The Chronology of Second and Third Molar Mineralization in Korean Population and Application to Forensic Age Estimation

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Introduction

Forensic age estimation with teeth is widely employed in human identification because of its more accurate nature than other age indicators in body. However after age 14, estimation becomes more difficult because most of dentition completely developed [1]. The second molar (M2) is latest developing teeth in dentition except third molar (M3) and may be helpful in estimating late teens. The M3 has been used widely in age estimation for the transition zone between non-adults and adults and there are many reports of estimation with this tooth [2-4, 7]. Moreover, in case of living individuals, the M2 and M3 maturity is likely to be the best age estimation method as it is noninvasive and easily obtained from radiographs [2].

Several studies reported the usefulness of the M3 as an age indicator have shown that development of teeth varies between different populations. Therefore, it is important to establish population specific standards of M2 and M3 for enhancing the accuracy of age estimation using the development of these teeth. There were a few reports about the mineralization of M2 and M3 for Korean population [5, 6]. However, these reports employed different criteria for evaluating the development of M3 and with these results it was difficult to compare the pattern of development of M2 and M3 of Korean population with those of other populations.

The purpose of this study was to investigate the chronology of M2 and M3 development in Korean population and to calculate multiple regression formulas for applying forensic age estimation of dead body or living individuals of Koreans.

Materials and Methods

A total of 2087 orthopantomograms were randomly selected from those stored at Dental Hospital of Yonsei University in Seoul. They consisted of 1030 males and 1057 females and the age range was 3 to 23 years (Table 1). The radiographs showing malformed, large decayed and endodontically treated teeth and those of patients with gross pathologic lesions in jaw bones and systemic endocrinal disorders were excluded. Protocols to collect orthopantomograms for human subjects were approved by the Severance Hospital Institutional Review Board (#4-2009-0175). Stage of maturity of the M2 and M3 in both the left and right sides in both maxillary and mandibular arches was evaluated according to the eight grade scheme presented by Demirjian et al. [8]. The two examiners observed all radiographs after a preliminary training session. The examiners were blind to sex and age of subjects during all phases of study. Interobserver reliability was tested based on the data from each examiner.

Mean ages, standard deviations are presented for each stage of mineralization for both sexes. Kappa statistics was used to assess interobserver reliability. The left-right symmetricity and arch difference of the degrees of maturation in all four M2 and M3 in both sexes were evaluated with chi-square test. Relationship between chronologic age and the degree of calcification of M2 and M3 was evaluated by multiple linear regression analysis. All Statistical analyses were performed using SAS 9.1 (Cary, NC, U.S.A.).

Table 1. Age and sex distribution of the sample. (M: male, F: female)

Age	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total
M	21	25	51	65	58	72	61	65	36	40	45	39	46	41	64	61	88	76	66	2	8	1030
F	16	32	43	52	50	57	39	48	37	39	37	47	49	43	49	98	113	108	89	6	5	1057
Total	37	57	94	117	108	129	100	113	73	79	82	86	95	84	113	159	201	184	155	8	13	2087

Results

The statistical data of the mineralization stages of M2 and M3 are presented in Table 2. Interobserver reliability was very excellent in M2 and M3 in both jaws and sexes (kappa value=0.905-0.948). The left-right symmetricity of the maturation degrees in M2 and M3 was observed in both sexes (p<0.001) while arch difference was not found (p<0.001). Statistically significant sex-specific differences were observed in some stages of maxillary and mandibular M2 and M3 (Table 2). In M3 formation, slightly advanced development in females than males was observed at early stages. However, the rate of formation reversed after stage D in both jaws. In case of M2, the development was faster in females at all stages (Figure 1, 2). In multiple regression analysis, the strong positive relationship was observed between chronologic age and the stages of mineralization of M2 and M3 (Table 3, 4).

Table 2. Mean and standard deviations of age of mineralization stages of M2 and M3.

Tooth	Stage	Male n	Male Mean	Male S.D.	Female n	Female Mean	Female S.D.
17	A	20	3.85	0.39	21	4.12	0.78
	B	23	5.00	0.67	21	4.68	0.47
	C*	84	6.09	0.75	66	5.83	0.59
	D*	155	7.95	1.03	107	7.64	1.02
	E**	135	10.15	1.15	100	9.71	1.23
	F	149	13.23	1.50	172	12.95	1.73
	G	89	16.23	1.54	87	15.91	1.15
	H	358	19.63	1.61	460	19.58	1.49
27	A	24	3.90	0.38	20	4.14	0.79
	B	22	5.15	0.66	22	5.11	2.05
	C	80	6.05	0.73	67	5.85	0.63
	D*	160	7.95	1.05	105	7.65	1.02
	E**	128	10.16	1.32	99	9.71	1.24
	F	155	13.12	1.49	167	12.84	1.64
	G	85	16.31	1.66	85	15.88	1.27
	H	362	19.59	1.64	473	19.67	1.53
37	A	22	3.94	0.45	20	3.98	0.54
	B	26	4.90	0.62	27	4.88	0.62
	C	81	6.07	0.67	67	5.92	0.64
	D**	139	7.82	0.96	95	7.51	0.75
	E	112	9.74	1.24	85	9.45	1.15
	F	184	12.70	1.73	197	12.63	1.88
	G*	110	16.36	1.88	88	15.91	1.25
	H	340	19.65	1.63	466	19.71	1.49
47	A	26	3.98	0.46	20	3.92	0.50
	B	24	4.99	0.67	27	4.88	0.62
	C	84	6.07	0.67	68	5.92	0.64
	D**	132	7.84	0.92	97	7.55	0.80
	E	112	9.65	0.93	82	9.45	1.04
	F	186	12.66	1.70	191	12.56	1.84
	G**	123	16.58	1.89	95	15.90	1.23
	H	332	19.71	1.60	463	19.75	1.48

