Imaging Science in Dentistry 2014; 44: 185-91
http://dx.doi.org/10.5624/isd.2014.44.3.185

Radiographic evaluation of third molar development in 6- to 24-year-olds

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ABSTRACT

Purpose: This study investigated the developmental stages of third molars in relation to chronological age and compared third molar development according to location and gender.

Materials and Methods: A retrospective analysis of panoramic radiographs of 2490 patients aged between 6 and 24 years was conducted, and the developmental stages of the third molars were evaluated using the modified Demirjian's classification. The mean age, standard deviation, minimal and maximal age, and percentile distributions were recorded for each stage of development. A Mann-Whitney *U* test was performed to test the developmental differences in the third molars between the maxillary and mandibular arches and between genders. A linear regression analysis was used for assessing the correlation between the third molar development and chronological age.

Results: The developmental stages of the third molars were more advanced in the maxillary arch than the mandibular arch. Males reached the developmental stages earlier than females. The average age of the initial mineralization of the third molars was 8.57 years, and the average age at apex closure was 21.96 years. The mean age of crown completion was 14.52 and 15.04 years for the maxillary and the mandibular third molars, respectively.

Conclusion: The developmental stages of the third molars clearly showed a strong correlation with age. The third molars developed earlier in the upper arch than the lower arch; further, they developed earlier in males than in females. (***Imaging Sci Dent 2014; 44: 185-91***)

KEY WORDS: Radiography, Panoramic; Molar, Third; Development; Classification

Introduction

Third molar development has been used to estimate chronological age.[1-4] The third molar is of particular interest because it is the last and most variable tooth in the dentition.[5] Unlike other teeth, it does not form completely until puberty.[5] Radiographic examination of the third molar is important in estimating the age of individuals and treatment planning.[6,7] This examination is used to aid decision making about saving or removing the third molar and to determine the most suitable time for extraction if necessary.[3] As the third molar grows and its roots become longer, the tooth becomes more difficult to remove, and the likelihood of complications increases.[3]

Tooth development is a good parameter for estimating chronological age.[8,9] Of the methods tested, the most accurate results have been obtained with Demirjian's classification, which performed best in terms of the observer agreement and the correlation between the estimated and the true age.[10,11] Demirjian's classification system[12] distinguished eight stages of crown and root development (Stages A-H). Stages A, B, C, and D represented crown formation from the appearance of the cusp to the crown completion, and Stages E, F, G, and H showed representative root formations from radicular bifurcation to apical closing. The stages proposed by Demirjian were based on changes in shape rather than length measurements.[13]

According to Thevissen et al,[14] the estimation of dental age, particularly in young individuals, should be based on data collected from an appropriate population. Previous studies found that the mineralization of the third molars was a population-specific process and that it varied accord-

*This study was supported by Clinical Research Grant, Pusan National University Dental Hospital (2013).
Received February 15, 2014; Revised March 7, 2014; Accepted March 17, 2014
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ing to age in different ethnic groups.[15-17]

The purpose of this study was to investigate the developmental stages of the third molars in relation to chronological age and to compare the third molar development according to location and gender.

Materials and Methods

In this retrospective study, the study sample was chosen randomly from patients who visited Pusan National University Dental Hospital and underwent panoramic radiographic examination in 2011. Panoramic radiographs were excluded if there was obvious dental pathology related to the third molars or if the image of the area of interest was unclear.

The subject population included 2490 patients between 6 and 24 years (1273 males and 1217 females, mean age: 15.7 years). Each patient's age was determined on the basis of the difference between the date of birth and the date of the X-ray. The age and gender distribution of the study population is shown in Table 1. This study evaluated 7081 third molars on 2490 panoramic radiographs (Table 2). All panoramic radiographs were taken with a Proline XC (Planmeca Co., Helsinki, Finland).

