Forensic Anthropology Population Data

Accuracy of Cameriere's cut-off value for third molar in assessing 18 years of age

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A B S T R A C T

Due to increasingly numerous international migrations, estimating the age of unaccompanied minors is becoming of enormous significance for forensic professionals who are required to deliver expert opinions. The third molar tooth is one of the few anatomical sites available for estimating the age of individuals in late adolescence. This study verifies the accuracy of Cameriere's cut-off value of the third molar index (I_{3M}) in assessing 18 years of age. For this purpose, a sample of orthopantomographs (OPTs) of 397 living subjects aged between 13 and 22 years (192 female and 205 male) was analyzed. Age distribution gradually decreases as I_{3M} increases in both males and females. The results show that the sensitivity of the test was 86.6%, with a 95% confidence interval of (80.8%, 91.1%), and its specificity was 95.7%, with a 95% confidence interval of (92.1%, 98%). The proportion of correctly classified individuals was 91.4%. Estimated post-test probability, p was 95.6%, with a 95% confidence interval of (92%, 98%). Hence, the probability that a subject positive on the test (i.e., $I_{3M} < 0.08$) was 18 years of age or older was 95.6%.

1. Introduction

Adult or minor? Answering this question is one of the most interesting challenges for forensic scientists. In the immigration context, and particularly for those undocumented minors seeking asylum in developed countries, age is a matter of considerable importance [1–3].

Italy and Spain have become the preferred destinations for immigrants from other parts of Europe, as well as from developing countries [4]. Undocumented minors in these countries are a diverse group: they may be minors arriving in Europe to be reunited with their families but not falling under official family reunification schemes; those who entered irregularly; or minors born in Europe but whose parents are undocumented. They also include minors who are sent by their families to Europe in search of better conditions or who have run away, and are therefore alone, but who prefer to remain outside the reception circuits for unaccompanied minors and are invisible to social services [3].

Control policies against irregular migration currently pursued by the European Union have dramatically switched the attention of governments and public opinion from the need to protect these young immigrants to repression of their irregular position [1,4].

To prevent abuse of the system and to protect minors, many countries have introduced age estimation procedures in cases where the given age is questioned. Some children have been unlawfully imprisoned in adult immigration detention centers because they were deemed to be adults but subsequently found to be under 18 years of age [5,6].

In this context, accurate age assessments are vitally important. There are three main approaches to age assessment: (1) non-medical methods, which may examine the credibility of papers and documentation; (2) the medical approach, which includes physical examination; (3) the third approach, which seeks to integrate data from both non-medical and medical approaches [3,7].

Medical protocols include bone maturity, and physical and dental development. Schmeling et al. [7] recommended physical and dental examination together with X-rays of the left hand and dentition. Both the AGFAD (Study Group on Forensic Age Diagnostics) and FASE (Forensic Anthropology Society of Europe), a subsection of the IALM (International Academy of Legal

Medicine), have also introduced in their guidelines for forensic age estimation the possibility of recourse to X-rays, CT scans or MR imaging of the clavicle to establish the threshold of the age of majority [8]. The latest version of these recommendations can be found on the AGFAD website at http://agfad.uni-muenster.de/german/start.htm.

In the age span of 15.7–23.3 years of age the third molar represents the only tooth still in development and are thereby very important for dental age calculation. However, its development is more variable than for all the other maturity markers, such as the clavicle and the knee. In addition, some individuals do not grow third molars at all. In some of them, matured (stage H) third molars may appear as early as 15 years of age, whereas in others, they may have not appeared at all, even at the age of 25 [9,10].

Although it has been categorized a non-ideal developmental marker, many studies have been carried out to evaluate 18 years of age by analysing the third molar. The degree of development of this tooth may be recorded as a measure of observed tooth length [11,12] or as a ratio of perceived tooth dimensions [12,13], or classified in various stages according to scores assigned to its maturation and eruption [14].

