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ORIGINAL ARTICLE

The third molar maturity index in indicating the legal adult age in Kosovar population

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Abstract

The third molar tooth, known as the "wisdom tooth," is the only tooth that can be used to determine legal adult age. This study aimed to test the accuracy of Cameriere's third molar maturity index (I_{3M}) in assessing the legal adult age of 18 years in the Kosovar population. Orthopantomographs (OPTs) of 1221 healthy living Kosovar individuals, aged between 12 and 23 years and with no congenital or developmental anomalies, were analyzed. Intra-class correlation coefficients were 0.858 (95% CI, 0.786 to 0.906) and 0.852 (95% CI, 0.779 to 0.903) for intra-rater and for inter-rater agreement, respectively. The sample was divided into training dataset (800 OPTs) and test dataset (421 OPTs). The training dataset was used to generate the logistic regression model, while the test dataset was used to study the performance of the model. I_{3M} and gender as independent variables and adult age (≥ 18 years) or minor age (< 18 years) as the dependent variable were used for logistic regression analysis. The receiver operating curve (ROC) analysis was used to determine the specific cut-off value of I_{3M} for predicting adult age. The results showed that only I_{3M} statistically significantly contributed to discriminating adults and minors. ROC analysis showed that the cut-off value of $I_{3M} < 0.08$ was the best in discriminating adults and minors. An analysis of the test dataset (421 OPTs) showed that as I_{3M} decreased the age gradually increased. The performance of the cut-off value of $I_{3M} < 0.08$, to discriminate between adults and minors, was analyzed by contingency tables for both sexes. In males, the accurate classification (*Acc*) was 0.968 (95% CI, 0.926 to 0.985), the sensitivity (*Se*) was 0.962 (95% CI, 0.925 to 0.978), and the specificity (*Sp*) was 0.976 (95% CI, 0.929 to 0.995). The Bayes post-test probability (Bayes PTP) was 0.975 (95% CI, 0.905 to 1.00). In females, Acc was 0.909 (95% CI, 0.870 to 0.917), Se and Sp were 0.826 (95% CI, 0.787 to 0.834) and 0.991 (95% CI, 0.953 to 1.00) respectively, while Bayes PTP was 0.989 (95% CI, 0.926 to 1.00). Our data support the usefulness of $I_{3M} < 0.08$ to indicate legal adult age in a Kosovar population.

- Third molar maturity index (I_{3M}) was tested in the Kosovar population for determining legal adult age (≥ 18 years).
- Logistic regression showed that gender was not significant in determining adult age.
- ROC analysis showed that the cut-off value of $I_{3M} < 0.08$ was the best for the Kosovar population.
- The applied cut-off showed high sensitivity and specificity.

Jeta Kelmendi and Roberto Cameriere equally contributed to this study

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Keywords Legal medicine · Third molar maturity index · Legal adult age · Kosovo

Introduction

Age estimation based on tooth mineralization during growth and development has been used since the availability of X-rays and showed to be more accurate than skeletal development for estimating chronological age [1, 2]. The age of majority is the onset of adulthood at which the law recognizes or declares someone as an entirely legal citizen [3]. Moreover, minors cease to be considered children and assume legal control over their persons, actions, and decisions, i.e., when they no longer require the control and legal responsibilities of their parents or guardian in civil matters [4, 5]. In many countries, as well as in the Republic of Kosovo, the age of 18 years represents the legal adult age or age of majority [6, 7]. It is necessary to use the least invasive procedure with the best precision and accuracy when determining whether a person is an adult or a minor [8]. Gulsahi et al. [9] discussed the financial penalties for the local government if a minor was improperly and wrongly assessed as an adult and inference for their deportation if an asylum claim is rejected. A good example is the case of 40 child asylum seekers in the UK who were determined to be over 18 years because of a flawed age estimation and were paid over 2 million pounds in a court settlement [9]. This case illustrates the importance to use and combine various age estimation methods for the best accuracy in indicating the legal adult age [10]. All procedures should be evidence based and previously published in a scientific journal and accepted by the scientific community [11]. The guidelines for age estimation in living individuals, suggested by the Study Group on Forensic Age Diagnostics (AGFAD), include a physical examination with determination of anthropometric measurements, inspection of sexual maturation, and identification of any relevant developmental disorder [12, 13].

