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EXTENDED ABSTRACT

A7 Comparison of different methods of medical legal age classification using ROC curve analysis

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Introduction

The legal ages of 12 and 14 years old are covered in the Portuguese penal code which promotes the protection of the juvenile individuals, giving priority to healing and prevention in the face of punishment. The legal ages of 14, 16 and 18 years old are also covered, where we are faced with the intervention area of crimes against sexual abuse [1-4].

Orthopantomography's (OPG) have been used in several methods for age assessment, being the most commonly used for this purpose [5].

Demirjian method classifies teeth's mineralization by means of an eight-stage system [6-7]. Cameriere's method is based on the development of second and third molars (second molar maturity index – I_{2M} and third molar maturity index - I_{3M}) [8,9]. European regression formula (ERF) is based on the maturity index of seven teeth [6,10].

The aim of this study is to compare several classification age methods, to identify if an individual is younger than 12, 14, 16, 18 or 21 years old.

Methods

Three independent samples were collected as a random basis from the radiograph database of the Stomatology Department at the Santa Maria Hospital located in Lisbon.

To assess second molar development, 591 OPG were selected between 7 and 15 years old (sample 1), and to assess the third molar development, 471 OPG were selected between 12 and 23 years old (sample 2). For the application of the ERF and Demirjian stages, a total of 483 OPG were collected from children aged between 6 and 15 (sample 3) [11-13].

Teeth were measured according to the method by Cameriere et al., and then the values were used in a linear regression [8]. The applied regression formula was the one described in the 2007 study by Cameriere et al. and will henceforth be referred to as the ERF [10]. Considering the purpose of this paper, we will only use the variable s of the formula. Teeth were classified according to the eight stages of the Demirjian method.

The intra-class correlation coefficient (ICC) and weighted Cohen's kappa were applied to quantify intra (3 months later) and inter observer (2 observers) agreement in 10% of each sample (randomly selected).

Besides the accuracy, the sensitivity and the specificity, other measures to assess misclassification were computed, such as the positive and negative predictive values. The Bayes post-test probabilities were computed to generalize the results to the Portuguese population, using data extracted from the Statistics Portugal data base [14]. Finally, the Receiver Operating Characteristic (ROC) curves were obtained and the area under the ROC curves (AUC) were computed.

Results

The ICC varies between 0.523 and 0.999 in all measurements and the weighted Cohen's kappa varies between 0.650 to 1 in all classifications. Hence, almost all measurements and classifications revealed excellent intra and inter concordance, with the rest obtaining good concordance.

Considering the maturity indexes and the Demirjian stages, it is intended to classify a person in under or at least a specific age. Hence, the cut-off points were computed using binary logistic regression.

Keywords:
Dental age assessment, Cameriere's I_{3M} and I_{2M}, European Formula, Demirjian's method, Legal age threshold, Logistic regression, ROC curve, Forensic Dentistry

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For sample 1, the cut-off points were computed for the ages of 12 and 14 (Table 1). For sample 2, the cut-off points were computed for the ages of 12, 14, 16, 18 and 21 years (Table 2). For 18 years of age, the cut-off point of 0.08 determined by Cameriere was also evaluated. For sample 3, the s variable from the ERF and Demirjian method were used to establish the cut-off point for the age of 12 (Table 3) as well as the ages of 8, 9, 10 and 11 years old. Figure 1 shows the ROC curve for the age of 12 years old, for all quantitative methods.

Table 1 - Reliability measures for the cut-off points for the ages of 12 and 14 years old using I_{2M} and Demirjian Methods in 591 OPG. Abbreviation: n, number of individuals in the sample older than age; PPV, Positive Predictive Value; NPV, Negative Predictive Value; Bayes PTP, Bayes Post Probability Theorem G and H- Stages of Demirjian.

Method	Age (years)	n	Cut-off point	Sensitivity	Specificity	Accuracy	PPV	NPV	Bayes PTP	AUC
I_{2M}	12	176	0.135	81.19%	90.36%	87.20%	81.57%	90.14%	91.57%	0.93
	14	53	0.001	90.53%	90.15%	90.21%	61.87%	98.18%	85.07%	0.938
Demirjian	12	176	G, H	88.53%	85.30%	86.41%	75.98%	93.40%	88.60%	0.925
	14	53	H	90.53%	90.15%	90.21%	61.87%	98.18%	85.07%	0.937

Table 2 - Reliability measures for the cut-off points for the ages of 12, 14, 16, 18 and 21 years old using I_{3M} and Demirjian Methods in 471 OPG. Abbreviation: n, number of individuals in the sample older than age; PPV, Positive Predictive Value; NPV, Negative Predictive Value; Bayes PTP,Bayes Post Probability Theorem, E,F,G and H - Stages of Demirjian.

