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ACCURACY OF THE THIRD MOLAR INDEX FOR ASSESSING THE LEGAL MAJORITY OF 18 YEARS IN TURKISH POPULATION

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ACCURACY OF THE THIRD MOLAR INDEX FOR ASSESSING THE LEGAL MAJORITY OF 18 YEARS IN TURKISH POPULATION

ABSTRACT

In the last few years, forced and unregistered child marriage has widely increased into Turkey. The aim of this study was to test the accuracy of cut-off value of 0.08 by measurement of third molar index (I_{3M}) in assessing legal adult age of 18 years. Digital panoramic images of 293 Turkish children and young adults (165 girls and 128 boys), aged between 14 and 22 years, were analysed. Age distribution gradually decreases as I_{3M} increases in both girls and boys. For girls, the sensitivity was 85.9% (95% CI 77.1% – 92.8%) and specificity was 100%. The proportion of correctly classified individuals was 92.7%. For boys, the sensitivity was 94.6% (95% CI 88.1% - 99.8%) and specificity was 100%. The proportion of correctly classified individuals was 97.6%. The cut-off value of 0.08 is a useful method to assess if a subject is older than 18 years of age or not.

Keywords

Forensic science, forensic odontology, age estimation, dental age, third molar index, Turkey.

Introduction

The age of majority is the age at which the law considers someone to have reached adulthood and is therefore a full legal citizen whose decisions no longer require the oversight of a parent or guardian [1-3]. In many countries, the age of 18 years represents the legal majority [1,3].

In Turkey, the minimum age of criminal and legal responsibility is 13 years. According to the new Turkish Civil Code, children who are under the age of 13 at the time of the offense and deaf or mute minors who are under the age of 16 at the time of the offense may not be apprehended for any offense [4,5]. If person between age 13 and 16 would be charged with a crime, subject would be tried in the juvenile court. If true juvenile faces the possibility of serving time in a detention center designated for non-adults. In addition, in the penal code, sexual relationships with individuals who are older than 15 but not yet mature are evaluated in sentencing which is complaint dependent [6].

The article 11 of the Turkish Civil Code states that the “[...] legal age of majority is 18” but also states that, on marrying, “[...] a person under the age of 18 assumes the same rights and responsibilities as an adult”. Boys and girls cannot marry until 18 years of age. However, under extenuating circumstances, a judge can give permission for boys and girls of 16 years to marry. In the last few years, the crisis in Syria and subsequent influx of refugees into Turkey has also caused a dramatic rise in the number of unregistered forced marriages [7,8]. A report by Social Institutions and Gender Index states: “Early or forced marriage is defined as a criminal offense in Turkey. Marriages must be registered with civil authorities before religious marriages can take place. Carrying out an unregistered religious marriage is in breach of Article 237 of the Criminal Code. The Civil Code grants women subjected to forced marriage the right to apply for an annulment within the first five years of the marriage. Data reported by the Turkish Statistics Institute (TUIK) in 2006 indicates that early marriage primarily affects women: 31.7% of women compared to 6.9% of men marry for the first time before the age of 18. The TUIK indicates that there were over 180,000 child brides in Turkey in 2012” [9].

Assigning an age to a living child of unknown identity may be necessary when the child is the victim of a crime, suspected of a crime or when the child is a refugee of uncertain age. In these cases, it is necessary to use non-invasive methods and higher accuracy and precision, because of specific legal requirements [4,10]. At this point, the “false adult” is the worst and the least desirable error, connoting unacceptable legal consequences [2]. In addition, there are important financial consequences for local authorities in looking after children, and practical implications for deportation if an asylum claim is rejected. In United Kingdom, it was recently revealed that over £2 million had been paid to 40 child asylum-seekers in a court settlement who were wrongly detained as adults due to a flawed process of age assessment [11]. In this context, it is important that legal representatives fully understand the age assessment process, especially the medical practices that are carried out.

Recently, the Study Group on Forensic Age Diagnostics (AGFAD) [12], recommends combining the examination of three independent development systems in criminal proceedings, to increase diagnostic accuracy and to improve the identification of age-relevant development disorders [13-15]. The proposed guidelines for age estimation in the living by AGFAD, includes a physical examination with determination of anthropometric measurements, inspection of sexual maturation and identification of any relevant developmental disorder. Examination of skeletal development include hand-wrist bones 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 panoramic radiographs [16,17]. The latest version of these recommendations can be found on the AGFAD website at http://campus.uni-muenster.de/6757.html?&L=1.

