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Validation of CT Scan Compared to Panoramic Dental X-ray in Forensic Age Assessment of Young Living French Individuals According to Demirjian Mandibular Third Molar Development Stages

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Abstract

In forensic medicine, there has been a marked rise in demand for age estimation in recent years with the growing global migration trend. Forensic age estimation should be based on clinical examinations, hand radiography, as well as orthopantomography and clavicle CT scan if wrist bone fusion is in a late maturation stage. Orthopantomography is based on the mandibular third molar mineralization stage according to the Demirjian method. This study was carried out to validate the efficacy of CT scan with the Demirjian method to determine whether a single CT scan would be sufficient for mandible and clavicle examination. This exhaustive monocentric study included 201 living individuals up to 25 years old who had undergone orthopantomography and CT scan less than 2 months apart between 2007 and 2020. We compared mandibular third molar development stages that had been attributed *via* the two techniques. A concordance calculation to assess the findings of the two techniques revealed almost perfect agreement with a weighted kappa of 0.86 for the 128 left mandibular third molars and 0.88 for the 126 right mandibular third molars analyzed. Calculations of agreement in the CT findings also showed almost perfect agreement for intra-observer variability with a kappa of 0.97 and 1.0, and close agreement for inter-observer variability with kappas of 0.86 and 0.73. CT scan was found to be accurate for mandibular third molar development staging, with almost perfect agreement with regard to the Demirjian method using orthopantomography. CT scan could therefore be an effective alternative to orthopantomography.

Keywords: Age estimation • Radiology • Demirjian method • Third molar • CT scan • Orthopantomogram

Introduction

Many legal and administrative decisions are made on the basis the age of the target individual. Minors or people under an official legal age have different rights and responsibilities in France and many other countries in the Global North.

As a consequence of the current globalization trend and increased population migration, institutions to an increasing extent have to deal with individuals whose age cannot be reliably determined on the basis of civil data. Legal authorities sometimes have to request an expert medical appraisal to determine the target individual's biological age.

In forensic medicine, biological age estimation requests have been growing with, for instance 157 cases processed in Berlin in 2014, i.e. twofold more than in 2004 [1], while 144 cases were processed at the Montpellier University Hospital (France) in 2018, representing 24-fold more than in 2013 (6 cases).

Biological age is estimated by a combination of several steps: a clinical examination screening for pathologies that could interfere with growth, and bone and dental age estimation *via* sequential X-ray examinations to assess the developmental stages of bone maturation of the hand, mandibular third molar and clavicle [1]. Mandibular third molar and clavicle maturations are only assessed if late-stage bone maturation of the hand is noted.

Bone maturation of the hand and mandibular third molar is currently assessed by X-ray, while clavicle ossification is assessed by CT scan. Bone maturation of the hand is assessed by comparison to a reference radiographic atlas [1-3]. Mineralization of the mandibular third molar is assessed on orthopantomograms by Demirjian staging [4], which is reportedly the most efficient method [5,6]. Medial clavicle ossification is assessed according to CT stages, as outlined by Kellinghaus M, et al. [7].

To facilitate legal proceedings and avoid having to carry out a range of different tests, it would be of interest to just carry out a single CT scan of the mandibular third molar and clavicles at the same time, instead of performing a clavicle CT scan as well as dental orthopantomogram. This would be more cost-effective and less time consuming. CT scan requires less patient collaboration than orthopantomography. Moreover, CT scanning facilities are now more available in some places than orthopantomography facilities.

The primary objective of this study was to validate the efficacy of CT scan in the assessment of mandibular third molar mineralization according to Demirjian stages as compared to orthopantomography findings. We also aimed to assess the concordance between mandibular and maxilla third molars, as well as between the right third and left third molars.

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Materials and Methods

Ethics approval

Ethical approval was waived by the local Ethics Committee of University Hospital of Montpellier in view of the retrospective nature of the study and all the procedures being performed were part of the routine care. This protocol obtained IRB approval number IRB-MTP_2020_11_202000615.