Age estimation is very efficient by the method of evaluation of mineralization of permanent teeth until the age of 12–14 when mineralization of the second molars is completed [14, 15]. Given the fact that third molars are still growing at the age of 18 in most individuals, their development has been considered a rarely suitable body region to study if a person is an adult or not [16–20]. In the last few years, several studies and different statistical approaches have focused on mineralization of the third molar [4, 21–30]. The third molar maturity index (I_{3M}), based on the measurement open apices by Cameriere et al. [18], has not been evaluated yet in Kosovar population. Furthermore, no study has addressed the issue of the age of maturity indication from I_{3M} in Kosovo.

This study aimed to test the usefulness of I_{3M} on a Kosovo sample and to test possible differences between sexes and determine the specific cut-off value of I_{3M} for prediction of an individual's majority/minority status.

Methods

Orthopantomographs (OPTs) of 1277 healthy living Kosovar individuals, aged between 12.0 and 23.9 years and with no congenital or developmental anomalies, were analyzed. The available sample of OPTs of patients attending the Unit of Orthodontics and Pediatric Dentistry, University Dentistry Clinical Center of Kosova (UDCCK) between June 2011 and September 2015 was analyzed. OPTs of unknown age, gender, or those with no third molars were excluded from the sample. This left 1221 OPTs (543 males and 678 females) for analysis (Table 1).

OPTs were retrieved as digitalized images from the local database and the images from the digital OPT machine. OPTs were saved as JPEG format using the Sidexis Next generation imaging software, version 2.4®, integrated with the I-Max Touch Line:220-240V-7A 50/60 Hz maximal exposure time, 15 s, produced by Owandy (Champs-sur-Marne, France). Next, the digital images were analyzed with image processing software Corel DRAW (Graphics Suite X7, Ottawa, Canada). During the analysis, "magnify" and "ruler" tools were used. We collected the following individual data: date of birth, date

Table 1 A distribution of the panoramic radiographs from Kosovo, numbers in parenthesis represent samples with closed apices of the left third mandibular molar (I_{3M} = 0.00)

Age (years)	Males	Females	Total
12	40	49	89
13	43	36	79
14	47	37	84
15	37	67	104
16	29	81	110
17	47 (4)	85 (2)	132 (6)
18	45 (14)	77 (15)	122 (29)
19	48 (39)	51 (26)	99 (65)
20	50 (49)	53 (39)	103 (88)
21	56 (55)	51 (40)	107 (95)
22	57 (56)	48 (48)	105 (104)
23	44 (44)	43 (43)	87 (87)
Total	543 (261)	678 (213)	1221 (474)

of the radiograph, gender, and identification number (ID). Individual's parents or guardians previously had to sign an agreement with UDCCK that dental record and radiographs could only be used for research and educational purposes in a fully anonymized way. Protocols to collect radiographs of individuals were approved by the Ethics Committee of the UDCCK, and the study was in agreement with the ethical standards imposed by the Declaration of Helsinki.

