Forensic Anthropology Population Data

Age of majority assessment in Dutch individuals based on Cameriere's third molar maturity index

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A B S T R A C T

Radiological examination of the third molar is done in living individuals for estimation of chronological age, especially in the late adolescence. The aim of this study was to assess the application of Cameriere's third molar maturity index (I₃M) to determine whether an individual is 18 years or older (adult) or younger than 18 years (minor) in a sample of Dutch individuals. The sample consisted of panoramic images of 360 individuals aged between 14 and 22 years old. Three observers performed the measurements. Gender was not statistically significant in discriminating adults and minors. The highest value of the Youden index of the receiver operating curve analysis was for the value of I₃M $< 0.08$ in discriminating individuals as minor or adult. The specificity (Sp) and sensitivity (Se) results for females were 96.3% and 72.7% respectively. The Sp and Se for males were 95.0% and 84.0% respectively. The probabilities of correctly classified individuals were 83.3% and 88.5%, and Bayes post-test probability was 96.3% and 95.7% in females and males respectively. Obtained results showed that the specific cut-off point of I₃M $< 0.08$ may be a useful and reliable method for adult age assessment in a Dutch population.

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1. Introduction

Age estimation of living individuals is increasingly important nowadays. Age plays a pivotal role in cases related to irregular immigration and asylum seekers. Age estimation is needed when identification documents such as passports or birth certificates are missing. Age estimation may be described as the determination of an individual's chronological age, based on biological characteristics. Many radiological skeletal and dental age estimation methods have been presented in the literature. The Study Group on Forensic Age Diagnostics (AGFAD) recommended a physical examination and X-ray examinations of the left hand and the dentition for age estimation in living individuals [1,2].

In many countries, 18 years is the age at which an individual will be held responsible for his/her actions (the legal age of majority). The definition of a child is in keeping with that of the Article 1:233 of the Dutch Civil Code, “Minors are persons who have not reached the age of eighteen years and are not and have never been married and have not been declared adult by the application of article 253 ha” [3]. Determining whether a person is older or younger than 18 years old is one of the important issues for many legal cases.

Around this critical age, the third molars are the latest teeth in the development and eruption process. Other permanent teeth finish their development up to the age of 14 years while third molars maturate up to the age of 22 years [4,5]. The third molars can be evaluated easily from dental panoramic radiographs. Most studies have evaluated third molar tooth development by scoring the stage of its calcification and eruption [6]. Different staging systems were used for this purpose [7–9]. Previous studies showed that third molar development differs in various populations, so it is recommended to verify the application of these techniques in different populations [10,11].

Cameriere et al. [12] showed a method to evaluate the third molar development based on tooth dimensions. This method uses the third molar maturity index (I₃M), which is the ratio between the lengths of open apices measurements and tooth length.
measurements. According to this method, a cut-off value for determining the age of 18 years was reported to be a value of $I_{\text{3M}} < 0.08$. Other researchers validated this cut-off value on different populations such as Italian, Croatian, Serbian, Albanian, Turkish, Brazilian, Colombian, Libyan, Saudi, Botswana and Peruvian [13–23].

The aim of this study was to apply the Cameriere's third molar maturity index method in a sample of Dutch young individuals to make a distinction between adults and minors.

2. Materials and methods

Panoramic radiographs (OPTs) were randomly selected from the digital archive of the Department of Oral Radiology, Academic Centre for Dentistry (ACTA) at the University of Amsterdam and the Vrije Universiteit, Amsterdam, The Netherlands. The reasons for the OPTs used in this study were related to different clinical purposes. This study was conducted by the provisions of ethical standards set by the Declaration of Helsinki (Finland) [24]. Each OPT was separately recorded in an Excel file, including RANK number, gender, date of birth and date of the OPT. Real age in years was calculated as the difference between the date of the OPT and the date of birth. The inclusion criteria for retrieving the sample for the analysis were: technically good-quality OPT, age between 14 and 22 years, no evidence of hereditary or systematic diseases which can affect the dental and skeletal development. Exclusion criteria were: missing data on birth, agenesis of any permanent teeth including all four third molars, extracted or rotated third molars.

