Morphologic Analysis of Third-Molar Maturity by Digital Orthopantomographic Assessment

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Abstract: Accurate timing of the eruption of first and permanent teeth is an important parameter in forensic odontology to establish the age of dead or live individuals. Determination of adulthood may determine, for example, whether an individual convicted of a crime is sentenced as an adult and incarcerated in a state penal institution or as a juvenile and sent to a juvenile camp. At present, there is a large immigrant population in Italy, and young foreign criminals sometimes have false passports bearing a later birth date, with the aim of evading punishment. In such circumstances, age determination is becoming a significant forensic issue.

Late in adolescence, after formation of the premolars and canines, only the third molars continue to develop. According to several studies, although the third molars are the most variable teeth in the dentition, they remain the most reliable biologic indicator available for estimation of age during the middle teens and early twenties.

In this study, the authors test the possibilities offered by orthopantomography executed by means of digital technology, with the aim of exploiting the advantages of the computerized digital technique compared with the conventional technique, to determine adult age on the basis of root development of the third molar.

Digital radiography is simple to use, quick, and effective, allowing superimposition and enlargement; the images can be electronically stored and transported. In comparison with traditional orthopantomography, the digital technique features greater diagnostic accuracy of some anatomic structures: upper and lower front teeth, root apexes, floor of the nasal fossa and maxillary sinus, nasal septum, mandibular condylus. Moreover, digital orthopantomography suffers less from artifacts.

The digital orthopantomographies of 83 Caucasian subjects (43 females and 40 males) aged between 16 and 22 years were analyzed in standard conditions, assessing the degree of maturation of the upper and lower third molars. A standardized computer procedure was used to acquire the x-ray images, recording 3 per plate: the overall orthopantomography and 2 enlargements of optical type of the left and right sides, to reveal the third molars while maintaining unaltered the image resolution.

For the analysis, the authors adopted Demirjian's staging system that classifies development of the third molar in 8 stages (A, B, C, D, E, F, G, H) on the basis of morphologic criteria. This has been statistically proved to feature notable precision and high predictive ability.

To assess any sex-related variations in mineralization speed, the series was subdivided by gender. The study demonstrated that such differences are more evident under the age of 18 years.

Overall, the observation of 245 third molars showed faster development of the upper than the lower third molars, a prevalence of stages D to G in the age range between 16 and 18 years, and a clear predominance of stage H in individuals over 18 years of age. Finally, an intermediate stage between G and H was demonstrated in subjects aged between 17 and 21 years.

Key Words: forensic odontology, digital radiology, third molar

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Apart from their ease of use, the adoption of sophisticated information technologies in the clinical field has yielded a greater diagnostic precision. This is why they are now being employed in medicolegal research, too, and the integration of innovative procedures with traditional techniques for such operations as personal identification can speed up data processing, as well as increase the precision and reliability of the information obtained. This has contributed to improved operations in a number of sectors in the medicolegal field, including forensic dentistry, the first and foremost procedure on which personal identification investigations rely, in both live subjects and cadavers. We have only to consider the rich variety of data that can be obtained from a detailed analysis of the dental formula in cadavers in an advanced stage of decomposition, such as victims of mass disasters, for instance, and indeed in all cases in which the body is virtually unrecognizable due to natural phenomena or external parasitism and aggressive agents. Detailed examination of the teeth can provide useful information about the subject's age, lifestyle, socioeconomic background, general health, and oral cavity. In the case of unidentified persons, if past clinical documentation (x-rays, dental records) of the subject when alive is available, it is often possible to confirm or exclude a suspected identity on the basis of analysis of the dental formula.