The developing lower left third molars on the OPT were analyzed. Dental age estimation was performed according to the method of Cameriere et al. [18]. In brief, the projections of the apical end of the roots of the left lower third molar of the individual were measured. The I_{3M} was defined as follows: if the root development of the third molar is complete, i.e., there is no possibility to measure open apices on the projections on OPT, then $I_{3M} = 0.0$. Otherwise, I_{3M} is evaluated as the sum of the distances between the inner sides of the two open apices divided by the tooth length [8]. I_{3M} is assessed in an analogous way to the ratio Ai to Li, when $i = 6,7$, as reported for the teeth with two roots in Cameriere et al. [31]. Both impacted and non-impacted third molars were included in this study, provided that their roots were radiographically visible [18]. All analyses of the OPTs were performed by the first author (JK). The analysis was carried out by using a blind approach, i.e., it was not possible to identify individual's ID, gender, or age. Pearson's correlation coefficient was calculated to test the correlation between I_{3M} and real age. The first (JK) and third author (IG) additionally analyzed 50 randomly selected OPTs 2 weeks after the first analysis. The intra-class correlation coefficient was calculated to assess intra-rater and inter-rater agreement of I_{3M} [32]. The final sample of 1221 OPTs was randomly divided into a training dataset of 800 OPTs and a test dataset of 421 OPTs, stratified by gender and age groups. A Kosovo-specific logistic prediction model, with the individuals who have attained the age of 18 years and more (E = 1, adults) or under the age of 18 (E = 0, minors) as response variable, and gender (g) and I_{3M} as predictors [18], was fitted on the individuals in the training dataset. The receiver operating curve (ROC) was used to determine the cut-off of I_{3M} which was the best in discriminating adults and minors. A Youden's index is a single measure of the performance of the dichotomous diagnostic test [33]. The maximum value Youden's index was set as the best performance of the ROC and corresponding cut-off value of I_{3M} will be taken for the analysis of the test dataset [33]. A distribution of age across different I_{3M} classes in a test dataset was evaluated. Possible differences of I_{3M} between genders in a test dataset were evaluated by independent samples t test [24, 34]. To verify the performance of the specific cut-off value of I_{3M} to discriminate Kosovar adults and minors, a two-by-two contingency table was used to list the results of the selected cases (Table 4). The percentage of accurate classification (*Acc*), sensitivity (*Se*), or the proportion of the individuals 18 years and older who had I_{3M} < cut-off and specificity (*Sp*) or the proportion of individuals younger than 18 who had $I_{3M} \geq$ cut-off, were calculated. The positive predictive value (*PPV*), negative predictive value (*NPV*), or the proportions of positive and negative results that are truly positive and truly negative results, respectively were calculated. The positive likelihood ratio (*LR+*) and negative likelihood ratio (*LR−*) were additionally calculated to express how many times more or less likely a test result is to be found in adults compared with minor individuals [33]. The post-test probability (p) of attainment of 18 years of age or older can help to discriminate between those individuals who are ≥ 18 years and those who are < 18 years. According to Bayes' theorem, the post-test probability may be written as:

$$p = \frac{\mathrm{Se} \times p_0}{\mathrm{Se} \times p_0 + (1-\mathrm{Sp}) \times (1-p_0)} \quad (1)$$

where p is post-test probability and p_0 is the probability that the individual in question is ≥ 18 years, given that he or she is aged between 12 and 23 years, which represented the target population. Probability p_0 was calculated as the proportion of individuals between 18 and 23 years of age who live in the Republic of Kosovo according to demographic data from the 2011 census and those between 12 and 23 years which was evaluated from data from the Kosovo Agency of Statistics (ASK) [35]. This proportion was considered to be 0.496 for males and 0.493 for females. Statistical analysis was performed by IBM SPSS 20.0 software program (IBM® SPSS® Statistics, Armonk, NY, USA). The significance threshold was set at $p < 0.05$.

Results

Pearson's correlation coefficients for the correlation between I_{3M} and real age were better for males, − 0.817 ($p < 0.001$) than for females, − 0.750 ($p < 0.001$) (Fig. 1).

The intra-class correlation coefficient for intra-rater agreement was 0.858 (95% CI, 0.786 to 0.906) whereas it was 0.852 (95% CI, 0.779 to 0.903) for the inter-rater agreement. Obtained results of intra-class correlation coefficient showed a very good repeatability of the variable I_{3M}.