The modified Demirjian's classification system was used

Table 1. Distribution of subjects according to gender and age

Age (years)	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Total
Male	83	68	79	56	55	64	40	54	54	41	62	71	105	76	63	92	68	73	69	1273
Female	45	37	45	58	51	47	56	46	68	75	67	72	97	87	80	77	71	69	69	1217
Total	128	105	124	114	106	111	96	100	122	116	129	143	202	163	143	169	139	142	138	2490

Table 2. Distribution of third molar analyzed

	Right maxilla	Left maxilla	Right mandible	Left mandible	Total
Male	844	834	953	931	3562
Female	812	824	950	933	3519
Total	1656	1658	1903	1864	7081

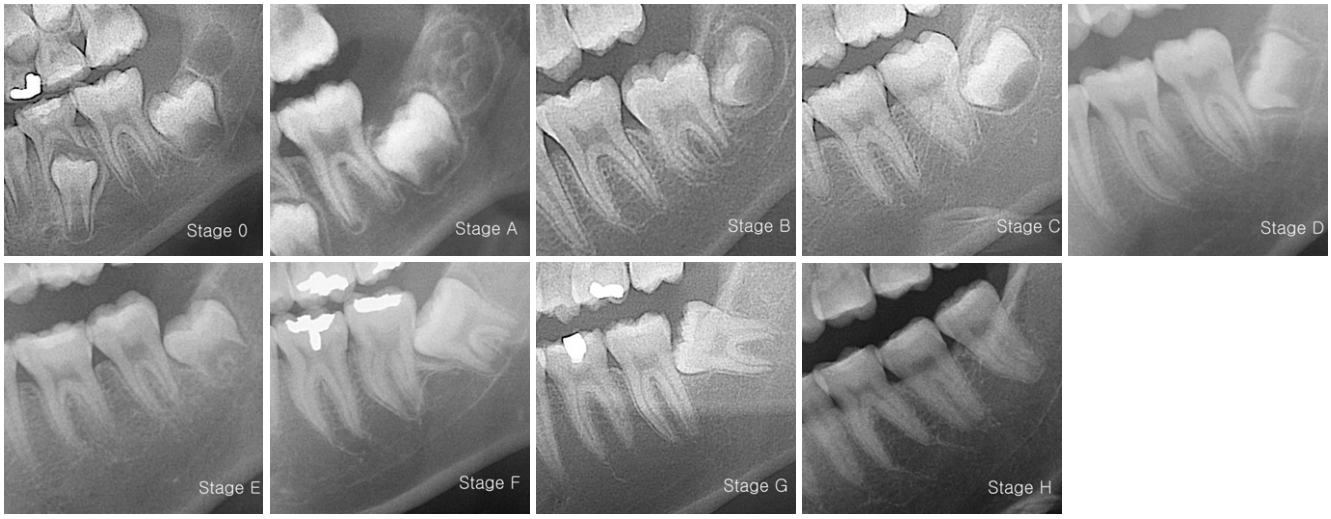

Fig. 1. Cropped panoramic radiographs show developmental stages of the third molars. Stage 0: Radiolucent bud with no calcification. Stage A: Cusp tips mineralized but not yet coalesced. Stage B: United mineralized cusps and well-defined mature coronal morphology. Stage C: Crown about half formed, evident pulp chamber, and visible dentinal deposition. Stage D: Crown formation completed to the cemento-enamel junction and pulp chamber with a trapezoidal form. Stage E: Commencement of formation of the inter-radicular bifurcation and root length less than the crown length. Stage F: Root length at least as great as the crown length and roots with funnel-shaped endings. Stage G: Root walls parallel, with apices remaining open. Stage H: Apical ends of the roots completely closed and uniform width of the periodontal membrane around the root.

Table 3. Frequency and proportion of maxillary third molar developmental stages

Age (years)	Developmental stage of maxillary third molars																				Total
	Stage 0*		Stage A		Stage B		Stage C		Stage D		Stage E		Stage F		Stage G		Stage H				
7	2	25.0	6	75.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0			8
8	13	22.0	42	71.2	4	6.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0			59
9	5	4.9	68	66.0	24	23.3	6	5.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0			103
10	4	3.2	62	49.6	42	33.6	17	13.6	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0			125
11	2	1.6	29	22.5	52	40.3	46	35.7	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0			129
12	1	0.8	14	10.5	33	24.8	59	44.4	22	16.5	4	3.0	0	0.0	0	0.0	0	0.0			133
13	0	0.0	5	3.5	14	9.9	66	46.5	41	28.9	16	11.3	0	0.0	0	0.0	0	0.0			142
14	0	0.0	2	1.0	8	4.1	53	27.0	70	35.7	53	27.0	10	5.1	0	0.0	0	0.0			196
15	0	0.0	0	0.0	10	5.2	23	12.0	50	26.2	65	34.0	43	22.5	0	0.0	0	0.0			191
16	0	0.0	0	0.0	1	0.5	13	6.0	24	11.1	79	36.4	66	30.4	34	15.7	0	0.0			217
17	0	0.0	1	0.4	0	0.0	1	0.4	13	5.4	73	30.4	88	36.7	55	22.9	9	3.8			240
18	0	0.0	0	0.0	0	0.0	2	0.6	4	1.2	43	12.4	94	27.2	160	46.2	43	12.4			346
19	0	0.0	0	0.0	0	0.0	0	0.0	4	1.5	28	10.4	26	9.6	154	57.0	58	21.5			270
20	0	0.0	0	0.0	0	0.0	0	0.0	4	1.6	6	2.5	21	8.6	118	48.6	94	38.7			243
21	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.4	28	10.6	67	25.3	169	63.8			265
22	0	0.0	0	0.0	0	0.0	0	0.0	1	0.5	0	0.0	4	1.9	19	8.8	191	88.8			215
23	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	0.9	4	1.7	223	97.4			229
24	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	1.0	1	0.5	200	98.5			203
Total	27	0.8	229	6.9	188	5.7	286	8.6	233	7.0	368	11.1	384	11.6	612	18.5	987	29.8			3314