Study design and patients

This single-center retrospective cross-sectional study was based on orthopantomograms and CT scans of 201 patients. All included patients were under 25 years old and were examined between 2007 and 2020 at the University Hospital of Montpellier (France). The examinations exhaustively included orthopantomogram and CT scan of at least two maxillary molars, performed within 2 months of each other. Patients were recruited *via* our institutional Picture Archiving and Communication System (PACS). All images were captured using two 64-detector CT scanners (General Electric Lightspeed VCT and 750 HD).

Procedure

The anonymized examinations were read by a musculoskeletal radiologist. The radiologist first read the orthopantomograms and classified the mandibular third molars according to Demirjian stages. A month later, the radiologist staged the available maxillary or mandibular third molars on the CT scan, while being blinded to the first reading.

Intra- and inter-observer consistency in the tooth developmental staging results by the same radiologist (7 years' experience) and a forensic physician were verified by a follow-up analysis performed 1 month later of CT scans and orthopantomograms of 50 patients randomly selected from the total patient population.

Mandibular third molars were identified according to the international dental denomination: 18 (right maxilla), 28 (left maxilla), 38 (left mandible) and 48 (right mandible). For each of them, the radiologist assigned the Demirjian (4) developmental stages on an eight-letter scale (A-H). No stages were assigned when the target tooth was uninterpretable, absent or not visible (patient too young).

In addition, age, sex and indications for imaging examinations (trauma/other) were collected from the medical records, while the radiologist and forensic physician were blinded to this information.

Statistical analysis

The total sample dataset was characterized by standard descriptive statistical analysis. Quantitative variables were described according to the number of available data, mean, standard deviation, median, quartiles Q1 (25th percentile) and Q3 (75th percentile), and minimum and maximum age. Categorical variables were described according to the numerical frequency and percentage.

A concordance analysis of the CT scan and orthopantomogram interpretations of the mandibular third molar developmental stages on the left, right, top and bottom (teeth 18, 28, 38 and 48) was performed. First a weighted coefficient kappa (considering the ordinal relationship between the Demirjian stages) as well as its 95% confidence interval were calculated between the radiologist's first scan and orthopantomogram interpretations for developmental stages of teeth 38 and 48.

For the radiologist's first CT scan interpretation, concordances between the upper and lower teeth on the left side, between the upper and lower teeth on the right side, between the left and right teeth on the maxillary level, and between the left and right teeth on the maxillary level were tested. For the radiologist's first orthopantomogram interpretation, concordance between the left and right mandibular teeth was tested. Inter- and intra-observer agreement was also calculated for each interpretation per tooth.

For all agreement analyses, a kappa value of less than 0 was considered a disagreement, between 0 and 0.2 was very weak agreement, between 0.21 and 0.4 was weak agreement, between 0.41 and 0.6 was moderate agreement, between 0.61 and 0.8 was close agreement, while between 0.81 and 1 was near perfect agreement. All analyses were performed using SAS 9.4 software (SAS Institute Inc, Cary, NC, USA).

Results

Study population

Among the 201 patients (76% male), 276 teeth (140 teeth #38 and 136 teeth #48) were classified *via* the CT findings, while 293 teeth (147 teeth #38 and 146 teeth #48) were classified *via* the orthopantomogram findings