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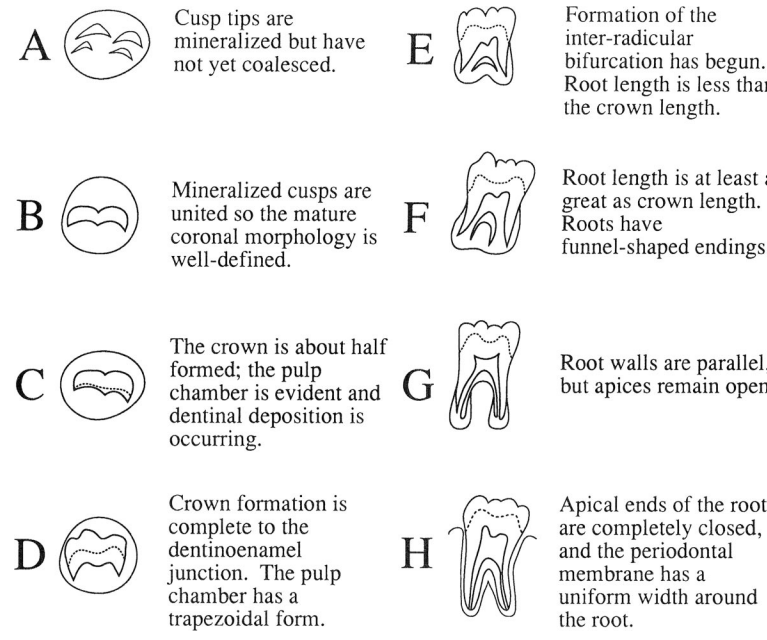

FIGURE 1. Demirjian's 8-stage classification (from Demirjian et al, 1973, modified).

Recourse to "traditional" orthopantomography (OPT) is a consolidated technique, together with radiography of the wrist bones, iliac crest, etc, in such cases as assessment of the degree of skeletal maturity in young non-EU citizens who lack identifying documents or wish to conceal their true age. On these premises, it is clearly extremely useful to revise past identification techniques in the light of the possibilities offered by modern technologies. The aim of our study was to test the possibilities of use of digital OPT to determine whether subjects have reached legal adulthood on the basis of morphologic analysis of the development of the third molar.

The focus was on the stage of maturity of the wisdom teeth because these are the only teeth to continue root growth after the age of 16, by which time apex closure is completed in all the other teeth.[1] Although many studies have been conducted of the stage of development and age of eruption of the teeth, relatively few have concentrated on the third molars, due to the lack of a universally accepted staging system of these teeth, characterized by their atypical morphology and development.[2–9]

The pioneers of radiologic studies for estimating age on the basis of the teeth were Logan and Kronfeld[10] in 1933, who drew up a scheme of the development of human dentition, both deciduous and permanent. This was expanded in 1940 by Shour and Massler[11] in a sample of subjects aged between 1 and 15 years. Additional contributions were made by Glaiser and Hunt,[12] who studied the development of the first lower molar, individuating 13 stages; later, Nolla[13] in 1960 and Moorrees and colleagues[14] in 1963 drew up graphs and tables to assist the estimation of the dental age of a subject.

Research in this field was continued by Liliequiest and Lundberg,[15] Haavikko,[16] and many other authors; Johanson[17] and Demirjian et al[18] were the first to study the third molar, correlating stages of maturity with different ages. Notably, Demirjan subdivided the development of wisdom teeth into 8 steps (A–H), as shown in Figure 1. On the basis of the results of his research, Demirjian concluded that wisdom teeth in the early stages of maturity (A, B, C, D) belong to subjects under the age of 18, while the last stage (H) corresponds to legal adulthood. Estimation of age was found to be rather more complex for the intermediate stages (E, F, G).

Work on the third molars to determine age was continued by other authors, including Kullman et al,[3] Mincer et al,[6] and, in Italy, Portigliatti Barbos et al,[9] who studied 3 dental elements (48, 47, 45) in each of their subjects aged between 12 and 22 years, and Pinchi et al,[7] who looked only at the third molar and based their research on Demirjian's classification. The results obtained in the latter study confirmed the correspondence between legal adulthood and stage H of development of these molars. The above research was all based on the observation of OPT obtained using traditional techniques; in our study, we have chosen to exploit the advantages of digital technology.