Method	Age (years)	n	Cut-off point	Sensitivity	Specificity	Accuracy	PPV	NPV	Bayes PTP	AUC
I_{3M}	12	350	1.133	93.98%	74.38%	88.94%	91.36%	81.08%	96.00%	0.959
	14	252	0.705	88.05%	72.45%	83.67%	89.11%	70.30%	94.57%	0.909
	16	176	0.358	90.29%	81.03%	85.67%	82.72%	89.24%	91.10%	0.939
	18	120	0.08	78.99%	93.48%	88.54%	86.24%	89.58%	92.82%	0.951
			0.135	88.24%	88.70%	88.54%	80.15%	93.58%	89.28%	
	21	57	0.007	91.07%	86.35%	87.11%	56.04%	98.06%	69.43%	0.917
Demirjian	12	350	E, F, G, H	94.56%	80.99%	91.06%	93.48%	83.76%	97.02%	0.947
	14	252	E, F, G, H	83.67%	85.71%	84.24%	93.75%	67.20%	96.96%	0.901
	16	176	F, G, H	89.14%	85.63%	87.39%	86.19%	88.69%	93.02%	0.933
	18	120	H	70.59%	96.96%	87.97%	92.31%	86.43%	96.12%	0.950
			G, H	93.28%	85.65%	88.25%	77.08%	96.10%	87.40%	
	21	57	H	91.07%	86.35%	87.11%	56.04%	98.06%	69.43%	0.918

Table 3 - Reliability measures for the cut-off points for the ages of 8, 9, 10, 11 and 12 years old using European Regression Formula and Demirjian Methods in 483 OPG. Abbreviation: n, number of individuals in the sample older than age; PPV, Positive Predictive Value; NPV, Negative Predictive Value; Bayes PTP,Bayes Post Probability Theorem.

Method	Age (Years)	n	Cut-off point	Sensitivity	Specificity	Accuracy	PPV	NPV	Bayes PTP	AUC
European regression Formula	8	380	2.09	94.1%	70.87%	89.23%	92.27%	76.84%	93.72%	0.946
	9	299	1.34	91.97%	84.78%	89.23%	90.76%	86.67%	94.05%	0.955
	10	236	0.87	90.25%	85.02%	87.58%	85.20%	90.13%	90.80%	0.957
	11	177	0.52	87.57%	87.91%	87.78%	80.73%	92.44%	88.78%	0.954
	12	122	0.28	81.97%	91.41%	89.03%	76.34%	93.75%	87.33%	0.948
Demirjian	8	380	78.5	96.58%	65.05%	89.86%	91.07%	83.75%	92.73%	0.944
	9	299	86	92.31%	82.07%	88.41%	89.32%	86.78%	93.08%	0.948
	10	236	90.75	92.37%	83.40%	87.78%	84.17%	91.96%	90.11%	0.947
	11	177	94	88.14%	85.29%	86.34%	77.61%	92.55%	86.75%	0.938
	12	122	96.2	70.49%	91.97%	86.54%	74.78%	90.22%	86.37%	0.932

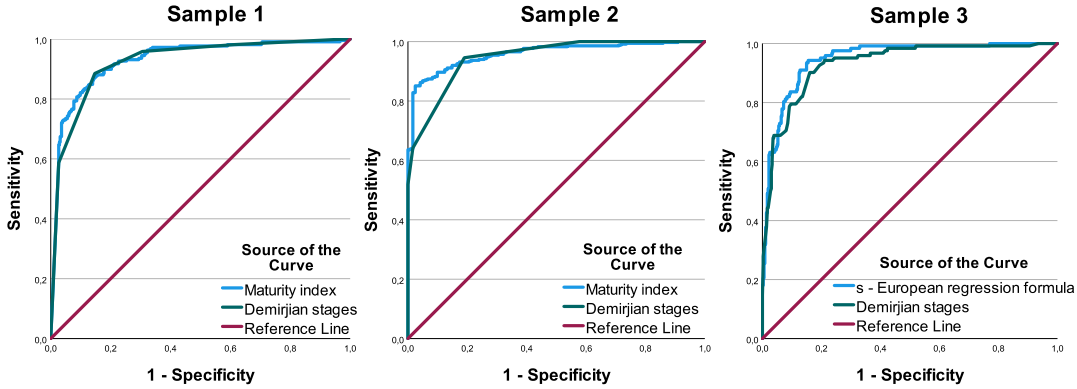

Figure 1 - ROC Curves

Discussion

All methods allow to properly identify an individual under a specific age when applied to the Portuguese population (area under the ROC curve above 0.90).

For the ages of 8 to 11 years old, both ERF and Demirjian methods provide similar suitable results, however the ERF achieved slightly better results. For the age of 12 years old, all methods revealed to be adequate, achieving better performance using third molar. Once again, for the age of 14 years old, the results are quite acceptable, but the use of second molar showed better precision. For the ages of 16, 18 and 21 years old, the use of third molar revealed a fine performance in the classification procedure, for both methods, and the cut-off point determined for the age of 18 years old in the Portuguese population attain better results than the cut-off point 0.08 proposed by Cameriere et al. in 2008 [10].

Conclusion:

The use of these methods for the legal ages in the Portuguese population are reliable and with medical-legal application. However, the choice of the best method to apply depends on the legal age that we want to positively identify in the individual.

Ethics committee and informed consent:

The current research was approved by an independent ethics committee and subjects gave their informed consent before they were enrolled in the study.

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