Validation of the third molar maturity index (I_{3M}): study of a Dominican Republic sample

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ABSTRACT

This retrospective study aims to test the third molar maturity index (I_{3M}) cut-off value of 0.08 for 18 years old in Dominican Republic population. Orthopantomograms of 513 subjects (284 females and 229 males) were evaluated, intra- and inter-observer agreement, ICC (intra-class correlation coefficient) values were 0.88% (95 % CI 0.86% to 0.91%), and 0.93% (95% CI 0.90% to 0.96%), for the intra- and inter-observer reliability, respectively. Accuracy in females was 0.96 (95% CI: 0.93-0.97); the sensitivity was 0.99 (95% CI: 0.96-0.99) and specificity was 0.92 (95% CI: 0.86-0.95). In males, the accuracy was 0.96 (95% CI: 0.93-0.98); the sensitivity was 0.94 (95% CI: 0.88-0.97) and specificity was 0.99 (95% CI: 0.95-0.99). The PPV (Positive Predictive Value) was 0.93 for females and 0.99 for males. The results of this study show that I_{3M} can be used for discriminating adults from minors in Dominican Republic subjects around the legal age of 18 years old.

INTRODUCTION

Age estimation in living individuals is often required by authorities when chronological age is in doubt and forensic professionals are usually asked to state their scientific opinion specifically for the legal age of adulthood. In most countries around the world the legal age is 18 years old and it is in this threshold from children to adult that more reliable scientific methods are needed. According with the Code of the minor in the Dominican Republic a person is considered a child from birth to 12 years of age, and an adolescent from 13 to 17 years of age, with majority attained on the 18th birthday. The juvenile criminal justice model adopted by the Dominican Republic, recognizes the young offender's criminal responsibility, making a distinction between social or family conflicts and actual criminal behaviour.[1] The length of penalties involving custody ranges from three years for young people between the ages of 13 and 15 when committing the offence, to five years for young people between the ages of 16 and 18 in similar conditions.[2]

There are several issues that affect the rights of minors in the Dominican Republic such as child marriage,[3] and more increasingly sexual exploitation of minors. The promotion of the Dominican Republic as a tourist attraction has brought a rapid growth in demand of minors to be sexually exploited, a study from 2015 concluded that the prevalence of Commercial Sexual Exploitation of Children in Dominican Republic was

higher in parks, beaches, and street areas, where 23.9% or nearly one in every four individuals observed were under 18. In establishments, such as bars, clubs, and car washes, 5.8% or one in twenty of all commercial sex workers were under 18. A significant majority (92.8%) of these minors were Dominican. The overwhelming majority of minors found engaged in commercial sexual exploitation in the Dominican Republic were between the ages of 15 and 17.[4]

Tourism is one of the main driving forces of the economy of the Dominican Republic and the aim is to reach 10 million visitors for 2022, which would increase the sexual exploitation of minors due to the impunity in which foreign tourists act and the number of unregistered minors. [5]

Due to the many issues involving this vulnerable population the country needs scientific methods that help to assess the critical age of 18 years old. In the Dominican Republic, undocumented minors are evaluated through a radiographic assessment of the left hand, and dental development. Since the third molar is the only tooth still in development after 14 years old, it has been the subject of several studies of age estimation. [6,7]

Cameriere et al in his study from 2008 established a cut-off value for the assessment of 18 years old evaluating the relationship between the open apices and the length of the developing third molar. This cut-off named third molar index (I_{3M}) was set up at 0.08.[8]

The aim of this study is to test the accuracy of the third molar index in evaluating if a subject is 18 years of age or older or not in a Dominican Republic sample of children and young adults.

MATERIALS AND METHODS

A retrospective, cross-sectional study was performed involving the analysis of orthopantomograms of 513 subjects (284 females and 229 males). All the X-rays were randomly collected (consecutive sampling) from the databases of two dental radiological centers: a dental clinic from the University of Santo Domingo (Dominican Republic) and another community dental clinic that includes the provinces of Santo Domingo, La Vega and Santiago. The disparity in the number of X-rays between females and males are a result of following the exclusion criteria that included : patients with facial trauma, gross pathology or history of orthodontic treatment, subjects of unknown age or without full dental records, with no third molars, or third molars with developmental anomalies such as partial pulp development and, finally, overlap of radiopaque structures in the apical third of the tooth that may result in inaccuracies. The radiographs were collected between 2011 and 2018 from individuals aged 14 to 22 years, taken for clinical and/or orthodontic diagnosis, with the presence of the third lower left molar. Age and sex distribution are shown in detail in Table 1.