*Stage 0 was added to Demirjian's classification system for representing follicle with no calcification.

Table 4. Frequency and proportion of mandibular third molar developmental stages

Age (years)	Developmental stage of mandibular third molars																				Total
	Stage 0*		Stage A		Stage B		Stage C		Stage D		Stage E		Stage F		Stage G		Stage H				
6	6	100.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0			6
7	20	76.9	6	23.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0			26
8	49	49.0	51	51.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0			100
9	24	18.2	96	72.7	8	6.1	4	3.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0			132
10	18	13.0	74	53.6	38	27.5	8	5.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0			138
11	7	4.3	65	40.1	68	42.0	22	13.6	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0			162
12	2	1.2	32	19.5	49	29.9	71	43.3	6	3.7	4	2.4	0	0.0	0	0.0	0	0.0			164
13	2	1.1	14	7.6	36	19.5	94	50.8	23	12.4	16	8.6	0	0.0	0	0.0	0	0.0			185
14	0	0.0	11	5.0	14	6.4	60	27.3	71	32.3	58	26.4	6	2.7	0	0.0	0	0.0			220
15	0	0.0	1	0.5	8	4.0	47	23.3	40	19.8	76	37.6	30	14.9	0	0.0	0	0.0			202
16	0	0.0	0	0.0	3	1.2	27	11.1	37	15.2	77	31.6	71	29.1	29	11.9	0	0.0			244
17	0	0.0	0	0.0	0	0.0	2	0.7	29	10.7	88	32.4	90	33.1	54	19.9	9	3.3			272
18	0	0.0	0	0.0	0	0.0	1	0.3	11	3.1	62	17.2	80	22.2	179	49.7	27	7.5			360
19	0	0.0	0	0.0	0	0.0	2	0.7	2	0.7	35	11.5	52	17.1	163	53.6	50	16.4			304
20	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	13	5.2	22	8.8	131	52.6	83	33.3			249
21	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	6	2.0	30	10.2	89	30.2	170	57.6			295
22	0	0.0	0	0.0	0	0.0	0	0.0	1	0.4	1	0.4	6	2.5	30	12.7	198	83.9			236
23	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.4	2	0.8	2	0.8	239	98.0			244
24	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.4	0	0.0	2	0.9	225	98.7			228
Total	128	3.4	350	9.3	224	5.9	338	9.0	220	5.8	438	11.6	389	10.3	679	18.0	1001	26.6			3767

*Stage 0 was added to Demirjian's classification system for representing follicle with no calcification.

to evaluate the developmental status of the third molars on the panoramic radiographs, as shown in Figure 1.[3,12] The assessments were carried out by one oral and maxillofacial radiologist with significant experience.

Cases of no follicles and extracted third molars were excluded from the statistical analysis. Spearman's correlation coefficients between the contralateral third molars were calculated. Descriptive statistics were obtained by calculat-

Table 5. Mean age and standard deviation for the developmental stages of the third molars