Before the analysis, all OPTs were anonymized, numbered and recorded in tagged image file (TIFF) format. Since the development of right and left teeth is strongly correlated, only third molars from the left side of the mandible were evaluated [25]. Measurements were performed using a freeware image processing program (Image 1.50n, National Institutes of Health, Bethesda, MD, USA) which also allowed to make an adjustment of grayscale, brightness, and contrast. The projections of open apices, $A_{0} = (A_{01} + A_{02})$ and heights, $L_{8}$ of third molars were measured and recorded (Fig. 1) and third molar maturity index ($I_{\text{3M}}$) was calculated as the ratio of the measurements of open apices and heights or $I_{\text{3M}} = A_{0}/L_{8}$. $I_{\text{3M}}$ is evaluated in a similar way as described for the first and second lower molars in Cameriere et al. [12]. Additionally, if the development of the root of the third molar was completed, then $I_{\text{3M}} = 0.0$ was recorded. Two dentomaxillofacial radiologists and a pediatric dentist evaluated the OPTs separately. The measurements were performed using a blind approach; observers were not able to detect identification, age or sex of the individuals. Each of three observers performed all measurements of the whole sample. Each observer evaluated 80 randomly selected OPTs two weeks after the first measurements. The intraclass correlation coefficient (ICC) was calculated to assess inter-rater and intra-rater agreement of $I_{\text{3M}}$ [26]. The mean values of $I_{\text{3M}}$ from all three observers were used for analysis. The dependent variable, age, was transformed to a binary response variable; ($E = 1$) if age $\geq 18$ years or adult, and ($E = 0$) if age $< 18$ years or minor. A binary logistic of Generalized Linear Model (GLM) was performed to test the significance of the variables $I_{\text{3M}}$ and sex on the binary answer whether an individual is an adult ($E = 1$) or a minor ($E = 0$). Additionally, a receiver operating curve (ROC) analysis was performed to test the best performance of specific cut-off values of $I_{\text{3M}}$ to discriminate adults and minors. The best performance of discrimination was set based on the highest value of Youden index ($J$) which is a summary measure of ROC curve [27].

2.1. Statistical analysis

A performance of the specific cut-off value of $I_{\text{3M}}$ to discriminate adults and minors will be evaluated for each gender separately by two-by-two contingency tables (CT).

The Accuracy (Acc), Sensitivity (Se) and Specificity (Sp) will be calculated. Sensitivity indicates the ability to correctly determine individuals who are adults, whereas specificity indicates the ability to determine individuals who are minor correctly. The positive likelihood ratio (LR+) and negative likelihood ratio (LR−) will also be calculated. The LR+ shows how much the probability of a being adult increases if the test is positive, while the LR− shows how much the probability of a being adult decreases if the test is negative. Values of LR+ between 2−5 correspond to a small increase, 5−10 present moderate; while over 10 present a large and often absolute increase in the likelihood of being an adult. LR− between 0.2 and 0.5 means a small, 0.2 and 0.1 means a moderate decrease in the probability of being an adult, while under 0.1 corresponds to a large and often conclusive reduction in the likelihood of being an adult [28].

The post-test probability, $p$, of being 18 years of age or older can help to discriminate between those individuals who are 18 and over and under 18.

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

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

where $p$ is Bayes post-test probability (Bayes PTP), and $p_0$ is the probability that the individual in question is 18 years old or older, given that he or she is aged between 14 and 22 years, which represent the target population. Probability $p_0$ was calculated as the proportion of Dutch between 18 and 22 years of age who live in the Netherlands according to demographic data from the 2011 census and those between 14 and 22 years which was evaluated from data from the same web source. This proportion was considered to be 0.572 for females and 0.568 for males. Statistical analysis was performed by IBM SPSS 16.0 software program (IBM SPSS Statistics, Armonk, NY). The significance was set at $p < 0.05$.

3. Results

The final sample consisted of 360 OPTs. Table 1 summarizes the age and gender characteristics of the sample. The inter-rater agreement of the measurements done by three different observers

![Fig. 1. An example of measurements of the projections of two roots ($A_{01}$ + $A_{02}$) and height ($L_{8}$) of the third molar.](image-url)
was 0.968 (95%CI, 0.962–0.973) while intra-rater agreements of three observers were 0.859 (95%CI, 0.789–0.908), 0.991 (95%CI, 0.993–0.997) and 0.978 (95%CI, 0.966–0.986) respectively. The results of ICC showed excellent results both on the precision and the repeatability of the variable $I_{3M}$.