Age estimation is very effective by evaluation of mineralization of permanent teeth until the age of 12–14, when mineralization of the second molars completed [18,19]. Since third molars are still growing at the age of 18, their development has recently been considered the most suitable evidence to determine whether a subject is an adult or not [4,12,20].

In the last few years, several studies and different statistical approaches have focused on mineralisation of the third molar [21]. In 2008, Cameriere at al. [22] developed a new method for assessing adult age based on the ratio between age and the normalized measures of the open apices and height of the third molar (I_{3M}). The method was developed to identify a threshold (cut-off) which could be used to discriminate between individuals who are 18 years of age or older.

To date, no studies have used the technique in the Turkish population. Therefore, the main aim of this study was to test the accuracy of cut-off value of 0.08 in order to determine whether an individual was older than 18 years or not.

Materials and Methods

Sample

Digital panoramic images of 293 healthy subjects (165 girls and 128 boys), aged between 14 and 22 years, with no obvious developmental abnormalities, were selected at random from the digital archive of the Baskent University, Faculty of Dentistry during 2014 and 2015 years. The inclusion criteria were the following: age between 14 and 22 years at the time the panoramic radiographs were obtained, good quality radiographs, healthy subjects with known precise age and free of systemic disorders. Individuals of unknown age or those with no third molars or third molars with developmental anomalies (abnormally short roots, dysmorphology) were excluded.

Patients' identification number, gender, date of birth and date of the X-rays were recorded. The CA (chronological age) for each subject was calculated by subtracting the date of the X-ray from the date of birth. This study was approved by ....University Institutional Review Board (Project no: D-KA15/17) and supported by Baskent University Research Fund. The study was conducted in accordance with the ethical standards laid down by the Declaration of Helsinki (Finland). The World Medical Association (WMA) developed the Declaration of Helsinki as a statement of ethical principles for medical research involving human subjects, including research on identifiable human material and data.

Measurements of digital panoramic images

Panoramic images were in digital format (Veraviewpocs 2D, Morita, Kyoto, Japan) and the measurements were processed utilizing a public domain, computer-aided drafting program (ImageJ 1.49). The FDI (Fédération Dentaire Internationale) two-digit system notation was used.

The radiographic appearances of the both erupted and non-erupted left lower third molars were evaluated. To discriminate whether the individual was under or over 18 years old, Cameriere's et al. technique [22] verifies the root apex of the lower left third molar of each individual and establishes the third molar maturity index (I_{3M}): if the lower left third molar presented completed root development (root apex closed), $I_{3M} = 0$; if the root apex was not completed, the I_{3M} was evaluated as being the sum of the distances of the inner sides of the open apexes (A + B) divided by the tooth length (C) (Figure 1). According to Cameriere's cut-off value [19,22,23] an individual is considered to be 18 years of age or older if the $I_{3M} < 0.08$. These measurements were balanced through division (A + B)/C, to consider the possible distortions among the images (Figure 1).

Three experts, two pediatric dentists and one dentomaxillofacial radiologist provided evaluations of the third molar index for each panoramic radiograph, working independently. The assessments of each observer were then collected in Excel© tables previously compiled with an identification code, gender and the actual age of each subject.

Statistical Analysis

To test intra-observer reproducibility, a random sample of 50 panoramic images was re-scored after an interval of at least 45 days and studied by concordance correlation coefficient (ρ_c).

The Intraclass Correlation Coefficient (ICC) was used to measure the inter-observer agreement. A new random sample of 50 subjects was selected and re-assessed after a period of 4 weeks by another observer with similar scientific background and experience who had not worked with this method before. κ statistics (Cohen's Kappa coefficient) were also used for intra-observer and inter-observer agreement between two different observers for agreement in selection on adult ($I_{3M} < 0.08$) or minor ($I_{3M} \geq 0.08$). For this purpose, 40 randomly selected images were re-assessed 45 days after examination by two observers.

