuracy of forensic age estimates based on wisdom tooth mineralization in living subjects [26].

In conclusion, the results of this paper encourage us also to test the cut-off value of $I_{3M} = 0.08$ on other European subjects. The further step is to study a cut-off value and I_{3M} on the other non-European samples, especially ones from Africa and Asia and to investigate possible ethnic variability.

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