Logistic regression was performed to assess the impact of I_{3M} and gender on the discrimination of the individuals into adults and minors. The logistic regression model showed the significance of variable I_{3M} ($p < 0.001$) whereas gender was not significant ($p = 0.280$). The full model, containing only I_{3M} as a predictor variable, was statistically significant ($p < 0.001$), indicating that model was able to discriminate individuals between adults and minors. The whole model explained between 0.496 (Cox and Snell R square) and 0.661 (Nagelkerke R square) of

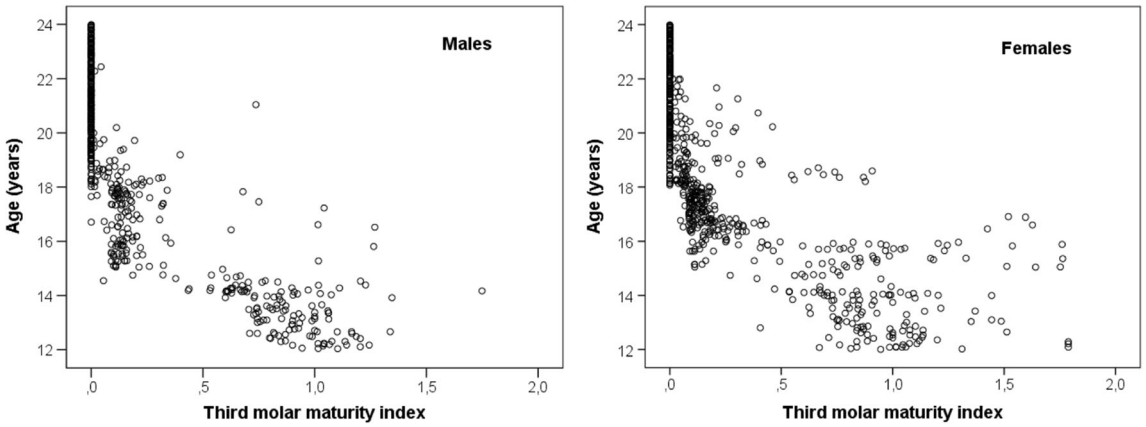

Fig. 1 Scatter plot of the relationship between the third molar maturity index and age

the variance in adult or minor status. The linear logistic model could be written as:

$$Logit\ (p) = 1.90 - 14.55 \times I_{3M} \quad (2)$$

ROC analysis was performed on the whole training dataset sample because the gender did not significantly contribute to the model. Figure 2 shows the ROC curve of the adult age status while the results of Se, Sp, and Youden index for the cohort of I_{3M} are shown in the Electronic supplementary material (Table S1).

The best performance of the discrimination between adults and minors or the maximum Youden index (J = 0.87) was for the I_{3M} value of 0.08 (Table S1). According to Kosovo-specific results, we set that an individual was an adult if the cut-off value of I_{3M} is lower than 0.08 ($I_{3M} < 0.08$), if not, the individual needs to be considered a minor.

In the test sample, age gradually increased as I_{3M} decreased in both males and females (Fig. 3). The mean age in each I_{3M} class varied between genders (Table 2). The differences were significant in the younger classes, while they were not in the older classes (Table 2).

To measure the performance of the Kosovo-specific cut-off value of $I_{3M} < 0.08$ to discriminate between adults and minors, the test dataset was analyzed. Because of the more accurate presentation of the results, the two-by-two contingency tables and quantities from the contingency tables were presented for males and females separately (Tables 3 and 4).

In males, the Acc was 0.968 (95% CI, 0.926 to 0.985). The proportion of individuals being ≥ 18 years of age whose test was positive or Se, was 0.962 (95% CI, 0.925 to 0.978). The proportion of individuals < 18 years whose test was negative or Sp was 0.976 (95% CI, 0.929 to 0.995). The positive predictive