Based on Cameriere et al. [22], a subject is considered to be 18 years of age or older if I_{3M} is lower than 0.08. The sensitivity of the test (i.e., the proportion of subjects older than or equal to 18 years of age who have $I_{3M} < 0.08$) and its specificity (i.e., the proportion of subjects younger than 18 years of age who have $I_{3M} \geq 0.08$) were evaluated, as well as the post-test probability of being 18 years of age or older (when $I_{3M} < 0.08$). Positive and negative Predictive Values (PPV and NPV), positive likelihood ratio positive (LR+) and negative (LR) were also calculated. Likelihood ratios indicate how many times more (or less) likely adults are to have $I_{3M} < 0.08$ than minors and minors are to have $I_{3M} \geq 0.08$ than adults. Because tests can be positive or negative, there are at least two likelihood ratios for each test. The LR+ shows how much to increase the probability of disease if the test is positive, while the LR- indicates us how much to decrease it if the test is negative. Using the principles of the Bayes theorem, likelihood ratios can be used in conjunction with pre-test probability to estimate an individual's post-test probability, that is his or her chance of being older than 18 years or not once the result of a test is known (24). According to Bayes' theorem, post-test probability may be written as:

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

where p is post-test probability and p_0 is the probability that the individual in question is 18 or older, given that s/he is aged between 14 and 22 years, which represents the target population. Probability p_0 was calculated as follow: it is the proportion of Turkish subjects aged between 18 and 22 years of age who live in Turkey according to the demographic data obtained from the Turkish Statistical Institute (TUIK) (http://www.turkstat.gov.tr/Start.do) and those between 14 and 22 years of age evaluated from the same web page. This proportion was considered to be 0.49 (49.1%) for girls and 0.49 (49.7%) for boys.

All statistical analyses were performed using the IBM SPSS 20.0 software program (IBM® SPSS® Statistics, Armonk, NY)[25].

Results

Table 1 shows the number of images used, according to age and sex. Distribution of chronological age gradually decreased as I_{3M} increased, in both girls and boys, as showed in Figure 2. The ICC (Intra-class Correlation Coefficient) showed an inter-observer agreement of 0.853 (p=0.001). Repeatability of the methods was investigated by testing for intra-observer error and no statistically significant difference between paired sets of measurements was detected: ρ_c=0.91. κ statistics for intra- and inter-observer agreement in decision on adult or minor was 0.901 and 0.855, respectively.

Table 2 shows in details the mean chronological age and the standard deviation according to the third molar maturity index. The mean age among girls and boys is 21.29 ± 0.80 years and 20.84 ± 1.14 years, respectively, when the I_{3M} ranges from 0.0 to 0.04. 47 girls and 36 boys with an $I_{3M} < 0.04$ were older than 20 years old. 26 girls and 17 boys, with an I_{3M} ranging from 0.04 to 0.08, were older than 19 years old. 42 girls and 32 boys, with an I_{3M} ranging from 0.08 to 0.3, were older than 17 and 16 years old, respectively.

Table 3 displays the close association between adult age and positivity of the test (i.e., $I_{3M} < 0.08$) in girls: 153 out of 165 individuals were accurately classified. The proportion of correctly classified subjects was 92.7%. The results (Table 3) show that the sensitivity of the test for girls (the proportion of subjects being 18 years of age or older whose test was positive) was 85.9% (95% CI 77.1% – 92.8%) and specificity was 100%. Estimated post-test probability p was 1. PPV of the test, that the participants whose $I_{3M} < 0.08$ were adult, was 85.9% (95% CI 78.5% - 93.3%), while NPV of the test, that the participants whose $I_{3M} \geq 0.08$ are minor, was 100%. The positive likelihood ratio (LR+) was 7.7 (95% CI 4.5% – 12.9%) while negative likelihood ratio (LR-) was 0. This means that a mature M3 is more than 7.7 times more likely in an individual in the older age category compared to an individual younger than 18.

Table 4 displays the close association between adult age and positivity of the test (i.e., $I_{3M} < 0.08$) in boys: 125 out of 128 individuals were accurately classified. The proportion of correctly classified subjects was 97.6%. The results (Table 4) show that the sensitivity of the test for boys (the proportion of subjects being 18 years of age or older whose test was positive) was 94.6% (95% CI 88.1% - 99.8%) and specificity was 100%. Estimated post-test probability p was 1. PPV of the test, that the participants whose $I_{3M} < 0.08$ were adult, was 94.6% (95% CI 88.7% - 100%), while NPV of the test, that the participants whose $I_{3M} \geq 0.08$ are minor, was 100%. The positive likelihood ratio (LR+) was 25 (95% CI 8.24% – 75.7%) while negative likelihood ratio (LR-) was 0. This means that a mature M3 is more than 25 times more likely in an individual in the older age category compared to an individual younger than 18.