Table 1. Sample distribution according to sex and age. Numbers in bold represent samples with closed apices of the lower left third molar (I_{3M} = 0.00).

FEMALES			MALES		
Age	N	Closed apex	Age	N	Closed apex
14	31		14	24	
15	33		15	41	
16	32		16	25	**1**
17	22	**1**	17	21	
18	32	**20**	18	22	**12**
19	45	**28**	19	31	**21**
20	45	**39**	20	25	**23**
21	31	**30**	21	28	**28**
22	13	**13**	22	12	**12**
	284			229	

Patient data was recorded in an excel file, along with patients' identification number, sex, date of birth and date of the X-rays. The CA (chronological age) for each subject was calculated by subtracting the date of the X-rays from the date of birth and recorded in years and decimal points. The study was conducted in accordance with the Declaration of Helsinki (Finland).[9]

Measurements

A single examiner (LVP), under blind conditions, performed data collection and, according to Cameriere et al.[8] the ratio between the tooth's longitudinal length and the distances between the inner sides of its roots (I_{3M}) was calculated with the aid of an open source image computer-aided drafting programme, used to process and analyze digital images (ImageJ 1.49). In the case of a tooth with two roots, the sum of the distances of both roots was divided by the tooth length.

Statistical analysis

Two observers (RC and LVP), two forensic odontologists with different experience in dental radiology, analyzed the feasibility and reliability of the paired set of measurements in similar conditions and background. The Intraclass Correlation Coefficient (ICC) was applied to calculate intra- and inter-observer concordance.

Repeated observations from the first author (LVP) were used to assess intra-observer agreement, while inter-observer analysis was based on comparisons with those of another observer. For this purpose, 62 radiographs were randomly selected one month following the initial scoring to calculate percentage of agreement, for both intra- (30 images) and inter-observer (30 images) analysis. Scatter plot and box plot graphs and tables were used to show relationships between chronological age and different I_{3M} values for both sexes.

The data were analyzed on SPSS 22.0 (Statistical Package for Social Sciences) by descriptive statistics and logistic regression, and the threshold of significance was set in all tests at 5%. Based on the I3M index, radiographs would correspond to individuals aged 18 years or older when the index result was lower than 0.08 (I3M < 0.08).

In order to test the performance of specific cut-off value of I_{3M}, and to determine the sensitivity (the proportion of subjects older than or equal to 18 years of age with $I_{3M} < 0.08$) and specificity (the proportion of individuals younger than 18 with $I_{3M} \geq 0.08$) of the test, a contingency table was used. The performance was assessed also using accurate classification (ACC), Positive Predictive Values (PPV), Negative Predictive Values (NPV) and, finally, positive and negative likelihood ratios (LR+ and LR-).

The I_{3M} may help to discriminate between individuals who are or not aged 18 years, or more, by the post-test probability of being 18 years of age or more (i.e., the proportion of individuals with $I_{3M} < 0.08$ who is older than or equal to 18 years). According to Bayes' theorem, post-test probability is described in the following formula:

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

In the post-test probability p, p_o is the probability that an individual is 18 or older given that he/she is aged between 14 and 22 years, which represents the target population. In this study, probability p_o was calculated as the proportion of participants between 14 and 22 years of age and those between 18 and 22 years of age who live in the Dominican Republic. This probability, p_o, was evaluated with the data obtained from the Statistical Office of the Dominican Republic [https://www.one.gob.do/#]. The proportion was 0.54 (54.9%) for females and 0.54 (54.6%) for males.

RESULTS

As regards the intra- and inter-observers' agreement, ICC values were 0.88% (95 % CI 0.86% to 0.91%), and 0.93% (95% CI 0.90% to 0.96%), for the intra- and inter-observer reliability, respectively.