Stage	Maxillary third molar			Mandibular third molar			Total			*P*
	N	Mean	SD	N	Mean	SD	N	Mean	SD	
0*	27	8.78	1.25	128	8.52	1.40	155	8.57	1.38	0.342
A	229	9.64	1.44	350	10.01	1.58	579	9.86	1.54	0.006*
B	188	11.15	1.66	224	11.70	1.47	412	11.45	1.58	0.000*
C	286	12.74	1.68	338	13.31	1.62	624	13.05	1.67	0.000*
D	233	14.52	1.74	220	15.04	1.58	453	14.77	1.68	0.000*
E	368	16.10	1.73	438	16.37	1.92	806	16.25	1.84	0.074
F	384	17.48	1.87	389	17.68	1.80	773	17.58	1.84	0.100
G	612	18.93	1.47	679	19.06	1.48	1291	19.00	1.48	0.140
H	987	21.87	1.74	1001	22.05	1.66	1988	21.96	1.70	0.033*
Total	3314	17.31	4.34	3767	17.01	4.52	7081	17.15	4.44	

*Stage 0 was added to Demirjian's classification system for representing follicle with no calcification.

ing the means, standard deviations, and range of the chronological ages for the nine stages of third molar development. A Mann-Whitney *U* test was used to analyze the age differences in the developmental stages between the maxillary and the mandibular third molars and between the gender groups. A linear regression analysis was used to assess the correlation between the third molar development and chronological age. For fully developed third molars (Stage H), the probability of an individual being older than 18 years was also calculated. Statistical analyses were performed using IBM SPSS Statistics 21.0 (IBM, Armonk, NY, USA). $P<0.05$ was considered statistically significant.

Table 6. Mean age and standard deviation for the developmental stages of the third molars in relation to gender

Stage	Male			Female			*P*
	N	Mean	SD	N	Mean	SD	
0*	107	8.36	1.32	48	9.02	1.41	0.002*
A	348	9.82	1.51	231	9.94	1.58	0.487
B	204	11.43	1.58	208	11.47	1.59	0.735
C	306	12.99	1.38	318	13.11	1.90	0.282
D	155	14.58	1.73	298	14.87	1.66	0.031*
E	347	16.06	1.70	459	16.39	1.93	0.012*
F	293	17.17	1.44	480	17.83	2.01	0.000*
G	698	18.70	1.44	593	19.35	1.45	0.000*
H	1104	21.85	1.70	884	22.10	1.69	0.000*
Total	3562	17.03	4.59	3519	17.28	4.27	

*Stage 0 was added to Demirjian's classification system for representing follicle with no calcification.

Results

As Spearman's correlation coefficients revealed a strong correlation between the left and the right third molars, the results of both were averaged for each developmental stage.

The frequency distribution of the stages for each age group is shown in Tables 3 and 4. Crypt formation of the maxillary third molars (Stage 0) was observed in two of 105 patients at age seven, and crypt formation of the mandibular third molars (Stage 0) was observed in six of 128 patients at age six. Stage A was observed from the age of 7 years and rarely beyond the age of 14 years. Crown completion (Stage D) was examined in patients aged 12 years and older. The third molars in the maxillary and mandibular arches were fully developed in 12.4% and 7.5% of the 18-year-olds, respectively, and in 98.5% and 98.7% of the 24-year-olds, respectively. Complete root formation (Stage H) in the third molars before the age of 18 years occurred in nine maxillary and mandibular third molars. The probability of an individual exhibiting Demirjian Stage H at 18 years or older was 99.1%.

The mean developmental age and standard deviation for the modified Demirjian stages of the third molars are shown in Table 5. Initial calcification of the cusp tips (Stage A) was seen at a mean age of 9.86 ± 1.54 years. Complete crown formation (Stage D) occurred at a mean age 14.77 ± 1.68 years, and the completion of root formation without closure of the apex (Stage G) was observed at a mean age of 19.00 ± 1.48 years. Apex closure (Stage H) occurred at a mean age of 21.96 ± 1.70 years. The development stage of the third molars was generally more advanced in the upper than in the lower third molar. Statistically significant differences between the upper and the lower jaws were noted in Stages A-D and H. Males reached the stages earlier than females, and there were significant between-gender differences in Stages 0 and D-H (Table 6).

