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Radiographic Survey of Third Molar Development in Relation to Chronological Age Among Japanese Juveniles

ABSTRACT: The aim of the present study was to establish Japanese reference material on the third molar development of Japanese juveniles for forensic application. Observations were performed on the orthopantomograms of 1282 Japanese patients between the ages of 14.0 and 24.0 years. Demirjian formation stages of the maxillary and mandibular third molars were recorded for chronological evaluation of wisdom teeth and applied for further statistical analysis. Statistically significant differences were noted between the upper and lower jaws and genders. Accordingly, males achieved root developmental grades earlier than females. We assessed the mean ages for all formation grades and predicted the probability that a Japanese juvenile would be older than the relevant ages of 14, 16, and 20 as defined by Japanese Juvenile Law. We determined the likelihood that a Japanese youth is older than the relevant age of 18 as defined by legislation in the United States.

KEYWORDS: forensic science, third molar, dental development, Japanese juvenile, chronological age

Teeth represent useful material for age estimation. In childhood, the observation of the dentition status results in highly accurate age assessment. However, this accuracy decreases simultaneously with the completion of a person's dental development (1). For the juvenile age group, basically two methods of age evaluation are available: the morphological examination of skeletal features and radiological examination of the development of third molars (2). Nevertheless, the applicability of third molars for dental age estimation has been reflected in the relevant literature as an often-debated, questionable method (3,4).

In general, the morphological and radiological examinations of third molars make up a part of the orthodontic, pedodontic, and oral surgical treatments and provide valuable information for the clinicians. From the aspect of the forensic odontologist, reliability and adequate precision of age determination using third molars is crucially important. Uncertainties emerge mainly from the remarkable biological variability of the third molars among all the permanent teeth and also from the significant individual differences in the developmental pattern of the wisdom teeth. Discrepancies have also been observed between the growth of the maxillary and the mandibular third molars (5,6). Moreover, variable estimates of dental age (7–9) as well as different frequencies of agenesis (10,11) were reported between ethnic groups. The development of wisdom teeth shows remarkable diversity among different ethnic groups, and thereby the elaboration of maturity standards based on various populations has been suggested for forensic purposes (12). Additionally, difficulties in the estimation of crown or root developmental stages may arise from the effect of subjectivity (13) inherent in the applied surveillance technique. On the other hand, other researchers report that even through objective, metric measurements of the root length, better precision in age estimation could not be produced (14). Nevertheless, third molars are still at the center of medicolegal interest because, except from the already-mentioned method of skeletal examination, no other precise method for estimating the adolescent ages is available.

Recently, for different ethnic groups, numerous reports have been published on the evaluation of third molar development (15,16) and further studies were warranted for Oriental populations (17). Hence, the present study aimed to meet this demand and to add reference data for forensic application about third molar formation among Japanese juveniles. Therefore, in this retrospective study, we decided to evaluate the recent trends in third molar growth and to determine the useful dental age limits defined for the wisdom teeth development in the Japanese population. From a medicolegal aspect, we decided to estimate the probability of an adolescent being older than the relevant ages of 14, 16, and 20 years as determined by Japanese Juvenile Law. Assessment of the likelihood of whether an adolescent is older than 18 years, which indicates adulthood status in the United States, was also made.

Materials and Methods

The material consisted of 1282 orthopantomograms taken at the Division of Dentistry and Oral Surgery, Akita University Hospital, Akita, Japan, in the period from 1995 to 2003. This research comprised 596 (46.5%) male and 686 (53.5%) female patients of Japanese origin, aged from 14.0 to 24.0 (mean of 19.6) years. Table 1 presents the age and sex distribution in detail. Patients only with no existing disease affecting the formation of wisdom teeth were included in the study.