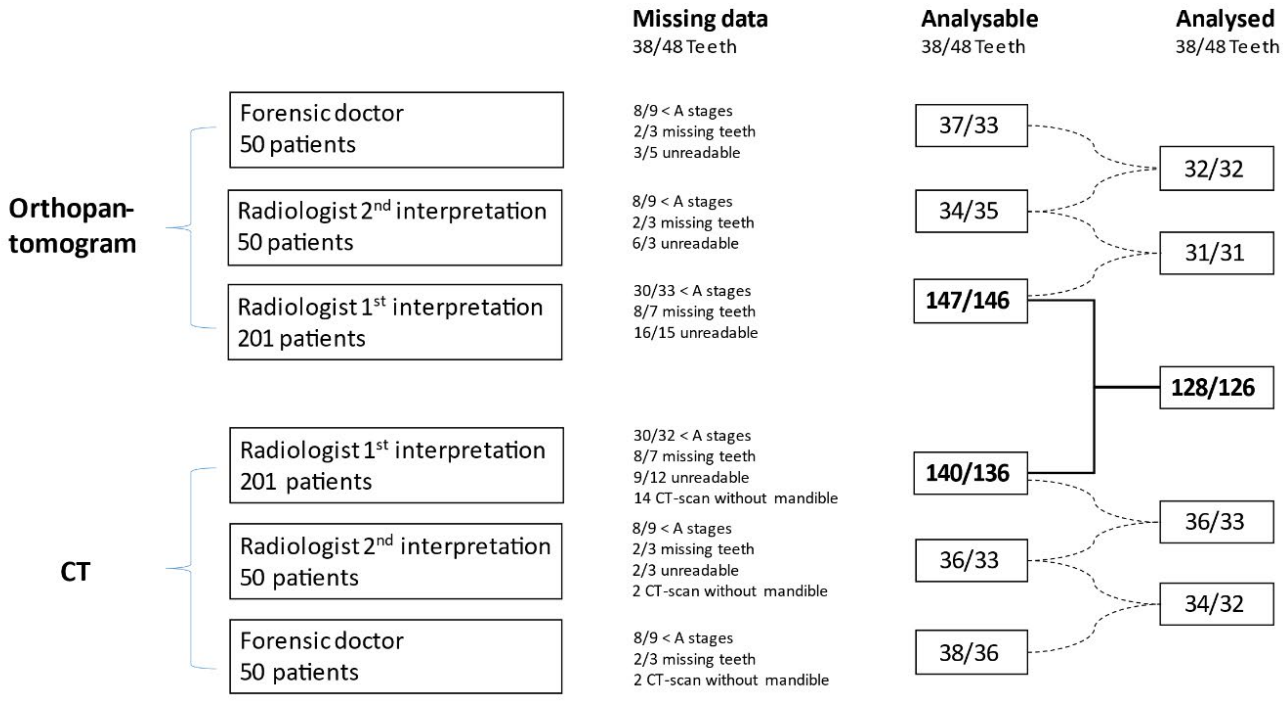

Figure 1. Flow chart of the population features.

according to Demirjian stages. As shown in Figure 1, there were multiple causes: patients too young, missing or uninterpretable teeth and CT scans not showing mandibles.

Imaging examinations were performed for 165 patients (82%) due to trauma, while the remaining patients presented with other indications (oncological disorders, infections, and congenital malformations) (Table 1).

Patient characteristics according to Demirjian stages of dental mineralization are reported in Table 2. Only images performed for trauma unrelated to mandibular third molars were included in this analysis. If a difference between the left and right mandibular teeth of the same patient was noted, the earliest stage of the two was assigned for the age description.

Concordance between orthopantomogram and CT scan findings

For the study of concordance between the orthopantomogram and CT scan findings, 254 teeth (128 teeth #38 and 126 teeth #48) were analyzed.

The agreement between the orthopantomogram and CT scan findings, as estimated by a weighted kappa calculation, was 0.86 (95% CI 0.81: 0.89) and 0.88 (95% CI 0.84: 0.92) for teeth 38 and 48, respectively (Table 3), which indicated near perfect agreement.

Intra- and inter-observer agreement

For the intra-observer agreement study, 62 teeth (31 teeth #38 and 31 teeth #48) were analyzed on the basis of the orthopantomograms, and 69 teeth (36 teeth #38 and 33 teeth #48) according to the CT scans.

The intra-observer agreement was estimated at 0.93 and 0.95 for the orthopantomograms and 0.97 and 1 for the CT scans for teeth 38 and 48, respectively, which indicated almost perfect agreement (Table 3).

For the inter-observer agreement study, 64 teeth (32 teeth #38 and 32 teeth #48) were analyzed by panoramic dental X-ray and 66 teeth (34 teeth #38 and 32 teeth #48) by CT.

The inter-observer agreement for teeth 38 and 48 was estimated at 0.87 and 0.91 for the orthopantomograms (near perfect agreement); 0.86 (near perfect agreement) and 0.73 for the CT scans (close agreement) (Table 3).

Concordance between the different teeth

For the CT scan results, the agreement between the upper and lower third molars on the left (120 teeth) was 0.85 and on the right (119 teeth) was 0.88, respectively, which indicated almost perfect agreement.