Table 7 shows the age at which each third molar development stage was observed. The third molar crypt forma-

Table 7. Age distribution in percentiles using a modified Demirjian's classification for the third molars in patients aged 6-24 years

Stage	Maxillary third molars								Mandibular third molars							
	N	Min	10%	25%	50%	75%	90%	Max	N	Min	10%	25%	50%	75%	90%	Max
0*	27	7	8	8	8	9.5	10.4	12	128	6	7	8	8	9	10	13
A	229	7	8	9	9	10	11	17	350	7	8	9	10	11	12	15
B	188	8	9	10	11	12	13.3	16	224	9	10	11	11	13	14	16
C	286	9	11	12	13	14	15	18	338	9	11.7	12	13	14	15	19
D	233	12	13	13	14	15	17	22	220	12	13	14	15	16	17	22
E	368	12	14	15	16	17	18	21	438	12	14	15	16	18	19	24
F	384	14	15	17	17	18	20	24	389	14	16	16	17	19	20	23
G	612	16	17	18	19	20	21	24	679	16	17	18	19	20	21	24
H	987	17	19	21	22	23	24	24	1001	17	20	21	22	23	24	24

*Stage 0 was added to Demirjian's classification system for representing follicle with no calcification. Min: minimum age, Max: maximum age

tion was observable at as early as 7 years of age in the maxilla and 6 years in the mandible. According to our data, 75% of Stage A was visible in the upper arch in those younger than 10 years and in the lower arch in those younger than 11 years. Seventy-five percent of complete crown calcification (Stage D) was observed in the maxillary third molars in patients younger than 15 years and in the mandibular third molars in patients younger than 16 years. The minimum age at Stage H was 17 years, and 75% of those at Stage H were younger than 23 years.

A strong positive relationship was observed between the developmental stage of the third molars and chronological age. A regression analysis showed a strong correlation between age and third molar development for the maxillary (r^2=0.840) and the mandibular third molars (r^2=0.857).

Discussion

We investigated the development of the third molars in a 6- to 24-year-old population by using the modified Demirjian classification. In the present study, the third molars appeared at the age of 6 years and had developed completely by the age of 24 years. Developmental stages were examined at the earliest and the oldest ages. Despite wide variability, there was a clear correspondence between the developmental stage of the third molar and the age of the subject.

Crypt formation (Stage 0) was observed as early as 7 years in the maxillary third molars and 6 years in the mandibular third molars. Almost no bud formation occurred after the age of 12 years in the maxillary third molars or after the age of 13 years in the mandibular third molars, and bud formation showed wide variation between the ages of 6 and 13 years. A previous study showed that the mean age of the mandibular third molar crypt formation was 8 or 9 years, with substantial variation from about 6 to 14 years.[18] Other studies reported that the crypt formation of the maxillary third molars could not be clearly seen because of overlapping adjacent structures.[19,20] We found it more difficult to observe the bud formation of the maxillary third molars than that of the mandibular third molars. Therefore, the radiolucent bud of the maxillary third molar was examined at a later age than that of the mandibular third molar.

Sisman et al[21] observed that the third molar began to calcify in subjects at 8 years of age. In the present study, third molar mineralization (Stage A) commenced at 7 years of age. The 9th year has been consistently reported as the mean age of the initial mineralization of the cusp tips.[18] The present study found similar results.

The mean age of reaching crown completion (Stage D) was 14.77 years. Compared with reports for other populations, it was later than in an Iranian population[3] and earlier than in Japanese[22] or German[16] populations. Bassed et al[23] reported that females reached Demirjian Stage D at the latest by the age of 19 years, whereas males reached this stage at the latest by the age of 18 years. In the present study, at Stage D, the maximum age was 22 years, although crown completion was achieved in 90% of the patients by the time they were 17 years. This diversity could be explained by the differences in the selected population.

In the current study, the apical ends of the third molars were completely closed at around 22 years. This is about 1 year later than that reported in one study[24] and similar to that reported in other studies.[20,22,23] According to our data, Stage H was first observed at the age of 17 years, and 75% of the third molars were completed by the time the patient was 23 years.

Many studies have described the tendency of the maxillary third molar development to be more advanced than the mandibular third molar development.[25-27] However, Olze

et al[28] reported no statistically significant differences in the chronology of the maxillary and the mandibular third molars. In the present study, mineralization of the maxillary third molars was more advanced than that of the mandibular third molars, and a statistically significant difference in mineralization was observed in Stages A-D and H. This finding was consistent with that reported in previous studies.[25-27]

Some studies have reported that males entered the Demirjian stages earlier than females,[29-31] although others found no significant between-gender differences in the developmental stages of the third molars.[3,7,28] In the current study, males showed earlier development than females, and there were significant gender differences in Stages D-H.

In conclusion, the present investigation could provide reference data for third molar development in the Korean population. The developmental stages of the third molars showed a strong correlation with age. The third molar developed earlier in the upper arch than in the lower arch and earlier in males than in females.

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