Radiographs of adequate quality were evaluated using an X-ray viewer for improved visualization. To assess the developmental stages of third molars from both sides of the maxilla and mandible, the classification system described by Demirjian et al. (18) was adopted. The scores were determined by two observers who had previously not established agreement concerning reference panoramic radiographs on the classification of teeth. Therefore, individual

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TABLE 1—*Distribution of subjects by gender at different ages.*

Age:	14	15	16	17	18	19	20	21	22	23	24
Male	40 (3.1)	35 (2.7)	43 (3.3)	43 (3.4)	53 (4.1)	58 (4.5)	57 (4.4)	72 (5.6)	70 (5.5)	61 (4.7)	64 (5.0)
Female	41 (3.2)	41 (3.2)	60 (4.7)	57 (4.4)	54 (4.2)	66 (5.2)	66 (5.2)	76 (5.9)	84 (6.5)	78 (6.1)	63 (4.9)
Total	81 (6.3)	76 (5.9)	103 (8.0)	100 (7.8)	107 (8.3)	124 (9.7)	123 (9.6)	148 (11.5)	154 (12.0)	139 (10.8)	127 (9.9)

Numbers in parentheses represent percentages.

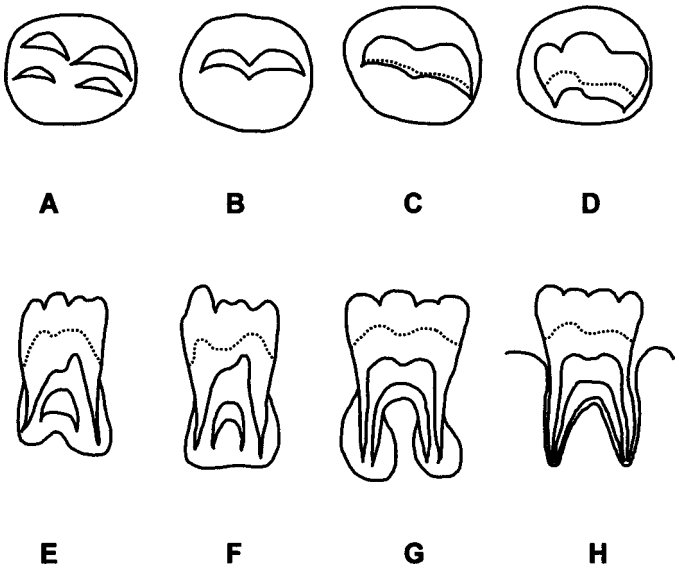

FIG. 1—*Schematic drawings of the eight formation stages of tooth development (modified from Demirjian et al.).*

differences in the examination were included intentionally in order to evaluate the variation between independent observers. Intra-examiner reliability was tested by repeated evaluations of 100 orthopantomograms at intervals of two months. Eight stages (from "A" to "H") plus "0", indicating the case of absence, were recorded from the four wisdom teeth of each subject (Fig. 1).

The mean age for developmental stages and characteristic cut points for dental age among Japanese juveniles were calculated. The prevalence of third molars in the four quadrants was also determined in order to estimate the frequency of missing teeth. Since the assessment of different formation stages was completed on the ordinal scale, comparisons between genders, between the upper and lower arches, and between both sides were obtained using the Mann-Whitney U test and Wilcoxon test, respectively. Inter- and intra-observer agreements were determined using the Wilcoxon matched-pairs signed-ranks test. Statistical analysis was performed using the SPSS 11.0 package (SPSS Inc., Chicago, IL) for Windows.

Results

Statistical analysis did not reveal significant intra-observer differences by repeated scoring of a subsample of 100 radiographs ($P > 0.05$). Inter-observer agreement was found to be 81.5% for maxillary and 85% for mandibular wisdom teeth. However, regarding the remaining disagreement cases, a significant difference existed between the two raters (teeth 18, $P = 0.005$; teeth 28, $P < 0.001$; teeth 38; $P < 0.001$, teeth 48; $P = 0.004$). Therefore, in the subsequent analysis for pooling, the lower scores were chosen.

TABLE 2—*Numbers of observed third molars in upper and lower jaws including all formation stages.*

Tooth	N	18	28	38	48
Male	595	438 (73.5)	444 (74.5)	502 (84.2)	503 (84.2)
Female	686	491 (71.6)	482 (70.3)	568 (82.8)	580 (84.5)

Percentages are indicated in parentheses.

The percentages of existence of third molars are detailed in Table 2. Subjects with four wisdom teeth comprised 740 (57.7%) out of 1282 patients. Both maxillary third molars were observed in 65.5% of the patients, and both mandibular third molars were recorded in 78.4% of the patients. Gender differences regarding missing third molars were not recognized; 6.6% of the subjects showed no signs of any third molars. Missing upper or lower third molars on both sides were found in 20.8% and 10.5% of the cases, respectively.

