Dental Age Assessment by $I_{2M}$ and $I_{3M}$: Portuguese Legal Age Thresholds of 12 and 14 Year Olds

Dental procjena dobi s pomoću $I_{2M}$ i $I_{3M}$: prema portugalskom zakonu za dob od 12 do 14 godina

Abstract

Objective: Better understanding of dental age assessment may help in cases of age estimation in Forensic Clinics. The first aim was to provide essential information on method reliability for upcoming studies using dental age assessment by second molar index ($I_{2M}$) and third molar index ($I_{3M}$) for age estimation on legal ages of 12-14 years. The second aim was to document forensic method outcomes of the Demirjian method which has already been used in forensic clinic. Material and methods: Two samples were used for this purpose: for $I_{2M}$ 633 orthopantomographs (270 females / 363 males), the age range from 7 to 17 years and for $I_{3M}$ 471 orthopantomographs (253 females / 218 males), the age range from 10 to 23 years, from the database population of Lisbon North University Hospital Center, approved by the Ethic Committee. Results: The $I_{2M}$ cut-off point (1.133) for 12-year-olds obtained better results than the cut-off point stated by the $I_{3M}$ (0.135). Besides, $I_{3M}$ cut-off point (0.001) for 14-year-olds showed better results when compared with the cut-off point (0.705) established by the $I_{2M}$. Both methods are reliable for the legal age thresholds of 12 and 14 years. However, using $I_{2M}$ and $I_{3M}$ allows us to vary the cut-off value to privilege sensitivities or specificity, depending on which is more appropriate to the intended application. Conclusions: The accuracy (88.94%) of $I_{2M}$ obtained better results for the 12-year-old cut-off point (1.133) and the accuracy (90.21%) of the $I_{3M}$ performed better for the 14-year-old cut-off point (0.001).

Address for correspondence

Cristiana Palmela Pereira, Professor with aggregation University of Lisbon, Faculty of Dental Medicine Centre of Statistics and Applications, University of Lisbon (CEAUL) Investigator in charge of FORENSEMED group from UICOB at the Faculty of Dental Medicine, University of Lisbon. cristiana.pereira@fmd.ulisboa.pt

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Introduction

Forensic Odontology is a discipline of Forensic Sciences. The main purpose consists of proper observation, handling, examination and technical-scientific evaluation of oral evidence, which will be presented in the major interest of the justice (1). The judicial system faces several difficulties regarding the identification of individuals without reliable identification, often categorizing them by physical appearance, which leads to errors and lack of equity when presented to the court (2). In children and adolescents, there are several forensic issues such as minimal age for criminal responsibility and the threshold age for civil adulthood where the biological age assessment through dental evidence can help (3–5).

In Portugal, the legal ages, between the ages of 12 and 14 years, are covered by the Portuguese penal code which promotes the protection of juvenile individuals, giving priority to healing and prevention over individual measures of punishment. For the application of criminal law, we assume the practice of a fact qualified as a crime by a minor less than 16 years of age is not imitable. This is valid for ages between 12 and 16 years. A child below the age of 16 years cannot be held criminally liable. Children aged between 12 and 16 years can be subject to penalties under the Guardianship and Education Law, which allows for detention of children in closed educational centers. Also, this allows the application of preventing educational measures when crimes are committed by children from 12 to 16 years of age, referred to as juvenile delinquency (6,7).

Within Section II of Chapter V, Book II of the Portuguese Penal Code, we are faced with the intervention area of crimes against sexual self-determination, that is, the classification of the crime, in undocumented victims, in order to blame the assailant through the action of the age estimate. According to Article 171º (Child sexual abuse), all children and young people less than 14 years of age are considered victims. In addition to this crime, article 173 refers to sexual acts with adolescents, where the victims are all children or young people between 14 and 16 years of age. If the victim is between 14 and 18 years of age, without documents, article 174 acts, resorting to the prostitution of minors. If the victim is under 18, articles 175 and 176 cover sexual exploitation of children and pornography of minors, respectively (8).

Since age estimation must be as precise as possible when applied to the medico-legal field, in the best interest of justice, the use of radiographic techniques, namely orthopantomography, is preferred over any other indirect method. It is a process that is relatively time-efficient, showing to be more accurate than skeletal development for estimating chronological age (9–12).

Several methods, using orthopantomographs, have been introduced to estimate age through dental observation. They have been commonly used in studies of dental maturity and for age estimation (13). Demirjian method is one of them, which consists in assigning one out of eight stages according to the mineralization state of the tooth (14,15). However, this system is highly subjective since it depends on the stage that the observer attributes to it.