In radiology, digital images are acquired by replacing the classic radiographic film with a matrix of radiation-sensitive detectors. While in analogical imaging the number of tones depends on the type of film (high or low latitude) and the power of the ray (the greater the power, the greater the number of greys), in digital imaging the tones depend on the "pixel depth," ie, the number of bits composing the pixel. Moreover, computer processing yields extremely precise diagnostic information because the image can be magnified and filtered down to the smallest level of detail, obtaining greater resolution and contrast values and thus widening the field of diagnosable alterations by about 70%.[19]

TABLE 1. Total Orthopantomography Examined (Males and Females, Age 16–22)

No.	Age	Stage Upper Right Third Molar	Stage Upper Left Third Molar	Stage of Lower Right Third Molar	Stage of Lower Left Third Molar
1	16	G	G	F	F
2	16	Absent	G	G	G
3	16	G	G	F	G
4	16	G	G	G	G
5	16	F	G	G	G
6	16	E	E	D	D
7	16	G	G	F	E
8	16	F	F	F	F
9	16	F	F	F	F
10	16	F	G	F	G
11	16	E	E	E	E
12	16	F	F	F	F
13	16	E	E	E	E
14	16	F	F	F	F
15	17	E	E	Absent	D
16	17	E	E	E	Absent
17	17	Not assessable	Not assessable	F	F
18	17	Not assessable	Not assessable	G-H	G
19	17	Not assessable	Not assessable	G	G
20	17	D	D	Absent	Absent
21	17	E	E	Absent	E
22	17	G	G	Absent	D
23	17	F	F	F	E
24	17	E	E	Absent	F
25	17	Not assessable	Not assessable	E-F	E
26	17	Not assessable	Not assessable	F-G	G
27	17	G	G	F	E-F
28	17	G	G	G	G
29	17	E	E	E	E
30	17	G	G	G	G
31	17	G	G	G	G
32	17	G	G	G	G
33	17	G	G	G	G-H
34	17	G	G	F	F
35	18	G	G	G	G
36	18	H	H	H	H
37	18	H	H	G-H	H
38	18	H	H	G	G
39	18	H	H	H	H
40	18	H	H	G	G
41	18	H	H	G	G
42	18	H	H	G	G
43	18	H	H	G	G
44	18	Not assessable	Not assessable	G	G-H
45	18	Absent	Not assessable	G	F-G
46	18	H	H	Absent	Absent
47	18	Not assessable	Not assessable	F	G
48	18	G	G	G	G
49	19	Not assessable	Not assessable	E	E
50	19	Not assessable	Not assessable	G	G
51	19	H	H	H	H

(*Continued*)

TABLE 1. (*Continued*)

No.	Age	Stage Upper Right Third Molar	Stage Upper Left Third Molar	Stage of Lower Right Third Molar	Stage of Lower Left Third Molar
52	19	Not assessable	Not assessable	H	G-H
53	19	Absent	Absent	Absent	Absent
54	19	Not assessable	Not assessable	E	E
55	19	Absent	Absent	Absent	Absent
56	19	H	H	H	H
57	19	H	H	G-H	H
58	19	H	H	H	H
59	19	H	H	H	H
60	19	H	H	H	H
61	20	H	H	H	H
62	20	H	H	H	H
63	20	H	H	H	H
64	20	Absent	Absent	Absent	Absent
65	20	Not assessable	Not assessable	H	G
66	20	H	H	H	H
67	20	H	H	H	H
68	20	H	H	H	H
69	20	H	H	H	H
70	20	Not assessable	Not assessable	G-H	H
71	20	H	H	H	H
72	21	H	H	H	G-H
73	21	H	H	H	H
74	21	H	H	H	H
75	21	H	H	H	H
76	22	H	H	H	H
77	22	H	H	H	H
78	22	H	H	H	H
79	22	H	H	H	H
80	22	H	H	H	H
81	22	H	H	H	H
82	22	H	H	H	H
83	22	H	H	H	H

To analyze whether there were any sex-linked variations in the speed of mineralization (Tables 2 and 3), we subdivided our series by sex, concentrating exclusively on the stage of the lower third molars for the reasons outlined above.