For the CT scan results, the agreement between the left and right third molars in the maxillary region (139 teeth) was 0.94, and in the mandibular

Table 1. Patient characteristics.

		N=201
Male, n (%)		152 (76)
Age, Median (Q1, Q3)		18.0 (12.4-21.6)
Age, n (%)	0-9	30 (15%)
	Oct-17	70 (35%)
	18-25	101 (50%)
Indication n (%)	Trauma	165 (82)
	Other[1]	36 (18)

Q1: first quartile, Q3: third quartile

[1]: hemopathy (acute leukemia/lymphoma), congenital malformation check-up (facial cleft, Pierre Robin sequence) or facial cellulitis

Table 2. Correlation of trauma patient age with Demirjian stages by gender.

		N	Male (N)	Mean	Median (Min; Max)
Patients		165	80% (132)	18.1	19.20 (2.70; 25.80)
Orthopantogram	**Stages**	**N**	**Civil Age Median (min-max) Male**	**N**	**Civil Age Median (min-max) Female**
	<A	11	6.50 (2.70;11.30)	6	8.80 (2.70; 11.30)
	A	2	11.85 (11.50;12.20)	0	-
	B	0	-	0	-
	C	1	15.40 (15.40;15.40)	2	13.90 (12.70; 15.1)
	D	16	14.55 (9.80;18.40)	3	13.40 (12.8; 16.9)
	E	12	15.40 (14.50; 20.30)	3	17.50 (14.80; 19.8)
	F	4	17.45 (14.30;18.80)	1	24.70 (24.70; 24.7)
	G	16	17.55 (15.40; 21.60)	5	19.40 (16.70; 22.1)
	H	60	22.40 (18.00; 25.70)	9	21.00 (18.60; 24.7)
	Total	122	-	29	-
CT	< A	10	6.80 (3.40;11.30)	6	7.80 (2.70; 9.60)
	A	2	7.250 (3.00; 11.50)	-	--
	B	1	12.20 (12.20;12.20)	-	-
	C		-	-	-
	D	14	14.90 (9.80;17.90)	4	14.25 (12.80;16.90)
	E	10	15.55 (13.20; 20.30)	4	16.15 (12.70;19.80)
	F	4	17.00 (15.20;18.60)	-	-
	G	29	19.30 (15.40; 25.00)	9	19.60 (16.70; 24.70)
	H	46	22.50 (15.50; 25.80)	7	21.00 (18.60; 24.70)
	Total	116	-	30	-

Table 3. Weighted kappa concordance.

		Tooth	N	Missing Data†	Kappa Weighted (IC 95%)
CT *vs.* Orthopantomogram	CT *vs.* orthopantomogram concordance (N=201)	38	128	73	0.86 (0.81; 0.90)
		48	126	75	0.88 (0.84; 0.93)
CT	Intra-observer agreement (N=50)	18	32	18	0.97 (0.93; 1.0)
		28	34	16	0.97 (0.94; 1.0)
		38	36	14	0.97 (0.93; 1.0)
		48	33	17	1.0 (1.0; 1.0)
	Inter-observer agreement (N=50)	38	34	16	0.86 (0.77; 0.95)
		48	32	16	0.73 (0.63; 0.83)
	Concordance between the different teeth (N=201)	18 *vs.* 38	120	81	0.85 (0.81; 0.90)
		28 *vs.* 48	119	82	0.88 (0.84; 0.93)
		18 *vs.* 28	139	62	0.94 (0.91; 0.97)
		38 *vs.* 48	132	69	0.95 (0.92; 0.97)
Orthopantomogram	Intra-observer agreement (N=50)	38	31	19	0.93 (0.88; 0.98)
		48	31	19	0.95 (0.91; 1.0)
	Inter-observer agreement (N=50)	38	32	18	0.87 (0.81; 0.94)
		48	32	18	0.91 (0.85; 0.97)
	Concordance between the different teeth (N=201)	38 *vs.* 48	133	68	0.95 (0.92; 0.97)

region (132 teeth) was 0.95, respectively, which indicated almost perfect agreement.