Tooth	Stage	Male n	Male Mean	Male S.D.	Female n	Female Mean	Female S.D.
18	A*	24	9.99	1.38	24	9.11	1.07
	B	56	10.75	1.64	39	10.32	1.42
	C	35	12.18	1.69	37	11.50	1.56
	D	65	13.93	1.78	80	13.79	2.05
	E	77	16.83	1.93	108	16.93	2.17
	F**	91	18.28	1.75	187	19.23	1.71
	G**	75	19.39	1.33	61	20.12	1.32
	H	67	20.87	1.19	28	21.09	1.05
28	A	20	9.55	0.99	20	9.07	1.42
	B	48	10.71	1.57	38	10.35	1.48
	C**	49	12.45	1.95	38	11.39	1.55
	D	59	14.11	1.80	89	13.73	2.00
	E	73	16.71	1.83	106	16.83	2.12
	F**	105	18.36	1.79	196	19.24	1.71
	G*	67	19.37	1.35	51	19.99	1.24
	H	60	20.75	1.27	28	21.10	1.12
38	A	50	9.88	1.06	45	9.49	1.48
	B	50	10.70	1.28	43	10.72	1.34
	C**	80	13.17	1.69	58	12.12	1.39
	D	64	14.75	2.01	100	14.91	2.05
	E	56	16.84	1.92	112	17.32	2.20
	F**	113	18.11	1.58	192	19.35	1.60
	G**	107	19.72	1.40	68	20.31	1.07
	H*	52	20.83	1.31	20	21.61	0.91
48	A	56	9.63	1.33	40	9.46	1.50
	B	46	10.65	1.22	46	11.02	1.70
	C**	81	13.05	1.61	60	11.96	1.35
	D	65	14.63	1.80	96	14.91	2.05
	E	52	17.11	1.89	111	17.33	2.23
	F**	113	18.15	1.66	202	19.33	1.63
	G**	107	19.60	1.39	73	20.22	1.17
	H*	61	20.86	1.32	21	21.60	0.89

(* : Stages showed statistically significant differences between sexes. * p<0.05, ** p<0.01)

Conclusion

The present research provides populational data on maxillary and mandibular M2 and M3 mineralization in Koreans. The strong positive correlation between chronological age and the mineralization stages of M2 and M3 is found. These results suggest that development of M2 and M3 can be considered valuable age estimating indicators in Korean adolescents and young adults.

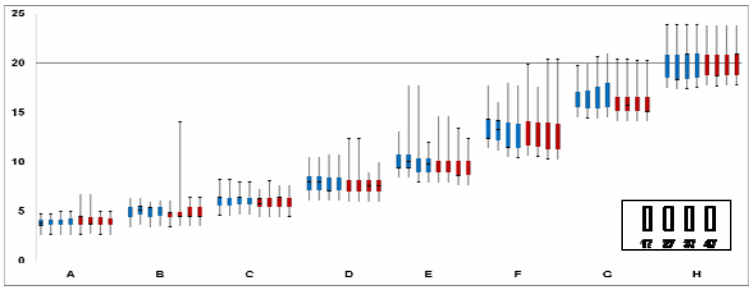

Figure 1. Box plots of relationship between chronological age and mineralization stages for teeth 17, 27, 37, 47. (blue: male, red: female)

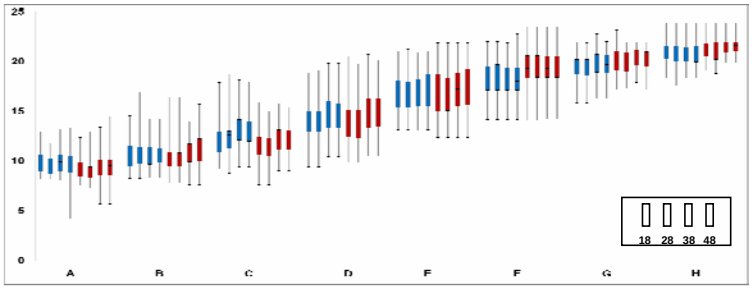

Figure 2. Box plots of relationship between chronological age and mineralization stages for teeth 18, 28, 38, 48. (blue: male, red: female)

Table 3. Intercepts and coefficients for age calculation of all subjects. The age can be computed by adding an intercept to the sum of numerical values of this table. The regression analysis was performed under assumption of variables as discrete data.