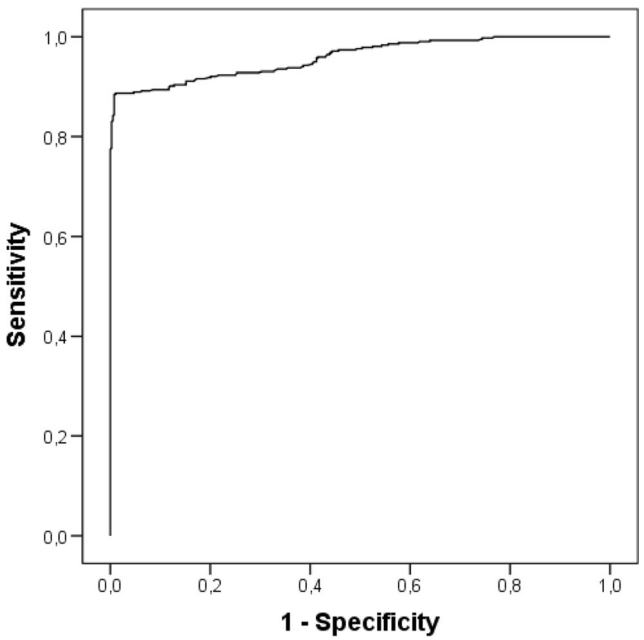

Fig. 2 Receiver operating characteristic (ROC) curve for the third molar maturity index for adult age (≥ 18 years) in Kosovars

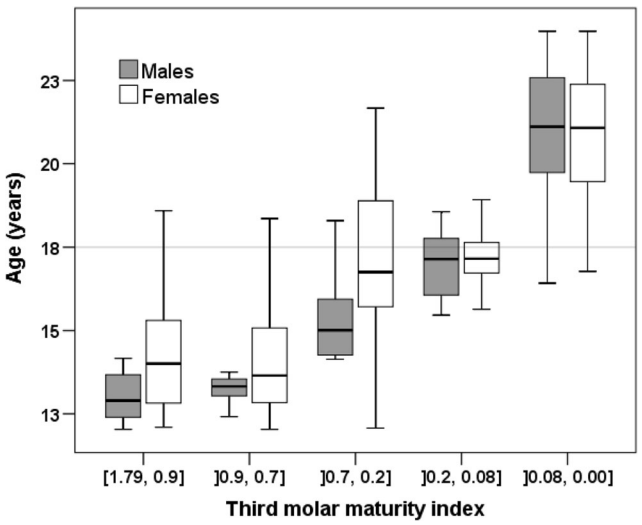

Fig. 3 Box plot of the relationship between real age (years) and the third molar maturity index of the test dataset from Kosovo; box plot shows median and inter-quartile ranges, whiskers maximum and minimum ages, excluding outliers

Table 2 Summary statistics of chronological age of the test dataset from Kosovo according to the third molar maturity index (I_{3M}) classes

I_{3M} class	Males								Females								
	N	Mean	Sd	Min	Q1	Med	Q3	Max	*N*	Mean	Sd	Min	Q1	Med	Q3	Max	*t* (*df*)	*p* value
[1.79, 0.9]	20	13.02	0.74	12.03	12.35	12.90	13.80	14.17	24	14.16	1.56	12.01	12.79	14.01	15.33	18.60	− 3.14 (34.1)$^{+}$	0.003
[0.9, 0.7]	13	13.30	0.56	12.42	12.83	13.32	13.58	14.55	21	14.15	1.74	12.03	12.82	13.65	15.15	18.36	− 2.08 (26.1)$^{+}$	0.048
[0.7, 0.2]	22	15.29	1.24	14.14	14.26	15.01	16.06	18.30	34	17.20	2.31	12.07	15.69	16.75	18.91	21.67	− 4.00 (52.6)$^{+}$	< 0.001
[0.2, 0.08]	30	16.97	0.94	15.46	16.02	17.14	17.77	18.57	57	17.18	0.90	15.63	16.72	17.15	17.65	19.84	− 1.27 (85)	0.204
[0.08, 0.00]	105	21.06	1.85	14.55	19.71	21.11	22.60	23.97	95	20.98	1.80	16.77	19.46	21.08	22.41	23.97	0.315 (198)	0.754