Uvod

Forenzička dentalna medicina disciplina je sudskih znanosti. Njezina je glavna svrha pravilno opažanje, rukovanje, pregledavanje te tehnička i znanstvena procjena oralnih dokaza koji se zahtijevaju uglavnom u interesu pravde (1). Pravni sustav suočava se s nekoliko poteškoća kad je riječ o identifikaciji osoba bez pouzdanog identiteta te se one često kategoriziraju prema fizičkom izgledu, što nerijetko završava pogreškama i nedostatkom jednakosti pred sudom. Kod djece i adolescenata nekoliko je forenzičkih točaka, kao što su najmanja dob za kriminalnu odgovornost te razina dobi za civilnu odraslost, kada dentalni dokazi mogu pomoći pri procjeni biološke dobi (3 – 5).

U Portugalu je dob od 12 do 14 godina regulirana Kaznenim zakonom koji promiče zaštitu mladih osoba te daje prednost oporavku i prevenciji, a ne individualnim kaznenim mjerama. Pri primjeni kaznenoga zakona pretpostavlja se da nema kaznene odgovornosti ako je čin koji se smatra kaznenim djelom učinio maloljetnik. To vrijedi za dob od 12 do 16 godina. Dakle, dijete mlade od 16 godina ne može kazneno odgovarati. Djeca u toj dobi mogu biti kažnjena prema Zakonu o skrbi i educaciji koja omogućuje njihovo upućivanje u odgojne centre zatvorenog tipa. Tako se mogu primijeniti preventivne odgojne mjeru u slučaju kada su djeca u dob dijeti od 12 do 16 godina učinila kazneno djelo, što se naziva juvenilnom delinkvencijom (6, 7).

U drugom dijelu 5. poglavlja, u drugoj knjizi portugalskoga Kaznenog zakona, govori se o intervencijama u slučaju kaznenih djela protiv vlastite seksualne orijentacije, odnosno o klasifikaciji kaznenoga djela nad nedokumentiranim žrtvama kako bi se počinitelj kaznio s obzirom na procijenjenu dob. Prema članku 171. (seksualno zlostavljanje djece) sva djece i osobe mlade od 14 godina smatraju se žrtvama. Članak 173. dodatno govori o seksualnom činu s adolescentima u kojem su žrtve sva djece i mlađe osobe u dobi od 14 do 16 godina. Ako žrtva ima od 14 do 18 godina, a nema dokumentacije, članak 174. definira zločin kao prostituiranje maloljetnika. Ako žrtva ima manje od 18 godina, članci 175. i 176. govore o seksualnom iskorištavanju djece te o maloljetničkoj pornografiji (8).

Budući da procjena dobi mora biti što je moguće točnija kada se primjenjuje u medicinsko-pravnom području u najboljem interesu pravde, upotreba rendgenskih tehnička, ponajprije ortopantomografije, najprihvatljivija je od svih neizvrsnih metoda. To je razmjerno brzo postupak koji se pokazao točnijim od skeletalnog razvoja pri procjenjivanju kronološke dobi (9 – 12).

Za procjenjivanje kronološke dobi s pomoću dentalnog pregleda koristi se nekoliko metoda, uključujući i ortopantomografiju. Njihova upotreba uobičajena je u istraživanjima dentalne zrelosti i pri procjeni dobi (13). Jedna od metoda jest Demirjianovu koja se sastoji od određivanja jednoga od osam stupnjeva prema stanju mineralizacije zuba (14, 15). No, taj je sustav svakako subjektivan, zato što ovisi o stupnju koji određuje osoba koja procjenjuje.

S druge strane, Cameriereova metoda s regresivnom formulom prema kojoj se određuje dob s pomoću omjera koji se
On the other hand, there is Cameriere’s method with a regressive formula in which it is established that the ratio given by the sum of the distances from the inner sides of the open apices and the height of the developing of second and third molars (second molar maturity index - $I_{2M}$ and third molar maturity index - $I_{3M}$) is a reliable method to discriminate, regardless of geographic origin and socio-economic status (16,17).

The aim of this study was to assess the cut-off points for the Portuguese legal ages of 12 and 14 years, important according to the Portuguese Penal Code, through the second molar maturity index ($I_{2M}$) and third molar maturity index ($I_{3M}$) and to compare this method to the Demirjian’s stages already applied in the forensic community for dental age assessment.

**Material and methods**

**Sample**

To assess the cut-off points through the $I_{2M}$ 633 orthopantomographs (270 females and 363 males) were selected between 7 and 17 year olds and to assess the cut off points through the $I_{3M}$ we selected 471 orthopantomographs (253 females and 218 males) between 10 and 23 years old (Table 1). The samples were taken as a random basis from the X-ray database of the Stomatology Department at Hospital Santa Maria, targeting patients from the Lisbon North University Hospital Center.