Table 2 shows the results of the logistic regression analysis. While $I_{3M}$ was significantly associated with being adult or minor, the effect of the gender was not statistically significant. Our analysis for the Dutch sample showed that the highest value of the Youden index, $J=0.75$, was for the $I_{3M}<0.08$, and the sensitivity and specificity at this cut-off value were 79.4% and 95.7% respectively. Fig. 1. Results of the sensitivity, specificity and Youden index for the cohort of $I_{3M}$ are shown in electronic Supplementary materials, Table S1. Fig. 2 shows the ROC analysis of $I_{3M}$ for discriminating adults and minors.

As the logistic regression analysis confirmed the best performance of specific cut-off value $I_{3M}<0.08$ to discriminate adults and minors, we evaluated the performance of cut-off value $I_{3M}<0.08$ on the same sample, for each gender separately, by two-by-two contingency tables (CT). CTs list the first row the results of those who are $\geq 18$ years and have $I_{3M}<0.08$ (true positives, TP), than those who are $<18$ and have $I_{3M}<0.08$ (false positives, FP). In the second row CT list those who are $\geq 18$ years and have $I_{3M}\geq 0.08$ (false negatives, FN) and finally those who are $<18$ and have $I_{3M}\geq 0.08$ (true negatives, TN).

We also evaluated the real age in relation to $I_{3M}$. Fig. 3 shows that $I_{3M}$ decreased while real age increased. Table 3 shows age distribution according to $I_{3M}$ classes and gender. The mean ages across all $I_{3M}$ classes were lower in males without a statistically significant difference which indicates a somewhat faster matura-
tion of the lower third molars in males.

Table 4 presents a cross-tabulation of the performance of the cut-off value of $I_{3M}<0.08$ by gender and Table 5 demonstrates the values of Acc, Sp, Se, LR+, LR− and Bayes PTP. In the female group, 150 out of 180 individuals were accurately classified. Sensitivity of the method was 72.7% (95%CI, 67.6–75.0%) and the specificity of the method was 96.3% (95%CI, 90.0–99.0%). LR+ was 19.64 (95% CI, 6.78–76.28) and LR− was 0.28 (95% CI, 0.25–0.36). Bayes PTP was 96.3% (95% CI, 89.1–100.0%). The error rate in selecting adult and minor females was the highest in the 18 years old, 74% were selected as minors following those in the 19 years group where 55% were wrongly selected, Table 6.

In the male group, 160 out of 180 individuals were accurately classified. Sensitivity of the method was 84.0% (95% CI, 78.9–86.6%) selected as minors following those in the 19 years group where 55% were wrongly selected, Table 6.

Table 2 Parameter estimates of the third molar maturity index ($I_{3M}$) and gender (g) and adult age ($\geq18$ years) as dependent variable on Binary Logistic of Generalized Linear Model (GLM).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>B</th>
<th>Std. error</th>
<th>95% Wald confidence interval</th>
<th>Hypothesis test</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>-2.344</td>
<td>0.3437</td>
<td>-3.018 to -1.671</td>
<td>46.529, df = 1, Sig. &lt;0.001</td>
</tr>
<tr>
<td>$I_{3M}$</td>
<td>15.236</td>
<td>2.219</td>
<td>10.9 to 19.571</td>
<td>47.442, df = 1, Sig. &lt;0.001</td>
</tr>
<tr>
<td>g</td>
<td>0.343</td>
<td>0.4609</td>
<td>-0.56 to 1.247</td>
<td>0.555, df = 1, Sig. 0.456</td>
</tr>
<tr>
<td>$I_{3M} \times g$</td>
<td>-5.141</td>
<td>2.735</td>
<td>-10.502 to 0.219</td>
<td>3.534, df = 1, Sig. 0.060</td>
</tr>
</tbody>
</table>
and the specificity of the method was 95.0% (95% CI, 88.7–98.3%). LR+ was 16.80 (95% CI, 6.97–51.09) and LR− was 0.17 (95% CI, 0.14–0.24). Bayes PTP was 95.7% (95% CI, 88.4–100.0%). The error rate in discrimination was smaller than in females. The greatest error-rate of 40% was found for the 18 years and 25% for the 19-year-old males, Table 6.