Abbreviation: N, number of individuals; mean, mean age within I_{3M} class; SD, standard deviation of mean age; Min, minimum age; Q1, 1st quartile of age; Med, median age; Q3, 3rd quartile of age; Max, maximum age; t, independent samples test; ; *df*, degrees of freedom

*< 0.05, level of significance

$^{+}$ Equal variances not assumed

value (*PPV*) and negative predictive value (*NPV*) were 0.981 (95% CI, 0.942 to 0.996) and 0.953 (95% CI, 0.907 to 0.972), respectively. LR+ and LR− were 40.415 (95% CI, 12.962 to 215.592) and 0.039 (95% CI, 0.023 to 0.081), respectively. The estimated Bayes post-test probability was 0.975 (95% CI, 0.905 to 1.00). The greatest error in selecting minor as adult males was for the 16-year-old participants, where 90% were correctly selected. The greatest error in selecting adult as minor males was for the 18-year old, 71.4% were correctly selected (Table 5).

In females, Acc was 0.909 (95% CI, 0.870 to 0.917), Se was 0.826 (95% CI, 0.787 to 0.834), and Sp was 0.991 (95% CI, 0.953 to 1.00). PPV and NPV were 0.990 (95% CI, 0.943 to 0.999) and 0.852 (95% CI, 0.819 to 0.859), respectively. LR+ and LR− were 95.826 (95% CI, 16.69 to 1848.47) and 0.175 (95% CI, 0.166 to 0.223), respectively. The estimated Bayes post-test probability was 0.989 (95% CI, 0.926 to 1.000). The only error in selecting minor as adult females was for the 16-year olds, where 96.3% were correctly selected. The greatest error in selecting adult as minor females was for the 18-year olds, where only 55.5% were correctly selected, followed by the 19- and 20-year olds, with 78.9% of correctly selected individuals (Table 5).

Discussion

We verified the sample of OPTs from Kosovo by I_{3M} with the purpose of use in legal and criminal procedures. Precisely, I_{3M} could be used to determine if a particular person is a minor or an adult and further for identification of missing persons or unidentified victims. We used the logistic regression model to demonstrate in the training sample from Kosovo that only I_{3M} significantly contributed to the discrimination of adults and minors, whereas gender was not statistically significant for this discrimination. Additionally, ROC analysis of the training sample and the maximum value of Youden index showed that a cut-off value of $I_{3M} < 0.08$ was the best in discrimination adults from minors.

Our results confirmed the usefulness of the specific cut-off value of $I_{3M} < 0.08$ to distinguish Kosovar adults from minors in the test sample. The accuracy of classification was better in males (Acc = 0.963) vs. females (Acc = 0.909). Se was better in males (0.962 in males vs. 0.826 in females) whereas Sp was slightly better for females (0.964 in males vs. 0.991 in females). Our results are better than the results presented by Cameriere et al. [18] in the Italian study (Acc = 0.83; Se = 0.70; and Sp = 0.98). Moreover, our results are within the range of the results of previous studies on testing of $I_{3M} < 0.08$ in discriminating adults and minors in various populations [4, 8, 9, 23, 24, 34, 36–43]. In the test sample, the accuracy differed between the genders because the third molars mature at a slightly faster rate in males in the Kosovar sample. The differences between genders were obvious in Table 1, from the age of 17 years, when the first apical closure was noticed in both genders, the number of closed apices followed the increase of age, but faster in males

Table 3 Contingency table of the test dataset from Kosovo describing discrimination performance of the cut-off value of third molar maturity index ($I_{3M} < 0.08$)

Test	Males		Total males	Females		Total females
	Age			Age		
	≥ 18	< 18		≥ 18	< 18	
$I_{3M} < 0.08$	102 TP	2 FP	104	95 TP	1 FP	96
$I_{3M} \geq 0.08$	4 FN	82 TN	86	20 FN	115 TN	105
Total	106	84	190	115	116	231