Selection criteria were healthy subjects of Portuguese origin, presence of the second and third molar in all lower quadrants, absence of congenital dental anomalies in shape or/and position, including root canal treatment, caries or restorations in the left mandibular permanent teeth. Heavily rotated, impacted, and unclear orthopantomographs were excluded from the analysis.

| Age (years) | Dob (godine) | Sample for $I_{2M}$ | Uzorak za $I_{2M}$ | Sample for $I_{3M}$ | Uzorak za $I_{3M}$ |
|-------------|--------------|---------------------|--------------------|--------------------|---------------------|
| 7           | 38           | 25                  | 63                 | -                  | -                   |
| 8           | 48           | 36                  | 84                 | -                  | -                   |
| 9           | 60           | 41                  | 101                | -                  | -                   |
| 10          | 54           | 39                  | 93                 | 26                 | 35                  |
| 11          | 45           | 29                  | 74                 | 23                 | 37                  |
| 12          | 35           | 38                  | 73                 | 22                 | 30                  |
| 13          | 28           | 22                  | 50                 | 27                 | 19                  |
| 14          | 23           | 17                  | 40                 | 23                 | 24                  |
| 15          | 7            | 6                   | 13                 | 16                 | 13                  |
| 16          | 8            | 10                  | 18                 | 13                 | 13                  |
| 17          | 17           | 7                   | 24                 | 8                  | 22                  |
| 18          |              | -                   | -                  | 10                 | 9                   |
| 19          |              | -                   | -                  | 15                 | 13                  |
| 20          |              | -                   | -                  | 11                 | 5                   |
| 21          |              | -                   | -                  | 10                 | 10                  |
| 22          |              | 8                   | -                  | 13                 | 21                  |
| 23          |              | -                   | -                  | 6                  | 10                  |
| Total       | 363          | 270                 | 633                | 218                | 253                 |

**Materijal i metode**

**Uzorak**

Da bismo odredili granične točke s pomoću $I_{2M}$, odabrali smo 633 ortopantomograma (270 uzetih od djevojčica i djevojaka i 363 od dječaka i mladića) u dobi od 7 do 17 godina, a da bismo odredili granične točke s pomoću $I_{3M}$ odabrali smo 471 ortopantomogram (253 od djevojčica i djevojaka i 218 od dječaka i mladića) u dobi od 10 do 23 godine (tablica 1.). Uzorak je prikupljen slučajnim obadirom iz baze rendentgenskih snimki Odjela za dentalnu medicinu Bolnice Santa Maria koja prima pacijente u sklopu Sveučilišnoga bolničkog centra Lisabon – Šever.

Kriteriji za odabir bili su zdrave osobe portugalskog podrijetla koje imaju drugi i treći kutnjak u oba donja kvadranta, bez kongenitalnih dentalnih anomalija kad je riječ o obliku i ili položaju zuba, uključujući endodontsko liječenje, karijes i ispune na donjim lijevim zubima. Jako rotirani, impaktirani zubi te mutni i nejasni ortopantomogrami bili su isključeni.
The subject’s sex, date of birth, and the date of the orthopantomography were recorded. The chronological age (CA) for each subject was computed by subtracting the date of the X-rays from the date of birth.

The study was performed in accordance with the ethical standards laid down by Faculty of Dental Medicine, University of Lisbon Health Ethics Committee, under the number 911105 and 911106.

Measurements

As proposed by Cameriere et al. in the original study, the maturity index was assessed as follows: a ratio between the sum of the inner side’s width of the open apices (A1 and A2) in the left and right lower third molar and the tooth's length (L) when more than one root were present, or a ratio between the width of the open apex (A) and the tooth’s length (L1) when a single root was present (18).

X-ray images in JPG format were analyzed by a software program, ImageJ®. The orthopantomographs were scaled at 400% and afterwards the measurement was changed from pixels to millimeters.

Mineralization of permanent teeth on the lower left mandible was also assessed according to the Demirjian (14) classification for later comparison with Cameriere’s molar maturity index.

Statistical analysis

The intra-class correlation coefficient (ICC) was applied to quantify intra- and inter-observer agreement. Weighted Cohen’s kappa was used to evaluate intra and inter-observer agreement in Demirjian’s stages classification. Spearman ρ rank correlation was also used to evaluate the order relation between two measurements. For this purpose, 10% of the sample was randomly selected 3 months following the initial scoring process to determine percentage of agreement, for both intra- and inter-observer agreement analyses.

Apart from the accuracy, the sensitivity and the specificity, other measures to assess misclassification were computed, such as the positive predictive value (PPV), the negative predictive value (NPV), and the positive and negative likelihood ratios (LR+ and LR−). Moreover, the post-test probabilities (Bayes PTP) were computed using Bayes’s theorem in order to generalize the results of the Portuguese population, using data extracted from the Statistics Portugal data base (https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_main), (11).