The LR value can range from zero to infinity. Values less than 1 correspond to a decrease in the post-test probability of a condition while values greater than 1 indicate an increase in the post-test probability of a condition. A LR value of 1 indicates the test has the same likelihood of being positive or negative in those with condition as in those without it and is not helpful [26,27].

Discussion

Nowadays, there is no consensus on which methods to use for age assessment. A majority of countries assess age based on a medical examination of bone and/or dental development, physical appearance and interviews, while a few states rely on nonmedical assessments only [28]. These techniques often do not take into account ethnic variations, they are based on reference materials that for the most commonly used tests are out of date, and generate a margin of error that makes them too inaccurate to use. In addition, different margins of precision for each method and different approaches for multiple indicators of age are used [29].

From a statistical point of view, a conscious use of combining methods and relevant methodology may provide more reliable estimates and better quantification of associated levels of uncertainty. In criminal proceedings, when the uncertainty is known, the acceptance level of the error rates is often a political decision, as there are no methods by which the chronological age can be estimated 100% precisely.

In spite of this, the age estimation of children and adolescents must protect the best interest of the presumed minor and ensures the compliance with the ethical principles of autonomy, beneficence, nonmalevolence, and justice [30,31]. Such as Abbing noted [32], a standardization of international protocols, resulting from collaboration between various scientific societies of professionals, is needed in order to protect young people subject to immigration control and coming from contexts in which childhood is defined in different ways reflecting their social, economic and political circumstances.

Since 2000, the researchers at the Institute of Legal Medicine of the University of Macerata (Italy) have been extensively studying new skeletal and dental methods for age estimation in the living, in order to provide the forensic specialist with techniques which have been tested by many on different and numerous populations, which are suitable for a specific forensic context, practical, user-friendly, relatively quick and cheap [33].

In one of the most recent studies, Cameriere at al. [22] developed a practical method for assessing adult age based on the relationship between age and the third molar maturity index (I_{3M}), which is related to the measurement of the open apices of the third molar. Their results were interesting: a cut-off value of I_{3M}=0.08 was reported, and the sensitivity and specificity were 70% and 98%, respectively. In addition, the proportion of individuals correctly classified was 83%. These results encouraged also to test the cut-off value of I_{3M} = 0.08 on two samples of Albanian and Croatian subjects, respectively [20,34]. These additional studies showed that the third molar index (I_{3M}) should be used as a useful determinant of the age of 18 in European countries [20,23,34].

This paper analyzed the results from a supplementary investigation of a new sample of 293 living subjects, aged between 14 and 22 years, in Turkey. The results of this new study indicated correct classification in 92.7% of cases for girls and in 97.6% of cases for boys. The sensitivity of the test was 85.9% for girls and 94.6% for boys. The specificity was 100% for both sexes. Positive Predictive Value (PPV) of the test is 94.6% (95% CI 88.7% - 100%) and 85.9% (95% CI 78.5% - 93.3%) for boys and girls, respectively. Negative Predictive Value (NPV), for both girls and boys, is 1. Positive Likelihood ratio (LR+), for both girls and boys, are 7.7 (95% CI 4.5% – 12.9%) and 25 (95% CI 8.24% – 75.7%), respectively. Negative Likelihood ratio (LR-) is 0 for both sexes. These data are comparable with those achieved in previous studies [20,22,23,34] but further information about PPV, NPV and likelihood ratios has been achieved.

The probability of an individual with a specific I_{M3} stage being at least 18 is expressed as the positive predictive value (PPV). It increases with root formation stage and in the present study was 94.6% and 85.9% for boys and girls, respectively. In the last few years, few studies have been carried out about the usefulness of PPV in a diagnostic test analysing the probability of being at least 18 [35]. Liversidge and Marsden [35] and Liversidge et al. [36] showed also high positive predictive values. Altough the PPV is highly useful, it could be sensitive to prevalence of the positive test group (older age category), takes account of neither false negative nor false positive values and can rarely be generalised beyond the study sample.

The sensitivity and specificity of a test can be combined into one measure called the likelihood ratio. Likelihood ratios are becoming increasingly popular for reporting the usefulness of diagnostic tests [24]. These are independent of prevalence and clinically relevant to express the probability of a diagnostic test result at the patient level. In this study, Likelihood ratios derived from sensitivity and specificity was used in conjunction with a subject's pre-test probability of having 18 years of age in order to estimate the post-test probability of this condition. Positive Likelihood ratios of 7.7 and 25, for girls and boys, significantly increased the probability of a subject to be older than 18 years of age. Conversely, Negative Likelihood ratios of 0, for both girls and boys, are very low and ruled out a chance that a subject is 18 years of age.