Finally, for the orthopantomography results, the agreement between the left and right mandibular third molars (133 teeth) was 0.95, which indicated almost perfect agreement (Table 3).

Discussion

In this study we analyzed CT and orthopantomography results for 254 third mandibular molars from 201 living patients and found very good agreement between evaluations of mineralization stages of mandibular third molar teeth according to the Demirjian method.

This original study is the first to compare the Demirjian staging method using two different techniques in living individuals. Despite the relatively small number of patients, the results were in line with those reported in the literature with regard to the developmental stages of mandibular third molar teeth in deceased people.

Bassed RB, et al. [8] performed a similar study on 667 deceased subjects from a forensic department using both techniques and reported a total kappa of 0.78, while we obtained kappas of 0.86 and 0.88 for teeth 38 and 48, respectively. The higher kappa results of our study could possibly have been due to the smaller number of cases (201 *vs.* 667 in the Bassed study). Our study involved recruitment of living patients seen in a conventional health care unit, so the findings are applicable to the general population, contrary to the results reported by Bassed on a deceased patient population.

In our study, the intra- and inter-observer correlation was excellent, with kappa values of 0.97 and 0.86, respectively. These values were consistent with those of Bassed, who reported a kappa of 0.94 for intra-observer variability and of 0.84 for inter-observer variability. Moreover, in our study the inter-observer correlation was high between the findings of the radiologist and the forensic physician, indicating that the technique is reliably applicable to both types of readers.

One of the limitations of our study could be the a priori selection of 50 patients for the intra- and inter-observer variability measurement, whereas only about 30 were finally analyzed because 20 patients were too young. This choice was deliberate in order to avoid selection bias in the tooth staging process. Therefore, to obtain at least 25 teeth for analysis (as often reported), we deliberately opted to focus on 50 randomly selected patients. Finally, we analyzed more than 30 patients whereas Bassed RB, et al. [8] only analyzed 25.

A further shortcoming of our study was the small number of patients, and especially the high number of patients that were too young to be classified according to Demirjian tooth developmental stages, as well as the under-representation of women (only 20%). It is commonly recognized that gender can significantly influence the staging results, e.g. as reported by Knell B, et al. [9] concerning 1,260 orthopantomograms, Gunst K, et al. [10] for 2,500 orthopantomograms and Kasper KA, et al. [11] for 950 orthopantomograms, who noted earlier dental development in men. However, there was no significant difference between males and females in our study, which was not designed to evaluate patient ages but rather to compare the two imaging procedures (CT scanning and orthopantomogram). Moreover, less than 5% of forensic age assessments concern female subjects, according to the 2019 annual report of the French Department of Justice.

A major advantage of CT scanning is the possibility of analyzing molars 18 and 28, which are not always clearly viewed on orthopantomograms when molars 38 and 48 are absent. Despite the fact that Kasper KA, et al. [11] found a difference in maturation between mandibular and maxillary molars in their study, we consider that CT scan is an accurate imaging option for staging maxillary molars using the Demirjian method in the absence of mandibular molars.

Although our study was retrospective and did not aim to assess ionizing radiation exposure, it remains a major issue. Recent technical advances (e.g. deep learning, artificial intelligence and iterative reconstruction) enables the operator to lower the radiation dose of CT acquisitions, which is very similar to that delivered in orthopantomography [12,13]. Cone beam CT is another technique often used in dental imaging, but this technology is not often available in imaging departments, contrary to CT scan, which is present in almost all the imaging departments close to a forensic medicine service.

The findings of this study validated the efficacy of CT for the classification of wisdom tooth mineralization according to the Demirjian technique in living individuals.

A retrospective study is currently ongoing, including only mandibular CT scans in living individuals of known age so as to be able to correlate age and Demirjian stages.

Conclusion

This study revealed that, in comparison to panoramic dental X-ray, CT scan is a valid technique for the evaluation of mineralization of mandibular third molars according to Demirjian stages. This imaging technique could thus be proposed for bone age assessment.

Trial Registration Number

IRB-MTP_2020_11_202000615; 19 NOV 2020 retrospectively registered. ClinicalTrials.gov Identifier: NCT04907552.

Conflict of Interest

The authors have no competing interests to declare that are relevant to the content of this article.

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