Finally, the Receiver Operating Characteristic (ROC) curves were obtained and the areas under the ROC curves (AUC) were computed.

Results

The results of Cohen’s kappa and ICC for second molar are showed in Tables 2 and 3. Intra-observer validation for $I_{2M}$ varies between 0.608 and 0.943. The weighted Cohen’s kappa for intra-observer validation of Demirjian stadiums is equal to 0.834. In terms of inter-observer validation, kappa coefficients were equal to 0.834 and to 1.000. The computed Spearman correlations have values greater than 0.95. Thus, bilježili su se spol, datum rođenja te datum snimke. Kronološka dob (CA) svakog ispitanika izračunata je oduzimanjem datuma rođenja od datuma snimke.

Istraživanje je provedeno u skladu sa standardima Etičkoga povjerenstva Fakulteta dentalne medicine Sveučilišta u Lisabonu (pod brojevima 911105 i 911106).

Mjerenja

Kao što su predložili Cameriere i suradnici u izvornom istraživanju, indeks zrelosti procjenjuje se na sljedeći način: ako zub ima više od jednog korijena, mjeri se omjer između zbroja dužina unutarnjih strana otvorenih apekse (A1 i A2) na lijevom i desnom donjem trećem molaru i dužine zuba (L), a ako postoji samo jedan korijen, mjeri se omjer između širine otvorenog apekse (A) i dužine zuba (L1) (18).

Rendgenske snimke u JPG formatu analizirane su u programu ImageJ. Ortopantomogrami su povećani na 400% te su mjerenja poslije izmijenjena iz piksela u milimetre.

Mineralizacija trajnih zuba u lijevom dijelu donje čelične procijenjena je Demirjjanovom (14) klasifikacijom za kasniju usporedbu s Camerierijeovim indeksom zrelosti molara.

Statistička analiza

Intraklasi koeficijent korelacije (ICC) primijenjen je da bi se kvantificiralo podudaranje mjerenja i mjeritelja. Cohenov kappa korišten je za mjerenje podudaranja kod klasifikacije Demirjjanovih stupnjeva. Korelacija Spearmanova ρ rangi upotrijebljena je za procjenu reda odnosa između dva mjerenja. U tu svrhu je 10 % uzorka ponovno izmjereno nakon tri mjeseca kako bi se odredio postotak podudaranja unutar ispitivača i između ispitivača.

Osim točnosti, osjetljivosti i specifičnosti izračunate su i druge vrijednosti procjene pogrešne klasifikacije kao što su površina predvida vrijednost (PPV), negativna predvida vrijednost (NPV) te pozitivni i negativni omjer sličnosti (LR+ i LR−). Nadalje, vjerojatnosti post-testa (Bayes PTP) izračunate su s pomoću Bayesova teorema (11) kako bi se generalizirali rezultati za portugalsku populaciju korištenjem podataka iz statističke baze podataka Portugala (https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_main).

Na kraju su dobivene krivulje karakteristika operativnog primatelja (ROC) te je izračunata vrijednost područja ispod ROC-a (AUC).

Rezultati

Rezultati Cohenova kappa indeksa i ICC za drugi molar prikazani su u tablicama 2 i 3. Validacija vrijednosti za ispitivača za $I_{2M}$ varira od 0,608 do 0,943. Cohenov kappa za validaciju između mjerenja Demirjjanovih stupnjeva iznosio je 0,834. Kad je riječ o validaciji između mjeritelja, kappa koeficijenti iznosili su 0,834 i 1,000. Izračunate Spearmanove korelacije imale su vrijednosti veće od 0,95. Zato nam po-
the obtained values denote, in most cases, excellent results both in precision and in reproducibility.

On the other hand, for the third molars, the results of Cohen's kappa and ICC are showed in Tables 4 and 5. The intra-observer validation for $I_{3M}$ varies between 0.852 and 0.998 for observer 1 and between 0.966 and 0.996 for observer 2. The inter observer validation varies between 0.964 and 0.999. The weighted Cohen's kappa for intra-observer validation of Demirjian stadiums was 0.969, while intra-observer varies between 0.919 and 0.930. All values showed excellent results regarding precision and repeatability.