The formation process of third molars was examined in the both sexes and the mean ages for Demirjian stages ("A," "B" stages were evaluated as insignificant) are described in Table 3. Significant differences ($P < 0.05$) in third molar development between males and females regarding the calcification stage "G" (18, 28, 38, 48), "E" (38, 48) and stage "D" (28) were revealed. These differences indicated that third molar genesis in males attained the above-mentioned formation stages at least eight months earlier than in the females. In addition, more than a half-year (not statistically significant) delay was recognized in females for the "E" and "F" stages (except the "F" stage for 18).

Mineralization of wisdom teeth was compared between the right and the left sides using the Wilcoxon test, although a difference between the two sides was not detected. Considerable variation was obtained by the comparison of the maxillary and mandibular arches (Table 4) and more advanced calcification was observed on the maxillary third molars.

Meaningful landmarks in tooth formation, such as the crown completion (stage "D"), the root length completion (stage "G"), and the apical closure (stage "H") were defined for Japanese juveniles. Percentile distributions by age of the patients with these formation stages are indicated in Fig. 2. According to our data for stage "D," around 75% of the males and 70% of the females were found in the age group under 16 years. For stage "G," approximately 60% of the males and 50% of the females were in the age group between 18 and 20 years. Among the patients categorized in stage "H," around 70% of the male and 75% of the female patients were in the age group over 21 years.

Further investigation included determining the probability of a Japanese juvenile being under 14, 16, 18, and 20 years of age based

TABLE 3—*Mean ages (with 95% confidence intervals) of Demirjian's stages assumed from Japanese juveniles.*

	Male				Female			
	18	28	38	48	18	28	38	48
C	**14.5** (14.0–15.0)	**...**	**14.8** (14.2–15.4)	**14.7** (14.0–15.6)	**15.7** (14.0–16.3)	**14.9** (14.0–16.2)	**14.7** (14.1–15.2)	**14.8** (14.1–15.4)
D	**15.8** (15.1–16.5)	**15.3** (14.8–15.8)	**15.4** (14.9–15.8)	**15.9** (15.2–16.6)	**15.8** (15.5–16.2)	**16.1** (15.7–16.5)	**16.0** (15.6–16.4)	**16.1** (15.7–16.5)
E	**16.6** (16.0–17.1)	**16.8** (16.1–17.5)	**16.4** (15.8–17.1)	**16.3** (15.7–16.9)	**17.1** (16.6–17.6)	**17.4** (16.9–18.0)	**17.3** (16.9–17.8)	**17.2** (16.8–17.6)
F	**18.3** (17.7–19.0)	**18.1** (17.5–18.8)	**17.4** (16.8–18.0)	**17.2** (16.6–17.8)	**18.6** (18.0–19.2)	**18.6** (17.9–19.3)	**18.3** (17.6–19.1)	**18.1** (17.3–18.8)
G	**18.5** (18.0–18.9)	**18.5** (18.0–19.0)	**18.6** (18.2–19.0)	**18.7** (18.3–19.2)	**19.3** (18.8–19.8)	**19.5** (19.0–20.0)	**19.4** (19.0–19.8)	**19.4** (19.0–19.9)
H	**21.4** (21.2–21.7)	**21.5** (21.3–21.7)	**21.6** (21.4–21.9)	**21.6** (21.4–21.8)	**21.7** (21.5–22.0)	**21.7** (21.5–21.9)	**21.8** (21.6–22.0)	**21.8** (21.6–22.0)

TABLE 4—*Comparison of third molar development in upper and lower jaws (Wilcoxon test).*

	Male, $n = 596$				Female, $n = 686$			
Tooth	18	38	28	48	18	38	28	48
Mean	5.01	5.83	5.13	5.84	4.64	5.37	4.58	5.51
SD	3.29	2.89	3.27	2.88	3.26	2.86	3.28	2.81
Z	−5.64		−4.77		−5.75		−7.67	
P	0.001		0.001		0.001		0.001	

on third molar development. The probabilities sorted by gender and arches are summarized in Table 5. The data showed that for most of the stages males reached the indicated ages earlier than females, and that the probabilities differ also between the maxilla and mandible.