The sample distribution consisted of 44.6% males (n = 229) and 55.3% females (n = 284) (Table 1), of which 253 (49.3%) were minors and 284 (55.3%) were 18 years or older. According to the results showed in in the following figures (Figure 1 a and b), the estimated age of majority was correlated with the chronological age (p = 0.000) and the I_{3M} values gradually decreased as age increased in both sexes.

As showed in the Figures 1 A and B, and in the Table 2, the lower third molar mineralization varies according to sex and it occurred slightly earlier in males than in females.

Figure 1. A and B. Boxplots of the relationship between chronological age and I_{3M} in Dominican sample (females and males). Boxplot shows median and inter-quartile ranges, whilst "whiskers" are lines extending from box to highest and lowest values, excluding outliers. The horizontal red dotted line is at 18 years of age.

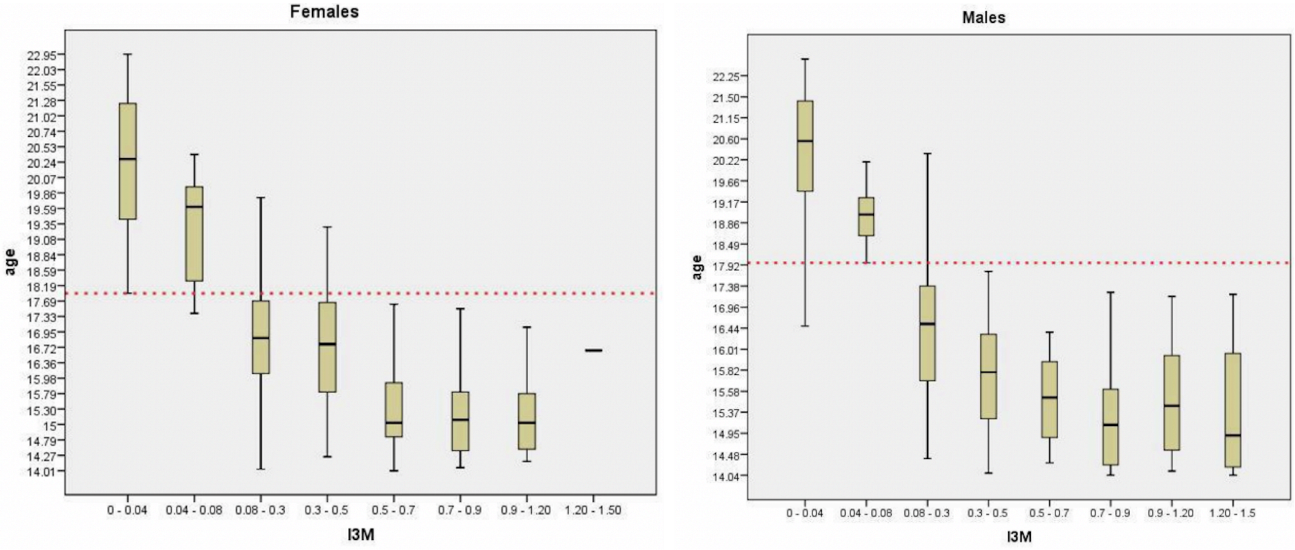

Table 2. Number of individuals mean and standard deviation (SD) of age distribution for each I_{3M} group in both sexes (F = females; M = males).

I_{3M}	F	Mean	SD	M	Mean	SD
0 – 0.04	135	20.36	1.200	100	20.46	1.328
0.04 – 0.08	16	19.23	0.894	12	18.97	0.592
0.09 – 0.3	53	17.05	1.434	61	16.60	1.261
0.3 – 0.5	26	16.78	1.632	18	15.83	0.968
0.5 – 0.7	21	15.43	1.008	14	15.34	0.642
0.7 – 0.9	20	15.14	0.879	14	15.33	1.281
0.9 – 1.2	12	15.22	0.934	6	15.44	1.137
1.2 – 1.5	1	16.64	-	4	15.26	1.471