MATERIALS AND METHODS

Our research was based on the observation of digital OPT images, which allow greater diagnostic accuracy than traditional imaging of various anatomic structures: the upper and lower frontal incisors, the root apexes, the floor of the nasal fossa and maxillary sinus, the nasal septum, the mandibular condyle. Moreover, digital OPT is less disturbed by noise (eg, false radiotransparency) and overlapping shadow (eg, projections of the cervical vertebrae onto the frontal sectors).

The digital orthopantomographies of 83 Caucasian subjects (43 females and 40 males), aged between 16 and 22 years (age confirmed by identity card), were analyzed in standard conditions to assess the degree of maturity of the upper and lower third molars. The Villa model "Strato X" orthopantomograph was used, with exposure time set at 12 seconds per radiograph. Image processing was done with the aid of the Vips 202 program, and previewing, with Agfa Windows NT software. The x-ray images were then transferred to single emulsion films. Standardized data collection was then performed with dedicated Pentium III software and an AV Master digital audio-video card that does not affect the standard of resolution.

For this purpose, an IFF Super Repro stative was used, equipped with a backlit plane where the radiographs were positioned. A Sony digital video camera, model DCR-TRV 17 E, was mounted on the stative, with Carl Ziess-Sonnar 1.7/3.3–33 optics, maintaining a distance of 78.5 cm between the lens and the focal plane.

Three acquisitions were made per radiograph: an overall view of the orthopantomograph and 2 magnifications (right and left), showing the third molars and surrounding regions. To assure unaltered resolution, magnification was of optical type, and the macrophotography option was not used to avoid image distortion. After acquiring all the films, each OPT was analyzed, paying particular attention to the magnifications of the right and left hemimandible. We elected to use Demirjian's staging system, which subdivides develop-

ment of the third molar into 8 stages, according to morphologic criteria. This has been found to yield statistically significant precision and a high predictive power,[18] unlike other classifications, such as Nolla's[13] which, as reported in other studies,[8] subdivides development of the third molar into poorly defined stages that are not easy to assess in the OPT.

A total of 245 teeth were observed, although in cases where all 4 wisdom teeth were present, we preferred to focus on the lower ones (totalling 151) because the apexes are more evident. In fact, in the upper arch the wall of the maxillary sinus hides the apex of the third molars, making it more difficult to interpret intermediate stages of development. In 5 cases, this examination could not be performed, because the lower third molars were missing.

RESULTS

Close examination of each OPT yielded the results listed in Table 1.

To analyze whether there were any sex-linked variations in the speed of mineralization (Tables 2 and 3), we subdivided our series by sex, concentrating exclusively on the

TABLE 2. Stages of Development of the Lower Third Molar in Female Subjects

Age	Stage of Lower Right Third Molar	Stage of Lower Left Third Molar
16	D	D
16	E	E
16	F	F
16	E	E
16	F	F
17	E–F	E
17	F–G	G
17	Absent	D
17	E	Absent
17	F	F
17	G	G
17	G	G–H
17	F	F
17	G–H	G
17	G	G
17	Absent	Absent
17	Absent	E
18	G	G–H
18	F	G
18	G	G
18	F–G	G
18	G–H	G
18	G	G
19	E	E
19	G–H	H
19	H	H
19	G	G
19	H	H
19	H	G–H
20	H	H
20	Absent	Absent
20	H	G
20	H	H
20	H	H
20	G–H	H
20	H	H
21	H	G–H
21	H	H
22	H	H
22	H	H
22	H	H
22	H	H
22	H	H

TABLE 3. Stages of Development of the Lower Third Molar in Male Subjects

Age	Stage of Lower Right Third Molar	Stage of Lower Left Third Molar
16	G	G
16	G	G
16	F	G
16	G	G
16	F	F
16	F	E
16	F	F
16	F	F
16	F	G
17	E	E
17	Absent	D
17	F	E
17	Absent	F
17	F	E–F
17	G	G
17	G	G
17	G	G
18	G	G
18	Absent	Absent
18	H	H
18	G–H	H
18	G	G
18	H	H
18	G	G
18	G	G
19	Absent	Absent
19	H	H
19	H	H
19	E	D–E
19	H	H
19	Absent	Absent
20	H	H
20	H	H
20	H	H
20	H	H
21	H	H
21	H	H
22	H	H
22	H	H
22	H	H