The accuracy of age estimation based on this method was calculated by average differences between the chronological age and the predicted age (computed from the degree of tooth development). The mean difference expressed in absolute value was 1.6 years for both sexes with 1.2 years standard deviation.

Discussion

Age estimation for medicolegal purposes (age at death, criminal law cases, legal matters, adult status establishment, etc.) represents a fundamental problem, and various methods have been established for age determination. Numerous reports have been published on the age estimation issue concerning adolescents and young adults in which the assessment of third molar development was frequently investigated. Although the reliability of third molars in age estimation has been evaluated by several research groups, consensus on the usefulness of these teeth has not been reached. As concluded by Mincer et al. (19) in the A.B.F.O study, the examination of third molars may provide reasonable accuracy for the likelihood that a person is at least, e.g., 18 years old, instead of the estimation of exact chronological age. Therefore, in our survey, we investigated the probability of a Japanese adolescent being older than the useful age cut points, 14, 16, and 20 years, as described by Japanese Juvenile Law. According to our findings, the recognition of earlier stages in teeth development up to and including crown completion ("A," "B," "C," "D" stages) indicates that the person in question is younger than 20 years and would therefore fall under juvenile legislation. Besides, when the root formation is sufficiently advanced to reach the length of the crown length ("F" stage), the likelihood is around 97% that the person is at least 14 years old and, in this case, could be subject to criminal liability. When third molar development has already been completed ("H" stage), the probability that the juvenile is at least 16 years old is 99% certain, which is crucial because those over the age of 16 are subject to criminal punishment. The likelihood that the person of Japanese origin reached 18 years of age and therefore would be considered as an adult in the United States was also calculated. Nevertheless, caution may be necessary in the application for forensic practice since these probabilities were constructed on a representative survey. Extremities in the degree of third molar formation might be observed occasionally, which could yield misleading results. For clarity, "A" and "B" stages, which indicate the very early phase in the crown calcification, were observed for 19 cases with an age range from 14 to 18 years in our investigation, despite the previously suggested upper age limit of 13 for third molar genesis by Gravely (20).

As previously indicated, questions accompany the application of third molars in age estimation because of the arguable accuracy. The observed accuracy of the current study was highly concordant with the reported values by other authors (17,19). Hence the unreliable, large difference between chronological age and predicted age may result in imprecise age determination using solely third molar developmental stages.

Since previous studies which investigated gender differences showed rather diverse results, we examined the mean ages of each stage for male and female patients. Our data strongly indicated that wisdom teeth formation in the males had more than six month's advancement in the "E," "F," and "G" stages than in the females. This observation is consistent with the study performed by Gunst et al. (4) for patients of Belgian Caucasian origin, by Solari et al. (17) for Hispanic patients, and by Kullmann et al. (14) for Scandinavian patients. In addition, based on our data for Japanese patients, gender difference seems to be fairly equalized before root completion.

Regarding the often-described asymmetry between upper and lower arches, the present work demonstrated that, similar to other populations such as Scandinavians or Belgian Caucasians, the wisdom teeth of Japanese adolescents exhibit different degrees of development between the maxilla and mandible. Thus, these differences should be considered in the forensic investigation. However,

TABLE 5—*Probabilites of a Japanese juvenile being older than 14, 16, 18, and 20 years, estimated by third molar radiological examination.*

Age (years)		Formation Stages									
		D		E		F		G		H	
		Maxilla	Mandible	Maxilla	Mandible	Maxilla	Mandible	Maxilla	Mandible	Maxilla	Mandible
Over 14	Male	79%	84%	90%	86%	97%	97%	99%	99%	99%	99%
	Female	86%	88%	91%	93%	98%	96%	99%	99%	99%	99%
Over 16	Male	46%	32%	60%	57%	85%	77%	93%	92%	99%	99%
	Female	45%	50%	62%	72%	87%	83%	93%	94%	99%	99%
Over 18	Male	16%	3%	23%	25%	56%	36%	61%	63%	97%	98%
	Female	9%	12%	24%	38%	60%	55%	72%	74%	99%	99%
Over 20	Male	3%	1%	4%	6%	23%	7%	18%	23%	78%	83%
	Female	1%	1%	4%	12%	27%	25%	36%	39%	85%	87%

differences between antimeres were not found, and these results were consistent with an earlier study on Japanese children by Daito et al. (21).