As noted above, specificity is the probability that the test will produce a true negative result. In the reference study, the specificity of 100% has to be also highlighted because this means that no false negatives (i.e., the proportion of individuals of 18 years of age or older who were erroneously assigned to the subadult population) have been generated in this diagnostic test and that all subjects younger than 18 years of age have been correctly classified.

For forensic purposes, it is important that the test shows positivity in a low proportion of individuals under 18 years of age, which is more likely of having a false positive rather than a false negative. As Garamendi et al. noted [37], technically inacceptable mistakes (false negatives) lead to a more beneficial criminal treatment; technically unethical errors (false positives) lead to the violation of the minor's rights. Consequently, in forensic age diagnosis, test methods must reduce technically unacceptable errors to a minimum, but it is even more important for ethically unacceptable errors to disappear, especially in cases involving the possible criminal responsibility of the presumed minor [38,39].

Conclusions

The present study is the first to analyse the accuracy of the third molar maturity index (I_{3M}) in a Turkish sample of children and adolescents. According to the results achieved, the major conclusion of this study is that, at the present time, the cut-off of 0.08 could be a useful diagnostic method to assess if a subject is older than 18 years of age or not.

However, further investigations are needed in order to study the possibility of using other radiographic techniques, such as the periapical radiography or Cone Beam Computed Tomography (CBCT). More specifically, it seems important to verify whether CBCT that cross-sectional technique could improve the accuracy of the I_{3M} in the context of criminal proceedings and the enormous burden on immigration control caused by soaring rate of influx of migration. Last but not least, the portability of the periapical X-ray devices can be transported and easily positioned in place like a cart, allowing its use on virtually any leveled temporary facility.

Finally, in forensic age estimation in living subjects, when assessing the likelihood of being on one or either side of an age threshold must be vital, further studies are needed in order to test the accuracy of I_{3M} in combination with multiple age indicators.

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Table 1. Sex and age distribution of the Turkish sample.

Age	Girls	Boys	Total
14	29	31	60
15	18	10	28
16	20	18	38
17	13	13	26
18	13	10	23
19	14	11	25
20	21	16	37
21	26	12	38
22	11	7	18
Total	165	128	293

Table 2. Descriptive statistic of chronological age according to sex and third molar index (I_{3M}).

I_{3M}	n	Mean	SD	Min	Q1	Median	Q3	Max	p
				Girls					
0 - 0.04	47	21.29	0.80	21.05	20.82	21.56	21.94	21.53	0.31
0.04 - 0.08	26	19.87	1.37	19.31	18.53	19.81	20.89	20.42	0.51
0.8 - 0.3	42	17.32	1.59	16.82	16.45	17.13	18.34	17.82	0.40
0.3 – 0.5	25	15.53	1.00	15.12	14.66	15.41	16.12	15.95	0.24
0.5 – 1.5	25	14.82	0.94	14.43	14.00	14.58	15.33	15.21	0.23
				Boys					
0 - 0.04	36	20.84	1.14	20.45	20.06	20.93	21.70	21.22	0.23
0.04 - 0.08	17	19.40	1.38	18.69	18.00	19.26	20.52	20.11	0.34
0.8 - 0.3	35	16.54	1.14	16.15	15.76	16.62	17.26	16.94	0.25
0.3 – 0.5	18	15.42	1.40	14.72	14.47	15.00	16.14	16.12	0.21
0.5 – 1.5	22	14.77	0.88	14.38	14.07	14.63	14.91	15.16	0.39

(n) number of individuals, (SD) standard deviation, (min) minimum value, (Q1) 1st quartile, (Q3) 3rd quartile, (p) significance at <0.05

Table 3. Contingency table of the cut-off value's performance for girls.