Table 3 displays separately the pooled data of sensibility and specificity in both sexes. In females, the accuracy is 0.96 (95% CI: 0.93-0.97); the sensitivity is 0.99 (95% CI: 0.96-0.99) and specificity is 0.92 (95% CI: 0.86-0.95). The PPVs of the test are 0.93 (PPV = True Positives/(True Positives + False Positives)(95% CI: 0.89-0.96); and the NPVs are 0.99 (95% CI: 0.95-0.99). As regard the LR+ and the LR-, the first one is 12.72 (95% CI: 7.01 to 23.06) whilst the second one is 0.01 (95% CI: 0.00 to 0.05). In males, the accuracy is 0.96 (95% CI: 0.93-0.98); the sensitivity is 0.94 (95% CI: 0.88-0.97) and specificity is 0.99 (95% CI: 0.95-0.99). The PPVs of the test are 0.99 (95% CI: 0.95-0.99); and the NPVs are 0.94 (95% CI: 0.88-0.97). Regarding the LR+ and the LR-, their values are 104.42 (95% CI: 14.83 to 735.13) and 0.06 (95% CI: 0.03 to 0.12), respectively.

Table 3. Contingency table of the I_{3M} index for age estimation in both females and males.

Test	Females			Males		
	Age (years)		Total	Age (years)		Total
	≥18	<18		≥18	<18	
(I_{3M}<0.08)	155*	10**	165	111*	1**	112
(I_{3M}≥0.08)	1***	118****	119	7***	110****	117

*True positives; **False positives; ***False negatives; ****True negatives

DISCUSSION

Being able to estimate the legal age of majority (18 years in some countries) through a reliable method is essential for the application of the law. In the Dominican Republic, in the field of civil, criminal and labour law, the method most frequently used to assess adult age in cases lacking documents has been the radiographic analysis of the left hand and wrist bones.

However, several studies have shown the limitation of using this method for adult age due to the difficulty in observing changes in the carpal bones after the age of 14-16 years old.[10,11]

Since chronological age is usually retrieved from birth registration or identification document, it is complex to manage legal situations in which the person has no document or the one they have is not reliable. Third molar development has demonstrated a correlation with legal age of 18 years old.[12,13] A recent systematic review and meta-analysis, regarding how well a fully mature third molar identifies adulthood (> 18 years), concluded that diagnostic accuracy was 71.3% confirming a high correlation. [14]

Based on this well-known relationship between adulthood and third molar development, the I_{3M} was proposed by Cameriere et al. [8] as a simple, user-friendly and inexpensive method based on the relationship between the open apices and the length of the third molar. It established a cut-off of 0.08, in which those resulting in a lower value than the cut-off were positive to the test meaning equal or older than 18 years old while results higher than 0.08 were negative to the test meaning younger than 18 years old. Several samples coming from different continents have been tested, Asia,[15-17] America, [18-21] Africa, [22-24] and Europe. [25-32]

The present study is the first in applying I_{3M} in a Dominican Republic sample and the results are similar with those observed in previous studies in other populations. The accuracy of the I_{3M} in the Dominican Republic was 0.96 both in females and males comparable with results observed in Colombia (0.95 and 0.89), Brazil (0.86 and 0.87), and France with 0.89 and 0.91, for females and males respectively. The results for sensitivity and specificity in this sample were 0.99 and 0.92 for females while for males were 0.94 and 0.99.

The consistency of the results in this study compares with the results obtained from samples from different populations, supports the usefulness of this method, agrees with previous studies,[22-24] and with additional observations made by the systematic review and meta- analysis from 2018. This systematic review assessed the accuracy of I_{3M} for estimating 18 years old from a selection of 16 studies which were used in populations from diverse countries and concluded that this test proved to be suitable for estimating adulthood and therefore the cut-off of 0.08 was regarded as valid to discriminate individuals between adults and minors.[33-35]

The estimation of the age of 18 years is one of the most studied subjects in the forensic field, and the impossibility of having samples to study from every existing population is one of the main problems when validating a method. Testing the reliability of the proposed single cut-off in multiple countries and observing similar results, confirms the application of this method in a subject from an untested population with a fair degree of confidence.

Research emphasizes the need to distinguish minors from adults as a means of protecting a vulnerable population but issues such as sexual exploitation and child brides in the Dominican Republic and around the world do not finish once legal age is attained. Science intervenes by providing means to assist the law, but these studies are also an opportunity to highlight the

responsibility of society to not only protect minors but to offer options for those older than 18 so they can have a different choice in life as adults.

Further application of this method in new samples from non-studied nations are necessary. Future research concerning the Dominican Republic population will be done regarding age estimation in children using the same principle of open apices and length of the developing permanent teeth.

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