Considering the delicate role of existing third molars in medicolegal investigations for the transition ages between childhood and adulthood, we assessed the frequency of missing third molars in Japanese juveniles. Agenesis of each of the four third molars reached 7% in all the patients and, interestingly, maxillary agenesis was recorded with double frequency compared to mandibular agenesis. These results correspond to the reported frequencies regarding the absence of four wisdom teeth, despite the fact that the relevant literature shows a wide range of frequencies (11). Note that the observed higher frequency of agenesis in the upper jaw might support the suggestions of Kajii et al. (22), i.e., the different tendencies in third molar genesis in the maxilla and mandible between the Asian and European-American population. Additionally, from a general aspect, missing molars do not necessarily indicate congenital absence since the extraction of third molars, which is a widely performed clinical practice, must be taken into account also in forensic examination.

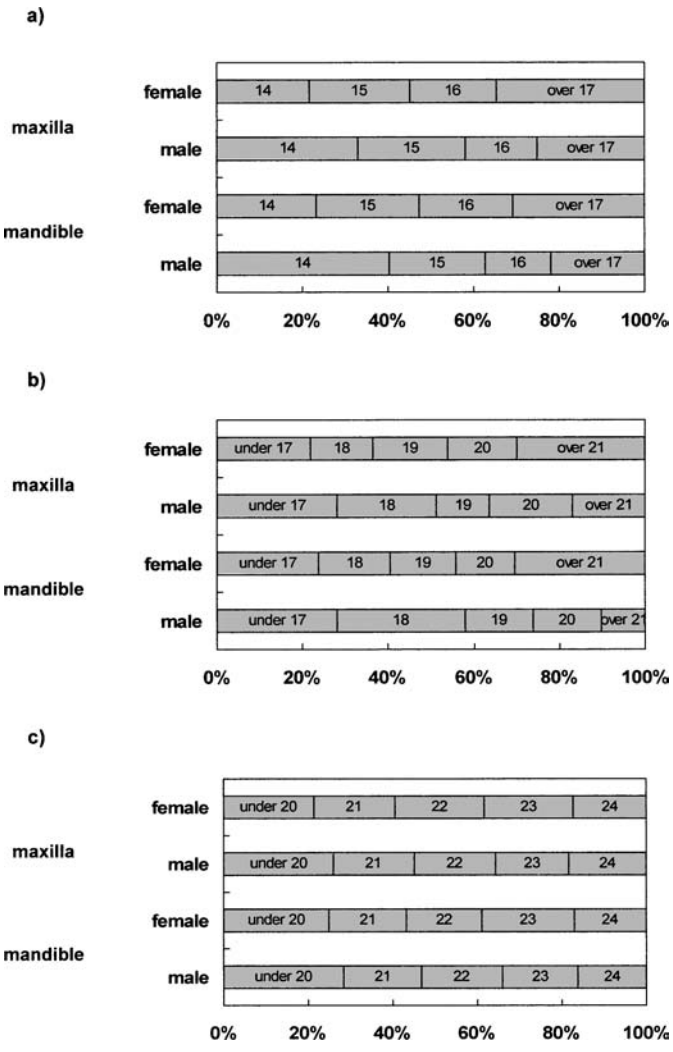

FIG. 2—*Age (years) distributions expressed in percentage within developmental stages: stage "D," crown completion* (a); *stage "G," root length completion* (b); *and stage "H," apical closure* (c).

In summary, considering the fact that only a few reports are available on Oriental populations, we conducted the present research to respond to the recently rising need of population-based information on third molar development. The described data may provide Japanese references for third molar examination for the purpose of forensic investigation. However, only limited conclusions can be drawn from a single study. The large numbers of criminal cases involving Japanese juveniles, which are increasingly being reported unambiguously, support the necessity of a larger, more comprehensive survey. Finally, this research has attempted to provide essential information concerning the sex-specific mean ages for each stage of tooth formation. The determined probability of a Japanese individual being younger or older than the relevant age cut points established for Japanese legislation might be valuable in future forensic practice. Since the age for legal prosecution varies according to country, the assessment of the probability of a Japanese youth being older than 18 years may prove also to be a valuable forensic tool outside of Japan.

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