Abbreviation: I_{3M}, third molar maturity index; TP, true positive; FP, false positive, FN, false negative, TN, true negative

than in females. Next, it can be seen that after 19 years, almost all apices of the roots of the third molars were closed in males, but in females, there were still few roots that did not have fully finished the development. All third molars finished their mineralization at age of 23 so there is no need to evaluate older individuals. These findings are in line with the previous studies from neighboring countries to the Kosovo, Serbian by Zelić et al. [34], and Croatian by Galić et al. [39], or from other continents like the Botswanian study on black Africans by Cavrić et al. [4], South Indian by Balla et al. [24], or Peruvian by Quispe Lizarbe et al. [23]. All these studies showed the similar capability of $I_{3M} < 0.08$ in discrimination adults and minors.

However, in the cases where the lower third molars were retained, there is a possibility to discriminate between adults and minors wrongly [44]. Additionally, in the cases where the third molars are angulated, missing, or intentionally extracted, other age estimation methods may be used [45, 46].

Our study provides the results for the error in discriminating adults and minors in each age group. The inaccuracies were present in participants between 16 and 20 years. The most significant error in discriminating adults and minors was in the age groups close to border age, at 18 and 17 years of age. The highest error rate was found in the 18-year age group in females, where 55.5% was classified as minors. Misclassification from the forensic point view can be ethically more or less acceptable [47]. The Bayes post-test probability *p* or the proportion of individuals who are 18 years or older with $I_{3M} < 0.08$, was 0.966 for males vs. 0.989 for females. The selection test should especially have a high specificity, to protect minors, which is achieved by the proposed method.

Our study on the Kosovar population contributes to the body of evidence from previous studies of verifying the use of the specific cut-off value of I_{3M} for classifying individuals of unknown age as minors or adults. In Kosovo, the legislation system recognizes some other age limits. The minimum age of criminal and juridical responsibility is 14 years [7]. The Juvenile Justice Code of Kosovo law determines differences in treating juveniles, adults, and young adults when a person is in various proceedings [7]. The qualifications of responsibility are not uniform in all countries, but they are individual of a determination under the special law. The same applies in Kosovo where the Family Law of Kosovo (Law No. 2004/32), in Article 15 under provision [2] states that "Majority is obtained upon the completion of the eighteenth year of age" [48]. Whereas under provision [3] states that "Full capacity to act is obtained upon reaching majority or by entering into wedlock prior to this age" [48]. However, under Article 16 of the Law, due to justifiable reasons, the competent court may allow wedlock for a minor person older than 16 years upon his request, if it concludes that the individual has reached the necessary physical and psychological maturity for exercising his marital rights and obligations [48]. According to Article 223 of the abovementioned law, a person may be deprived of the full or partial capacity to act, if, for

Table 4 The quantities from 2-by-2 contingency tables (95% confidence interval) to test the age of majority in the test dataset from Kosovo

Quantities	Males	Females
Accuracy	0.968 (95% CI, 0.926 to 0.985)	0.909 (95% CI, 0.870 to 0.917)
Sensitivity	0.962 (95% CI, 0.925 to 0.978)	0.826 (95% CI, 0.787 to 0.834)
Specificity	0.976 (95% CI, 0.929 to 0.995)	0.991 (95% CI, 0.953 to 1.00)
PPV	0.981 (95% CI, 0.942 to 0.996)	0.990 (95% CI, 0.943 to 0.999)
NPV	0.953 (95% CI, 0.907 to 0.972)	0.852 (95% CI, 0.819 to 0.859)
LR+	40.415 (95% CI, 12.962 to 215.592)	95.826 (95% CI, 16.69 to 1848.47)
LR−	0.039 (95% CI, 0.023 to 0.081)	0.175 (95% CI, 0.166 to 0.223)
Bayes PTP	0.975 (95% CI, 0.905 to 1.00)	0.989 (95% CI, 0.926 to 1.00)

Abbreviation: PPV, positive predictive value; NPV, negative predictive value; LR+, positive likelihood ratio; LR−, negative likelihood ratio; Bayes PTP, Bayes post-test probability