4. Discussion

The major concern of all age estimation methods utilized in legal issues is to preserve the best interest of the minors [29]. There still exists no specific procedure, which can identify the precise age of the young person [30]. There is apprehension about the

Table 3
Summary statistics of chronological age according to sex and third molar maturity index (I3M) classes from the sample of the Netherlands.

<table>
<thead>
<tr>
<th>I3M</th>
<th>Females</th>
<th>Males</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Mean</td>
</tr>
<tr>
<td>0.24</td>
<td>37</td>
<td>15.52</td>
</tr>
<tr>
<td>0.42</td>
<td>30</td>
<td>16.92</td>
</tr>
<tr>
<td>0.28</td>
<td>39</td>
<td>17.75</td>
</tr>
<tr>
<td>0.28</td>
<td>12</td>
<td>19.00</td>
</tr>
<tr>
<td>0.03</td>
<td>62</td>
<td>21.35</td>
</tr>
</tbody>
</table>

Abbreviation: number of individuals (N), mean age within I3M class (Mean), standard deviation of mean age (Sd), minimum value (Min), 1st quartile (Q1), median (Med), 3rd quartile (Q3) and maximum age (Max), independent samples test (t), degrees of freedom (df), significant if <0.05.

Table 4
Contingency table describing discrimination performance of the test for different cut-off values of third molar maturity index (I3M).

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Females</th>
<th>Males</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>72FP</td>
</tr>
<tr>
<td>Test</td>
<td>I3M ≤ 0.08</td>
<td>27PF</td>
</tr>
<tr>
<td>Total</td>
<td>99</td>
<td>81</td>
</tr>
</tbody>
</table>

Abbreviation: true positive (TP), false negative (FN), false positive (FP), true negative (TN).

Table 5
The quantities from 2-by-2 contingency tables (95% confidence interval) to test the age of majority in the sample from the Netherlands.

<table>
<thead>
<tr>
<th>Quantities</th>
<th>Females</th>
<th>Males</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC</td>
<td>83.3% (95%CI, 77.7–88.5%)</td>
<td>88.9% (95%CI, 83.3–91.8%)</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>72.7% (95%CI, 67.6–75.0%)</td>
<td>84.0% (95%CI, 78.9–86.6%)</td>
</tr>
<tr>
<td>Specificity</td>
<td>96.3% (95%CI, 90.0–99.0%)</td>
<td>95.0% (95%CI, 88.7–98.3%)</td>
</tr>
<tr>
<td>LR+</td>
<td>19.64 (95%CI, 6.78–76.28)</td>
<td>16.80 (95%CI, 6.97–51.09)</td>
</tr>
<tr>
<td>LR−</td>
<td>0.28 (95%CI, 0.25–0.36)</td>
<td>0.17 (95%CI, 0.14–0.24)</td>
</tr>
<tr>
<td>Bayes PTP</td>
<td>96.3% (95%CI, 89.1–100.0%)</td>
<td>95.7% (95%CI, 88.4–100.0%)</td>
</tr>
</tbody>
</table>

Abbreviation: AC, accurate classification; LR+, positive likelihood ratio; LR−, negative likelihood ratio; Bayes PTP, Bayes post-test probability.

Table 6
Number and percentage (%) of correct evaluations/total participants in each age group by using the cut-off value of I3M < 0.08 that subjects are adult or minor.

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Females</th>
<th>Males</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>21/21 (100%)</td>
</tr>
<tr>
<td>14</td>
<td>21/21 (100%)</td>
<td>20/20 (100%)</td>
</tr>
<tr>
<td>15</td>
<td>19/19 (100%)</td>
<td>20/20 (100%)</td>
</tr>
<tr>
<td>16</td>
<td>19/20 (95%)</td>
<td>20/20 (100%)</td>
</tr>
<tr>
<td>17</td>
<td>20/21 (95%)</td>
<td>16/20 (80%)</td>
</tr>
<tr>
<td>18</td>
<td>5/19 (26%)</td>
<td>12/20 (60%)</td>
</tr>
<tr>
<td>19</td>
<td>9/20 (45%)</td>
<td>15/20 (75%)</td>
</tr>
<tr>
<td>20</td>
<td>18/20 (90%)</td>
<td>17/20 (85%)</td>
</tr>
<tr>
<td>21</td>
<td>20/20 (100%)</td>
<td>20/20 (100%)</td>
</tr>
<tr>
<td>22</td>
<td>20/20 (100%)</td>
<td>20/20 (100%)</td>
</tr>
</tbody>
</table>