The Spearman's correlation was used to understand the relationship between chronological age and $I_{2M}$ and Demirjian's dental age.
Figure 1 Measurement of second molar index, according to the molar index proposed by Cameriere

Slika 1. Mjerenje indeksa drugog molara prema molarnom indeksu koji je predložio Cameriere

Figure 2 Measurement of the third molar index, according to the third molar index proposed by Cameriere

Slika 2. Mjerenje indeksa trećeg molarara prema molarnom indeksu koji je predložio Cameriere

Figure 3 ROC curves for $I_{2M}$ (osjetljivost, 1 – specifičnost)

Slika 3. ROC krivulje za $I_{2M}$ (osjetljivost, 1 – specifičnost)

Figure 4 ROC curves for $I_{3M}$

Slika 4. ROC krivulje za $I_{3M}$ (osjetljivost, 1 – specifičnost)
The correlation between the real age and the \( I_{2M} \) was 0.875, whereas with the Demirjian stadiums it was 0.861. Thus, both reveal a significant order relationship with chronological age. For the third molar, the Spearman correlation between real age and \( I_{3M} \) was 0.902, and the correlation between chronological age and Demirjian stadiums was 0.902, showing that both methods are equally reliable.

Based on the maturity indices and Demirjian stages, it was intended to classify a person as under 12-year-old or at least 12 year-old, as well as classify him/her as under 14-year-old or at least 14-year-old. To perform these classifications, the cut-off points for \( I_{2M} \) and for the \( I_{3M} \) were computed using a binary logistic regression, minimizing the occurrence of incorrect classification.

### Table 6

|                      | 12 years • 12 godina | Demirjian (G, H) |
|----------------------|----------------------|------------------|
| Sensitivity • Ojjetljivost | 81.19% | 88.53% |
| Specificity • Specifičnost | 90.36% | 85.30% |
| Accuracy • Točnost | 87.20% | 86.41% |
| PPV | 81.57% | 75.98% |
| NPV | 90.14% | 93.40% |
| LR+ | 8.42 | 6.02 |
| LR- | 0.21 | 0.13 |
| Bayes PTP | 91.57% | 88.60% |
| AUC | 0.93 | - |

### Table 7

|                      | 12 years • 14 godina | Demirjian (H) |
|----------------------|----------------------|----------------|
| Sensitivity • Ojjetljivost | 90.53% | 90.53% |
| Specificity • Specifičnost | 90.15% | 90.15% |
| Accuracy • Točnost | 90.21% | 90.21% |
| PPV | 61.87% | 61.87% |
| NPV | 98.18% | 98.18% |
| LR+ | 9.19 | 9.19 |
| LR- | 0.11 | 0.11 |
| Bayes PTP | 85.07% | 85.07% |
| AUC | 0.938 | - |

### Table 8

|                      | 14 years • 14 godina | Demirjian (D, E, F, G, H) |
|----------------------|----------------------|---------------------------|
| Sensitivity • Ojjetljivost | 93.98% | 94.56% |
| Specificity • Specifičnost | 74.38% | 80.99% |
| Accuracy • Točnost | 88.94% | 91.06% |
| PPV | 91.36% | 93.48% |
| NPV | 81.08% | 83.76% |
| LR+ | 3.67 | 4.97 |
| LR- | 0.08 | 0.07 |
| Bayes PTP | 96.00% | 97.02% |
| AUC | 0.959 | - |

### Table 9

|                      | 14 years • 14 godina | Demirjian (E, F, G, H) |
|----------------------|----------------------|------------------------|
| Sensitivity • Ojjetljivost | 86.85% | 88.25% |
| Specificity • Specifičnost | 88.13% | 92.69% |
| Accuracy • Točnost | 87.45% | 89.96% |
| PPV | 89.34% | 95.06% |
| NPV | 85.40% | 83.20% |
| LR+ | 7.32 | 12.08 |
| LR- | 0.15 | 0.13 |
| Bayes PTP | 95.26% | 97.07% |
| AUC | 0.95 | - |
ing binary logistic regression, minimizing the occurrence of misclassifications. For the Demirjian stadiums, the individuals were classified using the most similar age group for each stage since all individuals in the same stadium are classified in the same age group. In these procedures, the sex variable was used as an explanatory variable, but Wald’s test shows that this explanatory variable should be removed from the model (in all cases the p-value was greater than 0.05). Therefore, all results obtained measured the entire sample without distinguishing males from females.

The reliability measures of these classifications are shown in Table 6 for the second molar and in Table 7 for the third molar. Figure 3 shows the ROC curves for I2M and Figure 4 shows the ROC curves for I3M.

**Discussion**

Over the years, estimating age through dental methods has become crucial in the juvenile criminal justice. For that same reason, several studies have been conducted over the years to estimate the age accurately, mainly by considering the population affinity.

In this present study, the first one for the Portuguese legal age thresholds of 12 and 14 year-olds, we tested the discriminatory potential of a specific cut-off value of I2M and I3M in discriminating children aged 12 and 14. Secondly, we compared those quantitative dental age assessment methods with the qualitative dental age assessment method, the Demirjian classification, which has already been used in the Portuguese population.

The intra and inter-observer results (Tables 2 to 5) mostly represent excellent results both on precision and on reproducibility for the I2M, I3M and Demirjian’s stadiums, which is consistent with the existing literature regarding both methods (1,19-22).