In 2008, Cameriere at al. [15] developed a method for assessing adult age based on the relationship between age and the third molar maturity index (I_{3M}), according to measurement of the open apices of the third molar. The method was developed to identify a threshold (cut-off) which could be used to discriminate between individuals who are or are not 18 years of age or older.

According to Thevissen et al. [16], in various respects this technique is in contrast with all other techniques for recording and evaluating third molar development [11,12,14]. First, Cameriere's technique records continuous data. Second, its data are based on ratios between measurements of apical pulp widths and tooth lengths.

The main aim of this paper is to test the validity of this cut-off value on a new sample of living subjects.

2. Materials and methods

2.1. Sample

Orthopantomographs (OPTs) of 420 healthy living Italian subjects, aged between 13 and 22 years and with no obvious developmental abnormalities, were analyzed. The sample was randomly selected from patients at the Unit of Orthodontics and Pediatric Dentistry, University of Milan (Italy).

Individuals of unknown age or those with no third molars were excluded from the sample, leaving 397 OPTs (192 female and 205 male) (Table 1).

Patients' identification number, gender, date of birth and date of X-rays were recorded. Their parents had signed agreements with dental institutions that dental records and radiographs could be used only for research and educational purposes, without the possibility of personal identification. Protocols to collect radiographs for human subjects were approved by the Ethics Committee for Research Involving Human Subjects of the University of Milan (Italy), and 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.

2.2. Measurements

Radiographs were in digital form (Ortopantomograph® Orthoceph® OP200) and images were recorded on computer files,

Table 1
Sample of OPTs according to different age categories split up for females and males.

Age (years)	Females	Males	Total
13	21	14	35
14	33	37	70
15	23	26	49
16	19	14	33
17	8	16	24
18	18	23	41
19	17	16	33
20	21	22	43
21	10	16	26
22	22	21	43
Total	192	205	397

processed by a computer-aided drafting program (Adobe® Photoshop® CS4).

Radiographs of the left permanent developing third lower molar were evaluated. The selected nomenclature to classify the teeth was that proposed by the F.D.I. (Fédération Dentaire Internationale) or a two-digit numbering system. Upper third molars were eliminated from consideration in this study, as they are difficult to visualize and score accurately on standard OPTs and are more variable in their development, and so are seldom used for age estimation purposes [15].

Dental age estimation was performed according to the method of Cameriere et al. [15]. The apical ends of the roots of the left lower third molar of each individual were analyzed and the third molar maturity index, I_{3M}, was defined as follows: if the root development of the third molar is complete, i.e., the apical ends of the roots are completely closed, then $I_{3M} = 0$, otherwise I_{3M} is evaluated as the sum of the distances between the inner sides of the two open apices divided by tooth length. Maturity index I_{3M} is evaluated in a similar way to the ratio Ai to Li, when $I = 6.7$, as reported for the other two teeth with two roots in Cameriere et al. [13]. Both impacted and non-impacted third molars were included in this study, provided that their roots were radiographically distinguishable.

2.3. Statistical analysis

The names and surnames of all subjects, their gender, date of birth and date of X-rays were recorded on the orthopantomogram, together with data on the places of birth of the child and of both parents. The age of each individual was calculated as the difference between the date of birth provided in the dental record and the date on which the radiograph was taken, which was indicated by lead markers on the panoramic radiographs. Chronological age was also recorded in an Microsoft Excel® file.

Following the results reported in Cameriere et al. [15], a cut-off value 0.08 was established. This means that an individual is considered to be 18 years of age or older if the I_{3M} is lower than 0.08.

The sensitivity p_1 of the test (i.e., the proportion of subjects older than or equal to 18 years of age who have $I_{3M} < 0.08$) was evaluated, together with its specificity p_2 (i.e., the proportion of individuals younger than 18 who have $I_{3M} \geq 0.08$). The third molar index may help to discriminate between individuals who are or are 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 may be written as:

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