The results of previous studies on I3M ≤ 0.08 and presented herein showed that, along with being simple and involving a low X-ray dose compared to conventional X-rays of the median
clavicular epiphysis, the method is reliable and could be applied to the Dutch population [31].

Forensic age estimation is required by many governmental agencies, courts and legal procedures because some individuals are not able or don’t want to declare their real age [31]. United Nations International Children’s Emergency Fund reports indicate that in the developing countries only half of the children under five years have their births certificates [45]. Evidence of clear date of birth is an important issue regarding the unaccompanied minors seeking asylum worldwide, particularly in the European Union (EU). In December 2013, the European Asylum Support Office (EASO) released a document entitled “EASO Age Assessment Practice in Europe” [46]. It is evident that usage of the medical examination methods is different in specific countries [46]. For example, the Netherlands use hand-wrist and collar bone X-rays whereas Sweden combines hand-wrist with dental X-rays [46]. Norwegian forensic experts, additionally to the Swedish approach, apply dental observations [46–48]. In 2012 EASO commissioned a questionnaire regarding the common practice of age estimation approaches within EU and some other countries. Responses from 34 countries (i.e., EU member states, Norway, Switzerland, Australia, Canada, New Zealand, and the United States of America) revealed that 17 countries utilize dental X-rays as part of the age assessment process: Austria, Belgium, Denmark, Finland, Germany, Hungary, Iceland, Italy, Latvia, Norway, Poland, Portugal, Sweden, and Romania stated that they combine dental observation with various skeletal and dental X-ray methods [46].

Many changes and more than ten modifications have been made in the Dutch age assessment procedure since its introduction in 1999. An independent supervisory commission, the Age Assessment Commission, was finally set up in 2004 in response to many complaints. Afterward, the responsibility for carrying out the age assessment was transferred to the Dutch Forensic Institute (NFI) which is still the responsible institution in the Netherlands. The age evaluation methodology, used by the Dutch Immigration and Naturalization Service (IND), now involves an X-ray of the left carpals and three X-rays of the medial clavicular epiphyses [49].

An expert group from various scientific disciplines established the Dutch Association of Age Assessment Researchers (DA-AAR). DA-AAR met in 2012 to consider the current approach of age assessment of minor asylum seekers in the Netherlands, and to promote a fair, child-friendly and reliable age evaluation procedure. The researchers criticize the present evaluation methodology that uses clavicle epiphyses. Mainly, posterior-anterior exposure of the clavicle does not allow proper evaluation of the stage of epiphyseal closure, due to the superposition of other skeletal structures in the X-ray image [50]. According to DA-AAR, the current state of age estimation in the Netherlands has major flaws on both methodological and ethical aspects [49].

It is evident that when deciding the age of the asylum seeker, no country makes use of dental examination on its own. However, most of the countries take advantage of additional information from dental radiographs [46]. The third molars are the only permanent teeth in development during the specific age span from late adolescence to early adulthood that may be useful for age estimation and discrimination between adults and minors [21,51].

Validation of Cameriere’s third molar maturation method in various European populations can provide a simple and reliable support of the age estimation process over Europe. Thevisen et al. [52] stated that Cameriere’s technique differs from other methods, because it records continuous data, and it is based on values derived from the relationship between the measurement of the width of open apices and the length of the tooth itself. This advantage offers researchers a chance to collect samples from different sources since the geometric imaging standardization of the X-ray machine when obtaining the radiographs does not affect the measurements. On the other hand, the method depends on the presence of third molars, which may be congenitally absent or surgically removed [14].

According to the results presented in this study, the method based on the third molar maturity index can provide supplemental information for age estimation to distinguish between adult or minor in Dutch individuals.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.jorscint.2017.11.009.

References