Spearman’s correlation results show that all methods (I2M, I3M and Demirjian’s stadiums from the second and the third molar) reveal significant correlation with real age, which is consistent with the available literature (2,23).

In Portugal, the legal ages of 12 and 14 years are covered in the Portuguese penal code which promotes the protection of the juvenile individuals, giving priority to healing and prevention over punishment. Consequently, the determination of the cut-off points is very important in order to determine if an individual is younger than 12 or 14 years, or at least if the individual is 12 or 14-year-old (6). Regarding the cut-off points for 12 year olds (I2M = 1.133 and I3M = 0.135), I3M shows better sensitivity (93.98%) but lower specificity (74.38%) than I2M (sensitivity = 81.19% and specificity = 90.36%). For the Portuguese cut-off points for 14-year-olds (I2M = 0.001 and I3M = 0.705), I3M has higher values of sensitivity and specificity (90.53% and 90.15%) than I2M (sensitivity = 86.85% and specificity = 88.13%). The results of our study are consistent with the results obtained by Cameriere in 2018 (13). Although, the area under the ROC curve of I3M for both ages (AUC 12 years = 0.959 and AUC 14 years = 0.95) is greater than the area under the ROC curve of I2M (AUC 12 years = 0.93 and AUC 14 years = 0.938), both...
indexes obtain excellent results for the area under the ROC curve (greater than 0.9), (24).

The accuracy is measured under the ROC curve. The area of 1 represents a perfect method. The area measures discrimination, that is, the ability of the method to correctly classify those who are, or are not, 12 and 14-year-old (24). Hence, the areas under the ROC curves obtained in this study for 12- and 14-year-olds reveal that the use of I<sub>3M</sub> and I<sub>2M</sub> is a suitable methodology to classify the age of the analyzed individuals. However, when compared I<sub>2M</sub> to I<sub>3M</sub>, the latter shows better results regarding age estimation. The value of AUC obtained in this study is higher than in other studies (13,25).

The sensitivity obtained by Cameriere and Ferrante using dental age assessment by the 7 teeth regression, bone age assessment by hand-wrist bones or using the combination of both, biological indicators for the cut points of 12 and 14-year-olds were lower than the sensitivity obtained for the cut-points using only the dental parameters I<sub>2M</sub> or I<sub>3M</sub> for the Portuguese population (20). This means that it is better to use only dental age assessment for these Portuguese legal ages. The Bayes post-test probabilities with highest value were obtained using only the I<sub>3M</sub> for the cut points determining for the legal age threshold 12-year-old (Bayes PTP = 96%) and 14-year-old (Bayes PTP = 95,26%). Bayes post-test probability of being 12 and 14-year-old is computed to discriminate between those who are not 12-year-old and 14-year-old or over 14. Accurate age estimation is crucial to ensure that children and adolescents are identified and treated adequately in the Portuguese criminal field.

For the I<sub>2M</sub> results, there are no studies to sustain the results regarding the cut-off point for 12-year-olds. Nevertheless, the obtained results are very reasonable. For the cut-off point for the 14-year-olds, some studies assume I<sub>2M</sub> = 0 which is equal to the cut-off point obtained in this study by the binary logistic regression (the only cases in which I<sub>2M</sub> < 0.001 were I<sub>2M</sub> = 0). Thus, the reliability measures are similar to the ones obtained in those studies (2,13,26).

When comparing the Demirjian with Cameriere method, the results are quite similar. For 14-year-olds using the second molar, the results are identical because all individuals have obtained the same age classification in both methods since I<sub>2M</sub> = 0 implies Demirjian stadium equals to H. However, Cameriere’s method is better because the age group classification is based on a quantitative variable and, consequently, the cut-off point can be adjusted to improve one measure in relation to another (sensitivity or specificity), whereas this is not possible if Demirjian stadium is used.

Conclusions

This is the first study in Portugal to validate the reliability and the medico-legal application of I<sub>2M</sub> and I<sub>3M</sub> for the legal thresholds ages 12 and 14 years in the Portuguese population. Regarding our results for the cut-off points for Portuguese population for the 12-year-olds, I<sub>3M</sub> is better and for 14-year-olds, I<sub>1M</sub> has performed better. When comparing the age classification by I<sub>2M</sub> or I<sub>3M</sub> and the Demirjian stages, it is possible to conclude that there are no significant differenc-

st 1 savršena je metoda. Mjeri diskriminaciju, odnosno mogućnost metode da ispravno klasificira one koji imaju ili ne maju 12, odnosno 14 godina (24). Zato podrucje ispod ROC krivulje u ovom istraživanju za 12-godišnjake i 14-godišnjake pokazuje da je upotreba I<sub>2M</sub> i I<sub>3M</sub> prikladna metodologija za klasifikaciju dobi analiziranih pojedinaca. No, ako se usporede I<sub>2M</sub> i I<sub>3M</sub>, ovaj posljednji pokazuje bolje rezultate kad je riječ o procjeni dobi. Vrijednost AUC-a dobivena u ovom istraživanju viša je negoli u ranijim istraživanjima (13, 25).