		One variable				Two variables			Four variables
		Mx M2	Mx M3	Mn M2	Mn M3	Mx M2 + Mn M2	Mx M3 + Mn M3	Mx M2 + Mx M3	Mn M2 + Mn M3	Mx M2 & M3 + Mn M2 & M3
Intercept		19.68	20.94	19.69	21.05	19.79	21.24	20.93	21.05	21.22
Mx M2	A	-15.69				-8.42				
	B	-14.83				-7.97				
	C	-13.70				-7.59				
	D	-11.85				-6.73		-7.54		-4.02
	E	-9.71				-5.94		-6.43		-3.63
	F	-6.60				-3.77		-4.52		-2.51
	G	-3.61				-2.07		-2.59		-1.47
	H	0.00				0.00		0.00		0.00
Mx M3	A		-11.38				-5.60	-5.04		-2.62
	B		-10.36				-5.12	-4.54		-2.32
	C		-9.11				-4.94	-4.25		-2.39
	D		-7.08				-4.25	-3.23		-1.81
	E		-4.05				-2.36	-2.21		-1.29
	F		-2.02				-1.00	-1.66		-0.86
	G		-1.22				-0.75	-1.15		-0.68
	H		0.00				0.00	0.00		0.00
Mn M2	A			-15.73		-7.42				
	B			-14.80		-6.97				
	C			-13.69		-6.32			-9.22	
	D			-12.00		-5.32			-6.96	-3.82
	E			-10.07		-4.14			-5.29	-2.78
	F			-7.03		-3.11			-4.19	-2.20
	G			-3.53		-1.77			-2.29	-1.33
	H			0.00		0.00			0.00	0.00
Mn M3	A				-11.35		-6.29		-6.15	-2.90
	B				-10.34		-5.61		-5.72	-2.64
	C				-8.32		-4.17		-4.37	-2.00
	D				-6.20		-3.05		-3.16	-1.38
	E				-3.89		-2.21		-2.49	-1.23
	F				-2.16		-1.25		-1.69	-1.01
	G				-1.10		-0.66		-1.05	-0.70
	H				0.00		0.00		0.00	0.00
R-square		0.94	0.81	0.93	0.82	0.95	0.84	0.89	0.89	0.91

Table 4. Regression coefficients of regression equations based on the number of teeth and their location of all subjects. The regression analysis was performed under assumption of variables as continuous data.

	One variable				Two variables				Four variables
	Mx M2	Mx M3	Mn M2	Mn M3	Mx M2 + Mn M2	Mx M3 + Mn M3	Mx M2 + Mx M3	Mn M2 + Mn M3	Mx M2 & M3 + Mn M2 & M3
Intercept	-2.49	7.12	-2.59	7.70	-2.84	6.88	-2.70	-1.67	-3.22
Mx M2	2.71				1.80		2.20		1.18
Mx M3		1.85				0.87	0.72		0.39
Mn M2			2.71		0.96			1.97	1.06
Mn M3				1.79		1.04		0.86	0.37
R-square	0.91	0.78	0.90	0.81	0.92	0.82	0.89	0.88	0.90

References

[1] S. Martin-de las Heras, P. García-Fortea, A. Ortega et al. Third molar development according to chronological age in populations from Spanish and Magrebian origin, Forensic Sci. Int. 174(2008) 47-53.
[2] K.A. Kasper, D. Austin, A.H. Kvanli, et al. Reliability of third molar development for age estimation in a Texas Hispanic population: a comparison study, J. Forensic Sci. 54(2009) 651-7.
[3] H.H. Mincer, E.F. Harris, H.E. Berryman. The A.B.F.O. study of third molar development and its use as an estimator of chronological age, J. Forensic Sci. 38(1993) 379-90.
[4] K. Gunst, K. Mesotten, A. Carbonez, et al. Third molar root development in relation to chronological age: a large sample sized retrospective study, Forensic Sci. Int. 136(2003) 52-7.
[5] J.H. Choi, C.Y. Kim. A study of correlation between the development of the third molar and second molar as an aid in age determination, Korean. J. Oral Med. 16(1991) 121-36.
[6] W.H. Shim, K.S. Kim, K.J. Shin et al. Second and Third Molar Calcification in Relation to Chronological Age in Koreans, Korean. J. Oral Med. 29(2004) 329-40.
[7] A. Meinl, S. Tangl, C. Huber et al. The chronology of third molar mineralization in the Austrian population--a contribution to forensic age estimation, Forensic Sci. Int. 169(2007) 161-7
[8] A. Demirjian, H. Goldstein, J.M. Tanner. A new system of dental age assessment, Hum. Biol. 45(1973) 211-27.