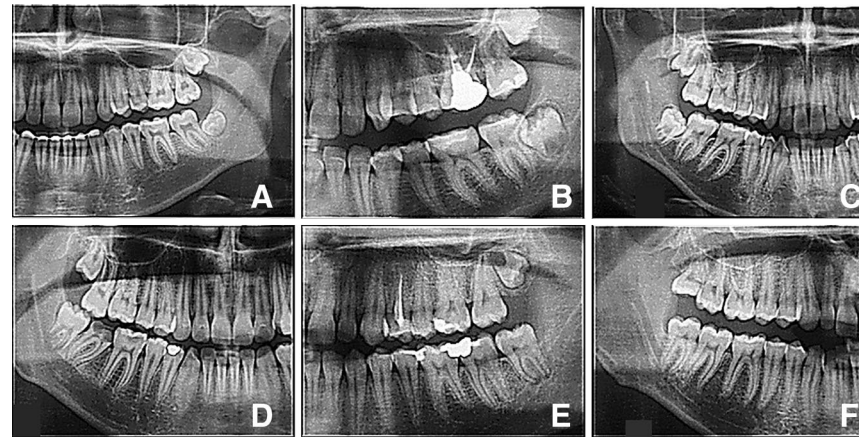

FIGURE 2. Examples of the stages of development on the magnifications of digital orthopantomographies. A, Stage D; B, stage E; C, stage F; D, stage G; E, stages G–H; F, stage H.

stage of the lower third molars for the reasons outlined above. Our study demonstrated that differences between the 2 sexes appear to be most evident under the age of 18 years, when female subjects have a higher percentage (65.5%) of early maturity stages (D, E, F) (Fig. 2) and hence a slight maturation delay as compared with male subjects (53%). This observation shows that the third molars behave differently from other teeth, which mature and erupt earlier in female subjects. Over the age of 18, no relevant differences were observed between the 2 sexes. This is in agreement with findings by other authors.[8,20,21]

Overall, our results for the age range between 16 and 18 years showed a prevalence of stages D to G in both sexes. By the age of 18, stage G (Fig. 2) was clearly preponderant (73%). At 19 years of age, stage H was prevalent (60%), although some teeth were still in stages E (20%) and G (10%) (Fig. 2). Instead, between 20 and 22, there was a marked predominance of stage H (93%) (Fig. 2). Notably, in our study we observed the presence of an intermediate stage between G and H (6.6%) in subjects aged between 17 and 21 years, featuring an initial but not complete mineralization of the root apex (Fig. 2). Finally, it was interesting to see that under the age of 18 the upper third molars show faster development than their lower counterparts. In other words, in subjects of 16 and 17, in whom the upper third molars were easily observable, a more advanced stage of maturity was apparent in 24% of cases (Table 1).

CONCLUSIONS

Our results confirm the utility of analysis of the stage of maturity of the third molars by means of digital OPT as a means of estimating skeletal age. In our case series, despite a few exceptions, there was a clear correspondence between the stage of mineralization of the wisdom teeth and the subject's age. This was particularly evident in subjects over the age of 18, when stage H is predominant in both males and females (93%).

Delayed maturation of the root, which could result in underestimation of the subject's age, was only exceptionally observed, whereas complete closure of the apex before the age of 18 was not observed in any case. This is an extremely important point because it shows that there is little danger of overestimating the age of a subject. The method can therefore be considered, without indulging in overoptimism, a valid aid in estimating legal adulthood. In fact, in our series there was complete maturation of the third molars in 93% of subjects over the age of 18. For this reason, it can reliably be assumed that individuals showing complete mineralization of the third molar on x-rays are over the age of 18. However, it is well to remember that other analyses should, if possible, also be performed to obtain a more precise estimate of age by associating OPT with the most commonly used anthropometric markers.[21,22]

Finally, the advantages of digital OPT for dental analysis must be acknowledged. Far better levels of resolution and contrast are obtained than with traditional radiology, facilitating the interpretation of the root development phases and often resolving doubts as to whether or not there is complete closure of the apex.

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