Osjetljivost koju su Cameriere i Ferrante dobili s pomoću dentalne procjene dobi regresijom 7 zuba na temelju koštane procjene kostiju ručnih zglobova ili kombinacijom bila je niža od one dobivene korištenjem samo dentalnih parametroa I<sub>3M</sub> i I<sub>2M</sub> za granične točke 12-godišnjaka i 14-godišnjaka u portugalskoj populaciji (20). To znači da je u Portugalu bolje koristiti se samo dentalnom procjenom dobi za te razine. Bayesove post-testne vjerojatnosti s najvišim vrijednostima dobivene su korištenjem samo I<sub>3M</sub> graničnih točaka za određivanje razine kod 12-godišnjaka (Bayes PTP = 96%) i 14-godišnjaka (Bayes PTP = 95,26%). Bayesova post-test vjerojatnost za dob od 12 i 14 godina računa se da bi se razlikovali oni koji nemaju 12 ili 14 godina, ili imaju više od 14 godina. Precizna procjena dobi ključna je za sigurnu identifikaciju djece i adolescenta koje je potrebno liječiti u sklopu portugalskog zakona.

Za rezultate I<sub>3M</sub> nema istraživanja koja bi poduprla granične točke za 12-godišnjake. No, dobiveni rezultati bili su prihvatljivi. Za graničnu točku 14-godišnjaka u nekim se istraživanjima pretpostavlja da je I<sub>2M</sub> = 0, što je jednako graničnoj točci dobivenoj u ovom istraživanju binarnom logističkom regresijom (jedini slučajevi kod kojih je I<sub>3M</sub> < 0,001 bili su I<sub>2M</sub> = 0). Zato je pouzdanost mjera slična onima koje su dobivene u drugim istraživanjima (2, 13, 26).

Usporedujući Demirjianovu i Cameriereovu metodu, rezultati su bili prilično slični. Za 14-godišnjake je upotreba drugog molara dala identične rezultate jer su svi pojedinci dobili istu dobru klasifikaciju u objema metodama, zato što I<sub>2M</sub> = 0 implicira Demirjianov stupanj H. No, Camerierovu metodu je bolja jer je grupna klasifikacija dobi utemeljena na kvantitativnoj varijabli, a posljedično granična točka može biti prilagođena kako bi poboljšala jedno mjerenje u odnosu prema drugom (osjetljivost ili specifičnost), no to nije moguće pri primjeni Demirjianove metode stupnjeva.

Zaklučak

Ovo je prvo istraživanje u Portugalu kojim se potvrđuje pouzdanost i medicinsko-pravna primjena I<sub>2M</sub> i I<sub>3M</sub> razina za dobi od 12 i 14 godina. Kad je riječ o našim rezultatima i graničnim točkama za portugalsku populaciju, čini se da je I<sub>3M</sub> bolji za određivanje granične točke 12-godišnjaka, a I<sub>2M</sub> za 14-godišnjake. U uspoređivanju dobne klasifikacije I<sub>2M</sub> i I<sub>3M</sub> i Demirjianovih stupnjeva, može se zaključiti da između tih metoda nema značajnih razlika u preciznosti. No, upotre-
es between the precision obtained by these methods. However, the use of \( I_{2M} \) and \( I_{3M} \) allows us to vary the cut-off value to privilege sensitivities or specificity, depending on which is more appropriate to the intended application. Thus, the \( I_{2M} \) and \( I_{3M} \) indexes provide reliable classification by each Portuguese legal age threshold of 12 and 14 year-olds. In medicolegal circumstances, a successful discrimination method must produce a smaller number of false positives than false negatives in order to legally protect the children’s rights.

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Conflict of Interest Statement

All authors declare no conflict of interest.

Ethical approval

This study was performed, approved and realized in accordance with the ethical standards specified by the Health Ethics Committee of the Faculty of Dental Medicine, University of Lisbon, Lisbon, Portugal.

Informed Consent

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No informed consent was obtained since this was a retrospective study based on anonymized clinical records.