Table 5 Number and percentage (%) of correct evaluations/total participants in each age group of the test dataset form Kosovo by using the third molar maturity index cut-off value ($I_{3M} < 0.08$), that subjects are 18 years of age and older or younger

Age groups (years)	Males	Females	Total
12	13/13 (100%)	14/14 (100%)	27/27 (100%)
13	15/15 (100%)	11/11 (100%)	26/26 (100%)
14	17/17 (100%)	11/11 (100%)	28/28 (100%)
15	13/13 (100%)	23/23 (100%)	36/36 (100%)
16	9/10 (90%)	26/27 (96.3%)	35/37 (94.5%)
17	15/16 (93.7%)	30/30 (100%)	45/46 (97.8%)
18	10/14 (71.4%)	15/27 (55.5%)	25/41 (61%)
19	18/18 (100%)	15/19 (78.9%)	33/37 (89.2%)
20	19/19 (100%)	15/19 (78.9%)	34/36 (94.4%)
21	18/18 (100%)	18/18 (100%)	36/36 (100%)
22	20/20 (100%)	16/16 (100%)	36/36 (100%)
23	17/17 (100%)	16/16 (100%)	33/33 (100%)
Total	184/190 (96.8%)	210/231 (90.9%)	394/421 (93.6%)

example, he is not capable of normal judgment or if by his actions, he gravely endangers his own or others' rights [48]. The criminal liability in Kosovo is stipulated under Article 17 of the Criminal Code of the Republic of Kosovo (Law No. 04/L-082) and it states as follows: "1. A perpetrator of a criminal offense is criminally liable if he or she is mentally competent and has committed the criminal offense intentionally or negligently; 2. A person is criminally liable for the negligent commission of a criminal offense only when this has been explicitly provided for by law; 3. A person is not criminally responsible, if at the time of the commission of a criminal offense, he or she is under the age of fourteen (14) years" [49, 50].

When it comes to estimating a person's age, there are many techniques, but none can be used with high reliability when the person is ending his/her growth [51]. However, from a legal point of view, it is important to give information as accurate as possible on whether the person is an adult or a minor [52]. During the identification procedure, the available documents of the person with unidentified age should be analyzed, followed by the physical examination and estimation of the puberty development [34]. Some of the countries do not support radiograph for age estimation because it is considered an unnecessary radiation exposure [53], but most of the others maintain the analysis of the development of the teeth, hand wrist bones, and clavicles [16].

In recent years, forensic and legal medicine experts in Europe are involved in many age estimation cases including investigation of unaccompanied minors, asylum seekers, and refugees [10, 45]. We are witnessing large migratory waves, first from the Balkans and now from the countries of the Near East and North and Sub-Saharan Africa. Many of migrants do not have personal documents [54]. At the moment, a large number of displaced persons and refugees and asylum seekers from the Middle East are passing through Balkan's routes, including Kosovo, to immigrate into high development European countries like Germany, Italy, UK, and some others [55]. The number of displaced persons and refugees dramatically raised from 2015 the number is still rising [55, 56]. Past wars in the Balkan region, including the last one in Kosovo in 1999, have left many unidentified victims and missing persons [57–59]. These circumstances emphasize the problem of a forensic expert in giving the opinion of a person's age. Thus, a reliable method for determining whether an individual is a minor or an adult is more than needed. This Kosovar study shows that small differences between populations can be expected even in the same geographical region. These small between-population differences are probably smaller than the within-population differences based on differences between individuals [9, 34, 41, 60, 61]. Thus, the results of our study are beneficial for the legal and criminal practice in Kosovo and other countries with Kosovar population. Further studies should address the usefulness of this method and the specific cut-off of I_{3M} for different populations.

Conclusion

This research confirms the usefulness of $I_{3M} < 0.08$ to indicate legal adult age in a Kosovar population. The same population should evaluated by the other scientific methods for possible combination for optimal accuracy.

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