Cut-off	Age		Total
	≥ 18	< 18	
$I_{3M} < 0.08$	73	12	85
$I_{3M} \geq 0.08$	0	80	80
Total	73	92	165

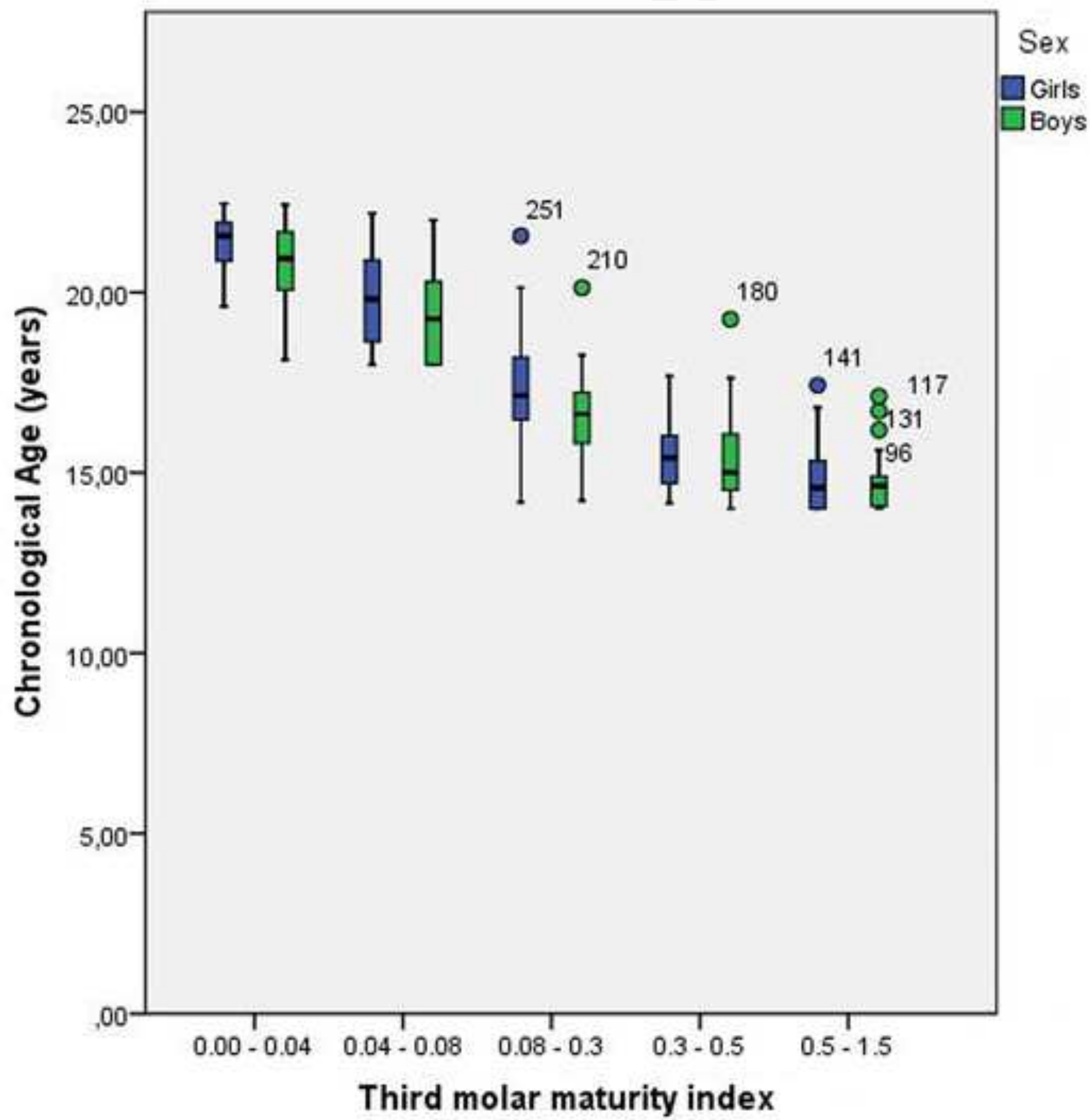
Table 4. Contingency table of the cut-off value's performance for boys.

Cut-off	Age		Total
	≥ 18	< 18	
$I_{3M} < 0.08$	53	3	56
$I_{3M} \geq 0.08$	0	72	72
Total	53	75	128

Figure 1 shows the measurement of the third molar index.
Figure 2 shows the decreasing of the chronological age as I3M increased in both girls and boys.

Figure 1

Figure 2



Sex
Girls
Boys
25,00
20,00
15,00
10,00
5,00
,00
Chronological Age (years)
251
210
180
141
117
131
96
0.00 - 0.04
0.04 - 0.08
0.08 - 0.3
0.3 - 0.5
0.5 - 1.5
Third molar maturity index