Author’s contribution: C. P. P. – Supervision, Conceptualization, Project Administration, Methodology, Validation, Formal Analysis, Investigation, Data curation, Writing-Review and Editing, Visualization, Researcher of research center with support Grant from the government; R. S. – Methodology, Validation, Formal Analysis, Investigation, Data curation, Writing-Review and Editing, Visualization, Researcher of research center with support Grant from the government; F. S. – Investigation, Resources, Writing - Review & Editing; R.C. – Investigation, Methodology, Writing - Review & Editing; D. A. – Investigation, Validation, Writing - Original Draft. She is a master student of master’s degree of Faculty of Dental Medicine, University of Lisbon; A.R. – Investigation, Validation, Writing - Original Draft. She is a master student of master’s degree of Faculty of Dental Medicine, University of Lisbon.

Zahvale

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Izjava o sukobu interesa

Autori nisu bili u sukobu interesa.

Etičko odobrenje

Istraživanje je provedeno, odobreno i realizirano u skladu s etičkim standardima Zdravstvenoga etičkog povjerenstva Fakulteta dentalne medicine Sveučilišta u Lisabonu, Portugal.

Informirani pristanak

Svi provedeni postupci koji kao sudionike uključuju ljudi bili su u skladu s etičkim standardima institucionalnih ili nacionalnih istraživačkih povjerenstava te s Helsinškom deklaracijom iz 1964. godine i njezinim kasnijim dodatcima, ili usporedivim etičkim standardima. Nisu traženi informirani pristanak zato što se radilo o retrospektivnom istraživanju na anonimnim kliničkim podacima.

Doprinos autora: C. P. P. – nadzor, konceptualizacija, administracija projekta, metodologija, validacija, formalna analiza, istraživanje, briga o podatcima, pregledavanje rukopisa i njegovo uređivanje, vizualizacija, istraživač s financijskom potporom vlade; R. S. – metodologija, validacija, formalna analiza, istraživanje, briga o podatcima, pregledavanje rukopisa i njegovo uređivanje, vizualizacija, istraživač s financijskom potporom vlade; F. S. – istraživanje, resursi, pregledavanje rukopisa i njegovo uređivanje; R.C. – istraživanje, metodologija, pregledavanje rukopisa i njegovo uređivanje; D. A. – istraživanje, validacija, pisanje izvornog teksta (poslijediplomski student na Fakultetu dentalne medicine Sveučilišta u Lisabonu); A.R. – istraživanje, validacija, pisanje izvornog teksta (poslijediplomski student na Fakultetu dentalne medicine Sveučilišta u Lisabonu).
**Sažetak**

Cilj: Bolje razumijevanje dentalne procjene dobi moglo bi pomoći pri procjeni dobi u kliničkoj forenzičkoj stomatologiji. Uzimajući u obzir ključne informacije o pouzdanosti metode za određivanje vremenskih granica izražava čiju bi se koristila odgovarajuća metodologija s pouzdanom indeksom drugog molara (I₂M) te indeksa trećeg molara (I₃M) kako bi se već primijenjivao u kliničkoj forenzičkoj stomatologiji. Međutim, za ovu svrhu korištena je metoda koja se već primijenjivao u kliničkoj forenzičkoj stomatologiji. **Materijal i metode:** Za ovu svrhu koristi osećaj za za I₃M određivanih djece i mladića od 10 do 23 godine. Svi su uzeti iz baze podataka Sveučilišnog kliničkog centra Lišabon – Sjever, a njihovu upotrebu odobrilo je Etičko povjerenstvo. **Rezultati:** Granična točka I₃M za 12-godišnjake (1,133) dala je bolje rezultate od one za I₂M. Nadalje, granična točka I₂M za 14-godišnjake (0,001) pokazala je bolje rezultate od granične točke I₃M (0,705). Obje su metode pouzdanije za određivanje dobi od 12 do 14 godina prema zakonu. No, korištenje I₂M/I₃M omogućuje ponižanje granične vrijednosti zbog osjetljivosti ili specifičnosti, ovisno o adekvatnoj primjeni. **Zaključak:** Točnost I₂M (88,94 %) davala je bolje rezultate kada se određivala granična vrijednost 12-godišnjaka (1,133), a točnost I₃M (90,21 %) bila je bolja u slučaju 14-godišnjaka (0,001).

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**Adresa za dopisivanje**  
Cristiana Palmeira Pereira, prof. u trajnom zvajanju  
Sveučilište u Lisabonu  
Fakultet dentinalne medicine  
Centar za statistiku i primjenu  
Sveučilišta u Lisabonu (CEAUL)  
Istraživačka zadužena za skupinu FORENEMED u UICOB-U  
cristiana.pereira@fmd.ulisboa.pt

**MeSH pojmovi:** određivanje dobi s pomoću zuba; forenzička stomatologija; kutnjak; adolescent

**Autorske ključne riječi:** dentalna procjena dobi, Cameriereov I₂M/I₃M, Demirjianov model, portugalski Kazneno zakon, 12-godišnjaci, 14-godišnjaci

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